University of Colorado **Boulder**

2017 Program Review

Department of Physics

Academic Review and Planning Advisory Committee Report

Approved _____ 03/20/2018

Provost and Executive Vice Chancellor for Academic Affairs: Date

Contents

Process Overview

The review of the Department of Physics was completed in accordance with the 2017 review guidelines. The Academic Review and Planning Advisory Committee (ARPAC) conducts and writes the final reviews of all Boulder campus academic units. The unit prepared a self-study during 2016, which was checked in January 2017 by an internal review committee of two CU Boulder faculty members from outside of Physics, who also met with department personnel and surveyed undergraduate and graduate students. The internal review committee generally found the report “clear, consistent, correct, and complete” and noted the high level of participation in the process and the consensus reached by faculty and staff. An external review committee, consisting of two experts within the discipline from outside of the University of Colorado, visited the unit over February 26-28, 2017, reviewed relevant documents, and met with faculty, students, staff, and university administrators. Internal and external reviewers’ comments and recommendations are cited where appropriate throughout the report. This public document reflects ARPAC’s assessment of and recommendations for the Department of Physics.

Academic Review and Planning Advisory Committee (ARPAC)

Academic Year 2017-18 Voting Members

Sanjai Bhagat, Professor, Business

Robert Erickson, Professor, Electrical, Energy, and Computer Engineering

Erin Furtak, Associate Professor, Education

David Korevaar, Professor, Music

Clayton Lewis, Professor, Computer Science

Daryl Maeda, Associate Professor, Ethnic Studies

David Mapel, Associate Professor, Political Science

Susan Nevelow Mart, Associate Professor, Law

Carole McGranahan, Associate Professor, Anthropology

Paul Moeller, Associate Professor, University Libraries

Bryan Taylor, Professor, Communication

Non-Voting Members

Jeff Cox, Chair, Vice Provost and Associate Vice Chancellor for Faculty Affairs and Professor of English and Humanities

Bob Boswell, Vice Chancellor for Diversity, Equity, and Community Engagement and Professor of Molecular, Cellular, and Developmental Biology

Katherine Eggert, Quality Initiative Leader and Professor of English

Bill Kaempfer, Senior Vice Provost and Associate Vice Chancellor for Budget and Planning and Professor of Economics

Mary Kraus, Vice Provost and Associate Vice Chancellor for Undergraduate Education and Professor of Geological Sciences

Ann Schmeising, Interim Vice Provost and Dean of the Graduate School and Professor of Germanic & Slavic Languages & Literatures

Staff

Andre Grothe, Office of Faculty Affairs

Emmanuel Melgoza Alfaro, Office of Faculty Affairs

Unit Overview

The campus's standardized description of the unit may be found on the website of the Office of Data Analytics (ODA) at https://www.colorado.edu/oda/institutional-research/institutional-level-data/information-department/academic-review-and-planning.
ODA updates the profile annually during the fall semester. This report cites the ODA data for Physics posted in October 2016, reflecting the state of the department as of academic year (AY) 2015-2016.

According to *U.S. News and World Report* rankings of graduate programs, the Department of Physics is among the top ten US-based public-university physics departments and is tied for eighteenth place overall. *U.S. News* ranks the department's atomic, molecular, and optics physics program as that field's top graduate program; its quantum physics program is ranked fifth. Physics serves undergraduate students across campus, generating 28,924 student credit hours (SCH) in academic year (AY) 2015-16, according to ODA data (the self-study reports 31,395 for 2016), with 85% of the SCH generated for non-majors (18th out of 54 relevant units on campus, according to ODA data). Over AY 2015-16, the department counted 631 majors. Physics has the largest number of Latin honors graduates on campus (24% over the last ten years). Over AY 2015-16, the department also counted 19 master's and 221 doctoral students. The self-study includes no data on postdoctoral fellows. In addition to holding national research prominence, the department is known for theoretical work in the sociocultural foundations of learning with innovations in physics education research, and for contributions to science, technology, engineering and mathematics (STEM) education.

Personnel and Governance

In addition to 47 tenured and tenure-track (TTT) faculty members, comprising 27 full professors, 11 associate

professors, and nine assistant professors, Physics faculty includes three instructors and six lecturers (these numbers reflect two new TTT faculty hires since 2015-16). The self-study reports higher numbers because it includes 11 faculty who hold at least one joint appointment with other units. The department is assisted by six classified staff and five exempt professionals. The department elects a chair to a four-year term. A chair's advisory committee, among other standing committees, supports leadership work. Physics is currently reviewing its governance process and plans to transition to an elected executive committee and a chair/vice-chair model. The department's bylaws conform to campus norms.

Staff have experienced increased work demands as enrollments have grown, the pressure to procure grants has intensified, and interactions with human resources and financial systems have become more complicated and time-consuming. While Physics staff members appear to be generally satisfied with working conditions, the external reviewers noted that staff request more help. ARPAC notes that the department has not formally requested more staff positions.

While assistant professors' salaries are close to peer averages (98%), full professors' salaries (94%) and associate professors' salaries (92%) lag slightly behind, according to ODA data. Physics requested and received several salary increases for full and associate professors in the fall 2017 non-merit salary allocation process.

Research and Scholarship

The department demonstrates high levels of research and scholarship productivity. The self-study expounds upon the interests of faculty research groups, describing major theoretical and practical accomplishments in such sub-fields as atomic/molecular, optical, and laser physics (AMO); biophysics;

chemical physics; condensed matter; geophysics; high energy physics; nuclear physics; plasma physics; the Optics Initiative; and physics education research. The department lists the interdisciplinary impact of each group's research, featuring, for example, the use of optical tweezers to study DNA and the development of "chip scale" atom clocks. The number of research honors and awards since the last review cycle is impressive. The Physics faculty have been awarded sixteen major honors and sixty-four extramural research honors and awards. The external reviewers note that Physics has grown even stronger in research since the 2010 review. Physics faculty members have received more than ninety awards, including Nobel prizes, MacArthur "genius" fellowships, and selection as fellows/members of the American Physical Society, the American Academy of Arts & Sciences, the American Geophysical Union, the Optical Society of America, and the National Academy of Sciences. Physics ranks highly in ODA data on research and scholarship and is in second place among eight units in this review cycle for refereed articles and chapters, and in fourth place for conference presentations and papers.

The faculty's research acumen has led to a sizeable increase in grants awarded. Grant funding has increased 38% since the last review cycle, and the direct grant value per tenure/tenure-track faculty member is the highest among the six relevant units in this review cycle ($298,000 per tenured/tenure-track faculty members).

Undergraduate Education

The department confers the B.A. in Physics, the B.S. in Engineering Physics, a Physics minor, and concurrent B.A./M.A. Engineering Physics and Physics degrees. The internal reviewers note that Physics has taken the lead nationally in restructuring Physics education with its Physics Education

Research (PER) program. According to the self-study, Physics has instituted assessments of actual student learning known as measures of conceptual mastery, and Physics students perform at two to three times the national average for traditional courses on these metrics. Physics faculty include four winners of national undergraduate teaching awards, and an awardee of the national teacher of the year award from the Society of Physics Students. Physics has documented increasing numbers of Physics undergraduate majors over time and expects the trend to continue.

However, a substantial share of students who declare Physics as their first major eventually change to another. An assessment by the Office of Data Analytics shows that, for undergraduate cohorts entering CU Boulder between 2007 and 2010, only 28% of students declaring Physics as their first major graduated with a Physics major within six years. Among all other natural sciences majors in the same period, 48% of students graduate within six years in the major that they first declared. Of those declaring Physics as their first major, 58% graduated with an Arts and Sciences degree (any major) within six years and 63% graduated from CU Boulder overall (any college). Campus-wide, the six-year graduation rate for these cohorts was 70%.

To tackle the problem of its below-average retention within the major, Physics has undertaken changes to improve the undergraduate experience, including using tests that examine concepts and not just facts, providing peer instruction, embracing online homework systems, establishing a dedicated homework help room, arranging Physics simulations, emphasizing the Learning Assistant Program, scheduling interactive group tutorials, and transforming the pedagogy of upper-division undergraduate courses. Physics has also

recently added an instructor who implemented a student poster program and redesigned the large laboratory course, Physics 1140.

Physics promotes undergraduate research and honors opportunities. For example, all students in the Plan 1 major (the largest track) conduct physics lab research, and the department has recently added the aforementioned student poster session and instituted a new MeTRO (Meteorology and Technology Research Opportunities) program with the National Institute of Standards and Technology (NIST). Students who work with NIST will have the opportunity to write an honors thesis based on their work. Physics has also implemented the R-cubed (Representation, Retention & Recruitment) program to work on community and culture, admissions and recruiting, and the structure of the department vis-à-vis undergraduates.

Tenured and tenure-track faculty teach 55% of undergraduate student credit hours (second place of six relevant units in this review cycle), while instructors teach 31% and lecturers teach the remaining 14%. Non-majors take 85% per cent of SCH. Physics awarded 94 bachelor's degrees in FY 2015-16 out of 633 total majors, numbers that seem to reflect the major's comparatively low retention rate. The median time to graduation is 4.33 years.

Students seem generally satisfied with the department's undergraduate teaching but slightly less happy with faculty advising. The internal reviewers' student survey (171 responses) indicates that 79% of undergraduate major respondents are "satisfied" or "very satisfied" with the department, while 83% are "satisfied" or "very satisfied" with the logical sequencing of courses, 80% with the availability of electives, and 81% with the degree of tolerance and respect for diversity demonstrated

by faculty. By contrast, only 64% are “satisfied” with faculty advising. The student comments expand upon these numbers, focusing on the quality of instruction in introductory courses, the extent of faculty mentoring, the need for more Physics programming courses, and the need for a stronger community. Undergraduate students are, overall, positive about the department.

Graduate Education

The department confers doctoral degrees in Physics, Chemical Physics, and Geophysics, as well as an interdisciplinary Quantitative Biology graduate certificate. Faculty have entertained offering professional masters’ degrees, but the department has no plan at this time to implement one. The self-study reports that Physics has the fourth largest number of Physics graduate students in the country, and that the size of the cohort has increased from 209 at the last review in 2010 to 254 currently. The self-study cites the number of external fellowships their graduate students receive as an indicator of student quality: in the last six years, 24 students were awarded NSF graduate research fellowships and 15 were awarded other prestigious graduate fellowships. Physics awarded 19 master’s degrees and 27 doctoral degrees in AY 2015-16. The median time to a doctoral degree is 6.32 years (sixth of six units in this review cycle). Tenured and tenure-track faculty teach 78% of graduate SCH, while lecturers teach 21%.

Graduate students show mixed approval of various aspects of their educational experience. They rate the program highly, with 80% of respondents to the internal reviewers’ survey reporting the maximum positive rating for quality, but advising, guidance, and assistance finding employment do not fare as well, with only 50% reporting maximum satisfaction. Student comments regarding inclusive excellence, advising, and fees also indicate areas for improvement. The external reviewers note that while

most written student responses to the internal reviewers were positive, when they met with graduate students they learned of dissatisfaction with career development, teaching, and the "Comps 2" exam.

The Physics self-study focuses on the department's efforts to increase graduate student research opportunities with affiliated organizations including NIST, JILA, the National Renewable Energy Laboratory (NREL), and the National Center for Atmospheric Research (NCAR). The study also addresses efforts to increase the number of women and underrepresented minority graduate students.

Physics did not provide information about graduate placements, though such information would be useful.

Space and Infrastructure

The self-study, and internal and external reviewers, all cite a space shortage as a critical issue for Physics, noting that the need for new space has been its highest priority for the last three review cycles. The department has run out of assignable office space, teaching space in the Duane Physics Complex is in short supply, and research and laboratory needs are critically under met. Physics has compared its space and infrastructure to its public peers, and they found that four of the nine universities ranked above Physics have new buildings completed or underway. Three of the next five major public universities ranked below Physics have initiated major physics-related infrastructure investments. While Physics makes the case that its ongoing success will depend in part on securing new teaching, office, laboratory, and research spaces, the review reporting leaves some questions about space needs unanswered. The internal reviewers, for one, note that the Physics self-study did not include a strategic plan. Subsequently, the department supplied a list of strategic needs

but space was not among the top three. Nor has Physics determined the relative priority of needs for renovated versus new space, although the department notes that multiple strategic campus needs might benefit from investments in shared facilities.

Inclusive Excellence

The Department of Physics has taken steps to improve inclusiveness and to attract faculty and students from underrepresented populations. In 2016 Physics convened an excellence and inclusion initiative, which identified the traits of excellent physicists with an eye to being inclusive. Following this work, the department settled on several changes intended to attract greater participation from individuals in underrepresented groups. In addition to improving advertising for the course Honors Introductory Physics to encourage more diverse enrollment, the department has increased its sponsorship of community events, advertised the physics students chapter, facilitated the women in physics groups, and started underrepresented minorities in physics group. The department is also considering options to provide training on equity, inclusion and discrimination-awareness via a "designated climate ombudsperson," to create designated safe spaces, to include more undergraduates in department events, and to continue collecting relevant data for its Representation, Retention & Recruitment Program. The self-study also notes that Physics "could make efforts to actively recruit faculty who will increase the diversity of the department" and who could improve mentoring.

The National Science Foundation's 2015 data on Physics' doctoral student population indicates that 19.7% are women, 18.8% are minorities, and 9.7% are underrepresented minorities (the percentages of Asian Americans are excluded). Physics meets the national norm, enrolling 19% female

graduate students, but fares less well in minority representation: Physics has 9% minorities (versus 18.8% nationally) and 5% underrepresented minorities (versus 9.7% nationally).

The department has initiated monthly meetings to address equity and inclusion and has conducted outreach to admitted students through the Women in Physics group. The chair also plans to request an American Physical Society site visit to assess department climate.

Past Reviews

ARPAC last reviewed the Department of Physics in 2010. At the time, the department aspired to become a top ten public-university program, and they have since achieved that goal. Further, Physics has complied with recommendations from the 2010 review to expand its learning assistant program, to implement a junior faculty mentoring program, and to improve its undergraduate educational experience. Despite these successes, graduate advising remains an area of concern. In the last review, a lack of space also presented a pressing worry. Happily, since that time, Physics has acquired two spaces: in the D Wing of Duane Physics after some LASP facilities relocated, and in the now shuttered Math/Physics library. A long-standing request for a capital investment to build out the Duane Physics H wing remains pending.

Campus Context

Physics is one of the largest departments on campus and a flagship program. The external reviewers note that Physics has grown stronger in both research and teaching since the 2010 review, leading the campus with innovations in teaching and learning and providing significant service teaching to undergraduates (as noted earlier, Physics generates 85% of its credit hours for non-majors). Additionally, the department has focused over the past years on building graduate student research opportunities with affiliated units; a significant step.

Disciplinary Context

The department's standing in the United States is matched internationally, the external reviewers note. Moving forward, the department plans to continue to pursue high rankings, a reasonable ambition it would seem, given the reviewers' praise for the unit. The department has remained competitive with other Physics departments in attracting and retaining the best faculty.

Physics faculty collaborate on several projects with scholars at a distance, including investigating "a nearly ideal Boltzmann gas" with Cornell University; developing "new nano-scale nonlinear and ultrafast spectroscopy and imaging techniques" with the University of Washington; studying "optical frequency combs" with the National Metrology Institute (PTB) in Germany ("Germany's NIST"); conducting a "search for axions" with Yale University; and recording "satellite observations of gravity changes" with the National Aeronautics and Space Administration's (NASA) Gravity Recovery and Climate Experiment (GRACE) mission.

Analysis

The department's laudable ambition to improve on its already high standing will come with challenges both large and small. The self-study, as well as internal and external reviewers identify several such concerns, including improving the physical plant, arranging for additional space, improving faculty start-up packages, and working through issues raised by department-versus-institute hiring.

Physics has also identified some pressing short-term needs to improve the department's standing, including hiring a third instructor to teach introductory courses, whose enrollment has increased given the growth of the College of Engineering and Applied Science (CEAS). Physics believes adding an instructor as a teacher/mentor would facilitate junior faculty staying involved at the introductory level. Junior faculty could teach single sessions of these courses to practice sound pedagogical techniques with guidance from the dedicated instructor. The external reviewers "strongly endorse" this request, and ARPAC concurs. The department's second priority is to hire a dedicated advancement officer. Physics is eager to participate in advancement work on behalf of new capital construction, graduate fellowships, named professorships, and startup packages. The external reviewers endorse this idea, and ARPAC agrees that Physics has much to gain from improved advancement help.

Finally, Physics would like to see the development of a new university-wide "chairs' council" to better communicate the needs of departments to CU Boulder's academic officers. The external reviewers noted that Physics currently feels restrained from advocating fully for the department's needs. In the view of Physics, a chairs' council, like the dean's council, would give departments another avenue for engaging administrators. Also, Physics and several other departments see value in separating

from the College of Arts & Sciences (A&S) and forming a new natural sciences college, though the self-study offers little empirical evidence in support of such a change. Physics argues that A&S is simply too large to manage its constituent parts well and has requested a review of this issue. The external reviewers note Physics' concerns but are agnostic on the benefits of such a change, though they do recommend that the campus address Physics' motivation for requesting a change. ARPAC suggests that Physics provide structured arguments that address the issues driving interest in new organizational models and provide comparisons with peer departments if it wishes to move forward with discussions about this option.

Research and Faculty Hiring

The self-study breaks down the department's analysis of research-related needs by subfield as follows:

- According to the report, the Biophysics program needs additional faculty, more space, and improved facilities, though the self-study does not support this claim with specific facts and analysis.

- Condensed Matter expresses a serious need for improved laboratory space and a renovation of some existing space into a "theory lounge."

- Geophysics wishes to increase its group to four in number, hoping to support intergroup faculty hires with Space Physics and Condensed Matter in the future.

- Physics Education Research (PER) program is pursuing several initiatives to improve physics teaching, including working on assessment, upper- and lower-division course transformation, the learning assistant program, and other initiatives. The self-study indicates that PER is positioned to

remain a national and international leader in physics education research. Surprisingly, the group has not had a faculty hire since 2003, and thus they request an immediate tenure/tenure-track faculty hire, followed by a second hire in three to five years. The PER group also needs office space and new specially-designed teaching spaces.

- Physics has made no specific requests for the programs in Atomic/Molecular, Optical, and Laser Physics; Chemical Physics; High Energy Physics; Nuclear Physics; the Optics Initiative; or Plasma Physics.

Except for advocating on behalf of an instructor line, neither the internal or external reviewers make specific faculty hiring suggestions. The external reviewers do note that seven looming retirements may stall the department's progress and Physics in its self-study affirms that it would like to "continue to strategically invest in new areas without negatively impacting our outstanding existing research areas." ARPAC recommends that Physics work with the college dean on a five-year comprehensive plan to address future hiring needs, thinking systemically about underrepresented minority and women faculty, as well as about the need to restrict the number of hires that are "due to external special opportunities" rather than resulting from the department's strategic plan.

The department also notes a need to develop procedures for fairly evaluating interdisciplinary faculty, whose work might not be fully understood in a department (or school) as it moves beyond conventional disciplinary boundaries. ARPAC supports this plan.

Undergraduate Education

One reason for the excellence of Physics' undergraduate curriculum is the fact that tenured and tenure-track faculty

teach 55% of the department's student credit hours generated by the department. Both the number of majors and overall class enrollment have increased since the last review and Physics faculty have won several prestigious teaching awards. The department also dedicates considerable resources to teaching initiatives, including the Physics Education Research program and the R-cubed (Representation, Retention & Recruitment) program, which strive to develop new ways to teach physics and to improve undergraduate education, including to undertake extensive pedagogical assessment activities. Because of these programs' successes, Physics has requested an additional instructor for dealing with the increased class sizes in undergraduate courses, as well as a tenured or tenure-track faculty hire for the Physics Education Research program.

While students have responded positively to undergraduate student surveys, effective mentoring remains an area of concern. Some problems with mentoring could be resolved by focusing the five-year hiring plan on increasing the number of women and underrepresented minority faculty, thereby increasing the diversity of potential mentors available to assist students from underrepresented backgrounds. Physics might look to the College of Engineering and Applied Science for ideas about best practices. Improvements in the department's mentorship apparatus should also lead to increased job placements for Physics majors, and the unit should focus on marketing the Physics undergraduate degree more aggressively. ARPAC is also concerned about the low retention rate of Physics undergraduate majors.

Graduate Education

Physics has correctly focused on improving graduate student participation with closely allied Boulder-based organizations, including with NIST, NREL, NCAR, and JILA. Physics has also ramped up efforts to increase its support for women and other

underrepresented graduate students. While the external reviewers note that, overall, graduate students are satisfied with the department, the reviewers also heard the students saying they want more help with career development and job placement. Students also protested that the Comps 2 exam was not consistently administered, that the procedures for assigning TAs were unfair, and that the department offered no recognition for performing well as a teaching assistant. ARPAC urges Physics to take these concerns to heart and recommit to mentoring graduate students and offering them more guidance on career development.

To improve its mentorship in professionalization and bolster placement rates, Physics must do a better job of collecting data on long-term graduate student placements. Lamentably, the department provided no information about graduate placements, though such information would be helpful. The self-study also provides no information about post-doctoral fellows, which should be remedied, as such data would assist Physics in improving mentoring, setting strategic goals for hiring, and analyzing space needs.

To accomplish its graduate education goals, Physics requests increased financial support for recruitment, funding for departmental promotional materials, travel support for faculty and students to attend conferences dedicated to women and underrepresented minorities, funding for multi-year graduate fellowships, and office space for experimental research assistants. ARPAC advises that the university should consider granting these requests if taken together the graduate outcomes assessments that Physics is preparing and its budget plan justify such expenditures. ARPAC also believes Physics should revisit the issue of professional master's credentialing,

given the recent restructuring of the proposal process for degrees and certificates.

Climate

Physics is, by all accounts, a collegial place. The internal reviewers note that faculty seem to be generally engaged, productive, and satisfied with the department's direction. The current chair receives positive reviews. The external reviewers note that untenured faculty seem pleased with newly instituted procedures for junior faculty mentoring and feel like participating members of the department. Some faculty, speaking to the external reviewers, criticized the department for relying too much on FCQs. The reviewers' conversations with senior faculty and the authors of the self-study routinely focused on a lack of effective communication with university administrators. ARPAC concurs with the external reviewers that improving the distribution of the administrative burden on department leaders would be a move in the right direction, and the department is moving toward the establishment of an assistant chair position, to help with the chair's workload.

Space and Infrastructure

The self-study, and internal and external reviewers, all note space issues as a major problem. The Duane building is outdated, which threatens the department's ability to stay current with scientific advances. Subpar facilities also interfere with the department's teaching mission, and Physics describes oversubscribed classrooms and a lack of office space as pressing concerns. Calls for major construction investments have been repeated over previous program reviews. While ARPAC understands that there may be a timetable for constructing a Duane H wing, Physics is concerned that this addition will not address all of its needs. Physics has not, however, performed a detailed analysis including a needs prioritization that lays out the department's preferences for renovated versus new space. Because Physics has been

allocated additional space after previous reviews, it is imperative that the department include a detailed account of how they've made use of those facilities as part of a comprehensive space needs analysis. ARPAC encourages discussions to resolve this issue with the appropriate stakeholders, including the Office of Advancement.

Inclusive Excellence

ARPAC commends Physics for its attention to increasing student gender and ethnic diversity and praises the department's continuing support of those students once they arrive on campus. Physics has also described plans to improve the representation of women and other underrepresented groups on its faculty. ARPAC urges Physics to continue this work and to look to the College of Engineering and Applied Science for possible next steps.

Recommendations

The members of the Academic Review and Planning Advisory Committee (ARPAC) address the following recommendations to the Department of Physics, and to the offices of responsible administrators:

To the Unit:

1. Complete the Department of Physics strategic planning process.

2. Develop a detailed space analysis, focusing both on needs that can be met by renovating existing space and on those requiring new space.

3. Develop a detailed faculty hiring plan.

4. Examine the factors affecting student retention in the undergraduate major and determine what changes should be made.

5. Enhance graduate and undergraduate mentoring to better meet the needs of students intending careers outside of academic research.

6. Develop proposals addressing student issues surrounding career development and job placement for graduates.

7. Work with the Office of Data Analytics and internal records to track graduate placements.

8. Provide evidence-based support and peer analysis for any requested changes in departmental and college structure, such as forming a new school of natural sciences.

9. Complete the process of revising the department's governance structure and bylaws, including institutionalizing

support for the chair and developing procedures for evaluating interdisciplinary faculty.

10. Develop requests to the college dean for a third instructor and a tenured or tenure-track faculty line for the Physics Education Research program, if supported by the strategic plan.

11. Work with the Office of Diversity, Equity, and Community Engagement (ODECE) and the Office of Faculty Affairs to develop a concrete faculty plan, using tools such as the Strategic, Targeted, and Accelerated Recruitment (STAR) program and the Chancellor's Postdoctoral Fellowship program, for recruiting women and members of underrepresented minorities. In reporting progress on this recommendation, include the makeup of the finalist pools for each faculty recruitment. Aim for pools that include multiple diverse candidates.

12. Prepare a detailed budget for enhanced graduate student support, addressing recruitment, travel, and stipend needs, and develop a plan for nurturing new financial sources, including training grants and external fundraising.

13. Revisit the idea of developing a physics professional master's, considering new procedures for professional master's certificates.

To the Dean of the College of Arts and Sciences:

14. Work with Physics and the provost on developing a method of meeting new faculty startup costs.

15. Work with Physics, the Office of the Vice Chancellor for Research and Innovation, and the provost on developing a

campus-wide policy on the correct balance between institute department hiring.

16. Consider a request from Physics for a third instructor and a tenured or tenure-track faculty line for the Physics Education Research Program, taking into account Physics' plans to increase the pool of potential faculty from underrepresented groups.

To the Vice Chancellor for Research and Innovation:

17. Investigate the financial and programmatic issues associated with the allocation of faculty positions to institutes rather than the college. Assist Physics in working with institutes to minimize problems and maximize benefits.

To the Provost:

18. Work with Physics and the college dean to develop a method of meeting new faculty startup costs.

19. Develop ways in which enrollment growth funding resources are appropriately distributed to the departments that are bearing the brunt of that growth in enrollment on their teaching resources.

20. Direct the Office of Advancement to provide resources appropriate to help Physics meet and expand its fundraising goals.

21. Help Physics to prioritize an achievable space plan based on the department's strategic plan.

Required Follow-Up

The Department of Physics chair shall report annually on the first of April for a period of three years following the year of the receipt of this report (i.e., April 1st of 2019, 2020, and 2021) to the deans of the College of Arts and Sciences and to the provost on the implementation of these recommendations. Likewise, the dean and the vice chancellor shall report annually on the first of May to the provost on the implementation of recommendations addressed to the team. The provost, as part of the review reforms, has agreed to respond annually to all outstanding matters under their purview arising from this review year. All official responses will be posted online.