VANDERBILT UNIVERSITY

Congressional Testimony

Subcommittee on Research and Science Education
Committee on Science and Technology
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Hearing on "Broadening Participation in Science, Technology, Engineering, and Mathematics (STEM)"

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Keivan Guadalupe Stassun, Ph.D.
Associate Professor of Astronomy, Vanderbilt University[1]
Adjunct Professor of Physics, Fisk University[2]
Co-Director, Fisk-Vanderbilt Master's-to-PhD Bridge Program
Director, Vanderbilt Initiative in Data-Intensive Astrophysics (VIDA)

Chairman Lipinski, Ranking Member Ehlers, Members of the Subcommittee, I am Keivan Stassun, associate professor of astronomy at Vanderbilt University, adjunct professor of physics at Fisk University, and co-director of the Fisk-Vanderbilt Master's-to-PhD Bridge Program. Thank you for inviting me to testify before you today. It is a privilege and an honor to tell you about the Fisk-Vanderbilt Master's-to-PhD Bridge program specifically and my thoughts on broadening participation in STEM fields more generally.

The Fisk-Vanderbilt Master's-to-PhD Bridge Program[3]

(additional comments and supporting material in Appendix A):

By completing a Master's degree at Fisk under the guidance of caring faculty mentors, students develop the strong academic foundation, research skills, and one-on-one mentoring relationships that will foster a successful transition to the PhD at Vanderbilt. The program is flexible and individualized to the goals and needs of each student. Courses are selected to address gaps in undergraduate preparation, and research experiences are provided that allow students to develop—and to demonstrate—their full scientific talent and potential.

The Fisk-Vanderbilt Master's-to-PhD Bridge Program is intended for:

- Students who have completed baccalaureate degrees in physics, chemistry, biology, or engineering.
- Students motivated to pursue the PhD but who require additional coursework, training, and/or research experience.

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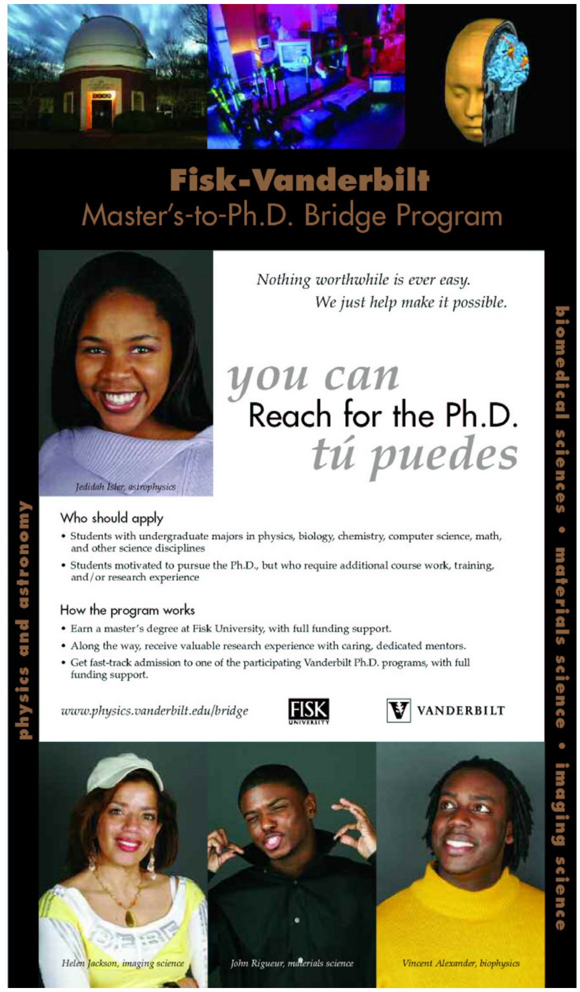
[1] Department of Physics & Astronomy, VU Station B 1807, Nashville, Tennessee, 37235
[2] Department of Physics, 1000 17th Ave. N., Nashville, Tennessee, 37208
[3] http://www.vanderbilt.edu/gradschool/bridge



How the program works, in a nutshell:

- Earn a Master's degree in physics, chemistry, or biology at Fisk, with full funding support.
- Along the way, get valuable research experience with caring, dedicated mentors. Emerge with the solid preparation for entry into a world-class PhD program, and the ongoing support of a network of dedicated mentors.
- Get fast-track admission to a participating Vanderbilt PhD program, with full funding. Participating PhD programs at Vanderbilt currently include: astronomy, physics, materials science, biology, and biomedical sciences.

Key milestones achieved by the Fisk-Vanderbilt Master's-to-PhD Bridge Program include:

- Since 2004, the program has attracted 35 students, 32 of them underrepresented minorities[4] (URMs), 59 percent female, and a retention rate of 92 percent (see Appendix A).
- The first Bridge Program PhD was awarded (in materials science) in 2009, just 5 years after the program's inception[5].
- The Bridge program is on track to award 10 times the US institutional average number of URM PhDs in astronomy, 9 times the average in materials science, 5 times the average in physics, and 2 times the average in biology (the biology track was newly added in 2008). The most recent incoming cohort alone includes more URM students in astronomy than the current annual production of URM PhD astronomers for the entire US.
- Bridge students have been awarded the nation's top graduate fellowships from NSF and NASA.

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[4] Underrepresented minorities (URMs) are defined as US citizens and permanent residents who are of African-American, Hispanic, or Native American descent.

[5] Read an article about the first Fisk-Vanderbilt Bridge Program PhD recipient: http://sitemason.vanderbilt.edu/vanderbiltview/articles/2010/02/26/crossing-the-bridge.108290

- In 2011, Vanderbilt will achieve the distinction of becoming the top research university to award PhDs to URMs in astronomy, physics, and materials science.
- Already, as of 2006, no US institution awards more Master's degrees in physics to Black US citizens than Fisk. Fisk has also become one of the top 10 US institutions awarding the Master's degree in physics to US citizens of all ethnic backgrounds [data source: American Institute of Physics].
- Extramural grants from NSF and NASA—supporting Bridge graduate students, faculty, and related undergraduate research—now exceed $25M.

The Fisk-Vanderbilt Master's-to-PhD Bridge Program started in 2004 with one student in each of astronomy, physics, and materials science. Catalyzing elements for initiating the program included the following:

- An NSF CAREER award to Prof. Keivan Stassun, which included collaborative research between Vanderbilt and Fisk faculty and students, with a major goal of training URM PhDs in astronomy as a centerpiece of the "broader impacts" component of the award.
- A NASA MUCERPI grant jointly to Fisk and Vanderbilt, centered on collaborative research between Fisk and Vanderbilt faculty and students, with a major goal of training URM PhDs in NASA-related STEM disciplines.
- An NSF IGERT grant jointly to Vanderbilt and Fisk, centered on collaborative research between Vanderbilt and Fisk faculty and students, with a major goal of training URM PhDs in materials science.
- Supportive administrators at both universities committing significant institutional funds as match to the above grants (e.g. tuition waivers), and directives permitting cooperation of the university bureaucracies, including course cross-registration and reciprocal access to university resources (e.g., research facilities, libraries, student services).

Soon after the program's inception, it was recognized that the "bridge" from Fisk to Vanderbilt needed to be formalized in order to establish clear guidelines by which a student successfully "crosses the bridge" and to ensure clear lines of responsibility, accountability, and support. Specifically:

- Each of the disciplinary "tracks" with the Bridge program (astronomy, physics, materials science) has *concrete requirements for students to successfully make the transition from the Fisk master's degree program to the Vanderbilt PhD program*, including specific graduate level courses that must be passed and specific requirements for research performance. These guidelines are approved by the respective deans at both universities.
- *Two program co-directors, one each at Fisk and Vanderbilt, have been formally appointed by the provosts of both universities*. These co-directors have official responsibility for administration of the Bridge program and are directly accountable to the provosts of the two universities.

- *A program Steering Committee* was established, with faculty leaders at both universities in each of the disciplinary tracks. These faculty leaders provide oversight, guidance, and tracking of student progress.
- *A formal mentoring structure* is in place, providing each Bridge student with "scaffolds of support" that help to ensure a successful transition across the bridge. This includes: (i) assignment of two faculty co-mentors, one from Fisk and one from Vanderbilt, for each student; (ii) a monthly "professional development seminar" aimed at demystifying the process of reaching the PhD for these students who, almost without exception, are the first-generation in their families to pursue higher education; (iii) a peer-to-peer mentoring structure allowing more senior Bridge students to help guide and counsel the students crossing the bridge behind them in a spirit of camaraderie; (iv) development of a "mentoring management console" for careful tracking of individual student progress, enabling Bridge faculty to identify potential problem cases early and to intervene quickly with additional support/resources as needed to prevent students from slipping through the cracks; and (v) dedicated administrative support staff (program coordinators) at both universities, providing an additional layer of mentoring support and a one-stop go-to person on each campus to help students solve bureaucratic/logistical problems that may arise.

In 2007, the Bridge program began to identify additional disciplinary tracks that could be introduced in order to expand the program's scale and impact. In addition, the Bridge program has begun to partner with additional institutions in order to (i) better connect Bridge students with mentors and cutting-edge research opportunities in the broad array of areas of interest to the students, and (ii) increase the pool of quality students whom we could recruit to our program.

- So far, a biology track has been added and formalized, including assignment of faculty leaders in biology. A new track in chemistry is under development.
- Several junior faculty leaders involved in the expansion of the Bridge program have now received prestigious NSF CAREER awards, including: Prof. Shane Hutson (biophysics), Prof. Eva Harth (chemistry), Prof. Kelly Holley-Bockelmann (astrophysics).
- Core partners now include: Boston University, Massachusetts Institute of Technology, National Optical Astronomy Observatories, National Solar Observatory, NASA Goddard Space Flight Center, Delaware State University, and University of Hawaii at Hilo.

There are two major characteristics of the Fisk-Vanderbilt Master's-to-PhD Bridge Program that we believe are central to its successes:

1. The Bridge program's basic design and structure—a "bridge" from the master's degree at an HBCU to the PhD at a major research university—is

grounded in research on the educational pathways that URMs in STEM follow en route to the PhD. In particular:

a. *Minority Serving Institutions*[6] *(MSIs) represent large—and largely untapped—pools of URM talent in STEM*. For example, the top 15 producers of African American physics baccalaureates in the US are all HBCUs, and just 20 HBCUs were responsible for producing fully 55 percent of all African American physics baccalaureates in the US between 1998 and 2007[7]. Moreover, these institutions are successful at placing students in PhD programs. Among the US baccalaureate-origin institutions of African American STEM PhD recipients for the years 1997-2006, the top 8, and 20 of the top 50, were HBCUs[8] (see Appendix A).

b. *URMs who earn PhDs in STEM fields are about 50 percent more likely than their non-URM counterparts to have earned a "terminal" master's degree (i.e. not a master's degree earned as part of a PhD program) before eventually transitioning to a PhD program*[9]. The number of MSIs with research-active faculty, and that offer advanced STEM degrees, has undergone dramatic growth. For example, the number of MSIs offering Master's degrees in the physical sciences or engineering has increased over the past decade by 79 percent, and the number of URMs earning Master's degrees from these institutions increased correspondingly by 533 percent (see Appendix A).

2. Because of the critical nature of the master's-to-PhD transition, at the heart of the Bridge program's model is the concept of *facilitating a successful transition to the PhD*. In collaboration with researchers at the Columbia University School of Law, we have identified the following four key components that are critical to facilitating a successful transition to the PhD, and that are deliberately put into practice by the Bridge program:

a. *Build and sustain research-based partnerships between Fisk and Vanderbilt faculty*. Joint research is the engine of institutional collaboration, the basis for extramural funding, and provides a concrete "performance-based metric" by which to assess student ability and promise for a research-based PhD.

b. *Identify students with unrealized potential*; recruit and support "diamonds in the rough" who can be honed for top-notch PhD level work given adequate mentoring and preparation.

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[6] MSIs include Historically Black Colleges and Universities (HBCUs), Hispanic Serving Institutions (HSIs), and Tribal Colleges and Universities (TCUs), as defined by the US Department of Education.

[7] AIP Statistical Research Center, Enrollment and Degrees Survey.

[8] Burrelli, J., & Rapoport, A. 2008, "Role of HBCUs as Baccalaureate-Origin Institutions of Black S&E Doctorate Recipients," NSF 08-319.

[9] Lange, S. E. 2006, "The Master's Degree: A Critical Transition in STEM Doctoral Education", Ph.D. Dissertation, University of Washington.
Syverson, P. 2003, "Data Sources", Graduate School Communicator, XXXVI, 5

- **c.** *Continually monitor student performance and remain alert to small inflections in trajectory*; do not wait for small missteps to accumulate and derail an otherwise promising student. Detect potential problems early and intervene with support quickly and often.
- **d.** *Leverage professional networks*; connect students with the broader STEM community for mentorship and research opportunities.
- **e.** In addition, the program includes these key elements to ensure successful student transitions:
  - *Full financial support.* Rationale: Financial burden should not be an impediment to participation and satisfactory progress.
  - *Joint advisory committee of both Fisk and Vanderbilt mentors*. Rationale: Track student progress and ensure student readiness for PhD-level work.
  - *Publication-quality Master's thesis through research in both Fisk and Vanderbilt labs*. Rationale: Develop relationships with faculty who serve as mentors, advisors and advocates. Demonstrate readiness for PhD-level work through core competencies that are more predictive of success than simple numerical metrics such as GRE scores.
  - *Course requirements at both Fisk and Vanderbilt*. Rationale: Demonstrating competency in core courses is essential to showing promise for PhD study.

There are three main challenges to replicating the successes of the Fisk-Vanderbilt Master's-to-PhD Bridge Program at other institutions, including at other major research universities:

1. *Dedicated faculty leaders at both of the bridged institutions are the single most important ingredient*. In lieu of a critical mass of URM STEM faculty who may identify with the goal increasing diversity in STEM as a core personal commitment, faculty "bridge builders" will likely need to be motivated and incentivized through institutional and external rewards (such as recognition in the tenure process and through the prestige associated with NSF CAREER awards). In truth, we expect that this will remain a fundamental challenge for replicating the program. The faculty leaders in the Fisk-Vanderbilt Bridge program view diversity in STEM as a priority for reasons that are at once strategic, moral, competitive, even patriotic—such passion and deep commitment are difficult to blueprint, export, or mass produce.
2. *The type of intensive, ongoing, one-on-one student mentoring that is so central to the Fisk-Vanderbilt Bridge model is very difficult to "scale up," depending as it does on a commitment of time and energy from faculty mentors* who already shoulder extensive demands on their time in the form of teaching, mentoring other students, managing a world-class research laboratory and team, university administrative duties, and of course a commitment to continually

produce top-notch research. Fortunately, even incremental increases in the number of URM STEM PhDs at one institution can represent significant gains on a national scale. For example, an institution that produces one URM PhD per year in physics will produce more than 5 times the national average. PhDs are earned one student at a time, and every single URM PhD makes a difference in the national numbers.

3. *A challenge is to identify capable, promising URM students for PhD study, who may come from small minority-serving institutions and/or may not have GRE scores that are competitive in comparison to the talented foreign students who apply to our programs in large numbers*. The Fisk-Vanderbilt Bridge program is built on the belief that there exists a large pool of talented URM students—who have already progressed to the baccalaureate level in STEM—with the promise and potential to continue successfully to PhD level. The challenge, in other words, is to learn to recognize "unrealized potential" in a student, to recognize and nurture the human traits that make for a great scientist but that are not easily quantified—creativity, ingenuity, genius even. The Fisk-Vanderbilt Bridge program does this through an "audition" approach: By the time a student has crossed the Bridge, there is no need to guess whether the student has "what it takes" for a PhD or to rely solely on "by the numbers" metrics—we know the student, have actually watched him/her perform in the laboratory. We therefore enjoy a much richer set of data about our incoming students than is usually available in PhD admissions.

Challenges to Achieving more Diversity in STEM
(additional comments and supporting material in Appendix B):

Three major challenges to achieving more diversity in science and engineering are:

1. *The very low production rate of URM STEM PhDs limits the number of URM faculty in STEM available to serve as mentors and role models*. Some gains have been achieved over the past few decades in the overall number of URMs earning baccalaureate degrees in STEM disciplines, yet the number of URMs earning PhDs in STEM disciplines remains very small (less than 4 percent of all STEM PhDs awarded by American universities). Taking my own field of astronomy as an example, a recent survey of all 51 astronomy and astrophysics PhD-granting programs in the US counted a total of just 17 individuals who identify as URMs among the full-time faculty (2 percent of all astronomy and astrophysics faculty)[10]. Consequently the number of URM faculty available to train, and to serve as role models for, the next generation of URM students in STEM remains extremely limited. An immediate five-fold increase in the production rate of URM STEM PhDs over the coming decade is

[10] Nelson, D., & Lopez, L. 2004, "The Diversity of Tenure Track Astronomy Faculty," American Astronomical Committee on the Status of Minorities in Astronomy, Spectrum Newsletter, June 2004.

required if we are to achieve parity relative to the US population within 30 to 35 years (see Appendix B).

2. *American citizens no longer earn the majority of STEM PhDs awarded by the US*. Global competition in STEM has become fierce; the dominance of American students in STEM graduate programs is no longer a given. In fact, American citizens now constitute the minority (44 percent) of PhD recipients from American graduate programs, across all STEM disciplines (Appendix B).
3. *The vast majority of PhD programs are underutilized as training grounds for URM STEM PhDs*. A disproportionate number of URM PhDs in STEM disciplines are produced by a very small number of institutions—just 27 institutions produce fully one-third of all URM STEM PhDs (see Appendix B). These institutions represent two very narrow segments of the higher education system in the US: A few MSIs that award PhDs (e.g. Howard University, University of Puerto Rico), and the very top-ranked major research universities (e.g. University of Michigan, University of California Berkeley). The overwhelming majority of PhD-granting research universities (particularly second-tier research universities such as Vanderbilt) are generally underutilized as training grounds for future URM PhDs in STEM.

Two noteworthy variations by STEM discipline are as follows:

1. *The small proportion of STEM PhDs awarded to URMs is most acute in the physical sciences*. For example, URMs receive just 2 percent of all PhDs awarded by American universities in physics and astronomy. Such small percentages in turn mean very small absolute numbers, making it a challenge for most URM PhD students to find role models, cohort or community during their PhD training. In astronomy, for example, the average PhD-granting institution produces 1 URM PhD every 13 years.
2. *There is now emerging at the baccalaureate level a very large national pool of URM talent in the computational sciences and in several sub-disciplines of engineering*. The overwhelming majority (80 percent) of these college-educated URM computer scientists and engineers exit the higher education system at the baccalaureate level. There is an opportunity to further develop this talent toward PhDs through interdisciplinary programs that combine the "pure" STEM disciplines (e.g. physics, biology) with "applied" skills such as systems engineering, high-performance computing, and informatics.

Two particular challenges for a major research university such as Vanderbilt are the following:

1. *The challenge of identifying the most promising STEM students for PhD training*. Selecting the best students for STEM PhD study is not a perfect science. Major research universities such as Vanderbilt have traditionally relied on certain quantitative and standardized metrics, such as Graduate Record Examination (GRE) scores and undergraduate grade-point average

(GPA). However, many of our domestic STEM students are being out-performed on these metrics by their peers from China, India, and other nations. A straight "by the numbers" approach to PhD admissions therefore results in a major underutilization of our domestic STEM talent. The challenge for a major research university such as Vanderbilt, therefore, is to maintain our high standard for excellence while identifying new ways of assessing student potential for the human traits we most value (e.g. creativity, innovativeness, entrepreneurial spirit, leadership, grit). These traits continue to distinguish American students from their peers around the world and are at the heart of our global leadership and competitiveness.

2. *The challenge of connecting the value of broadening participation to the merit basis by which STEM faculty are assessed, promoted, and rewarded*. The STEM faculty at a major research university are the engines of discovery, as well as the mentors and role models for the next generation of STEM PhD students. It is imperative that STEM faculty be motivated and incentivized to lead the broadening participation charge. A particularly promising example is the NSF CAREER[11] awards. These are among the most prestigious grants that a young STEM faculty member can receive, and it requires *both* a cutting-edge research program *and* "broader impact" including broadening participation. Indeed, the NSF CAREER awards to several young faculty (including especially women and URM faculty) at Vanderbilt in the past few years have been instrumental in simultaneously launching their careers and catalyzing the successful Fisk-Vanderbilt Master's-to-PhD Bridge program for broadening participation (described above).

The Federal Role in Broadening Participation in STEM

The Federal government can play a very important role in addressing challenges and barriers to broadening participation in STEM are as follows. In particular, the government should continue to link the national interest in broadening participation in STEM to Federal R&D initiatives, particularly in the context of development and full utilization of the domestic STEM workforce. There are at least three inter-related components to this:

1. *Individual principal investigators*. Individual researchers (e.g. faculty at research universities) are the "front lines" in America's STEM competitiveness imperative. These entrepreneurial individuals can and do respond to Federal mandates in R&D funding programs. The NSF's "broader impacts" criterion, which explicitly includes broadening participation language in the evaluation of all funding proposals, is an excellent model for accomplishing this. Similarly, the NSF CAREER awards program, which recognizes and supports America's top junior STEM faculty innovators, is

[11] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503214

another excellent example by which the broadening participation goal can be linked to the national system of incentives and rewards for America's best and brightest.

2. *Research universities*. The Science and Engineering Equal Opportunities Act (SEEOA) and Executive Order 11246 remain in effect and apply to virtually all research universities.
3. *Federally funded research centers and Federal funding agencies*. Major research facilities funded and/or operated by the Federal government or its contractors can play a critical role of leadership by example. Research centers such as the National Solar Observatory, the Department of Energy national labs, the NASA centers (e.g. Jet Propulsion Laboratory), and others, are major government R&D employers of the STEM labor force, and therefore rely critically on a healthy STEM workforce pipeline. However, with the exception of NSF facilities (NSF is explicitly mentioned in the SEEOA language), most of these Federal research centers generally do not include "broadening participation" language in their hiring or funding evaluation criteria. Extension of the NSF "broader impacts" criterion to the other Federal funding agencies (i.e. DOE, NASA, NOAA, NIH, NIST) could be a powerful step forward.

We suggest three recommendations with respect to NSF specifically:

1. *The NSF "broader impacts" criterion*, as discussed above, used in the evaluation of all funding proposals considered by the agency has had a very positive effect in motivating individual investigators specifically, and universities more generally, to address the broadening participation imperative. The NSF CAREER awards program in particular is a promising model for linking the prestige of our best STEM university faculty to the goal of broadening participation in STEM.
2. *Within NSF, some Divisions have taken the initiative to develop funding programs that specifically enable research-based collaborative partnerships between MSIs and major research universities* (including NSF-funded research centers) with the goal of training URM students toward STEM PhDs. Examples include the PREM[12] and PAARE[13] programs. In addition, the Innovation through Institutional Integration (a.k.a. I-cubed) program administered by the Education and Human Resources (EHR) Directorate has supports innovative programs that broaden participation in STEM and that

[12] The PREM (Partnerships for Research and Education in Materials) program is administered by the NSF Division of Materials Research (DMR) in the Math and Physical Sciences (MPS) Directorate.

[13] The PAARE (Partnerships for Astronomy and Astrophysics Research and Education) program is administered by the NSF Division of Astronomical Sciences (AST) in the Math and Physical Sciences (MPS) Directorate.

specifically attend to "critical educational junctures" such as the Master's-to-PhD transition.

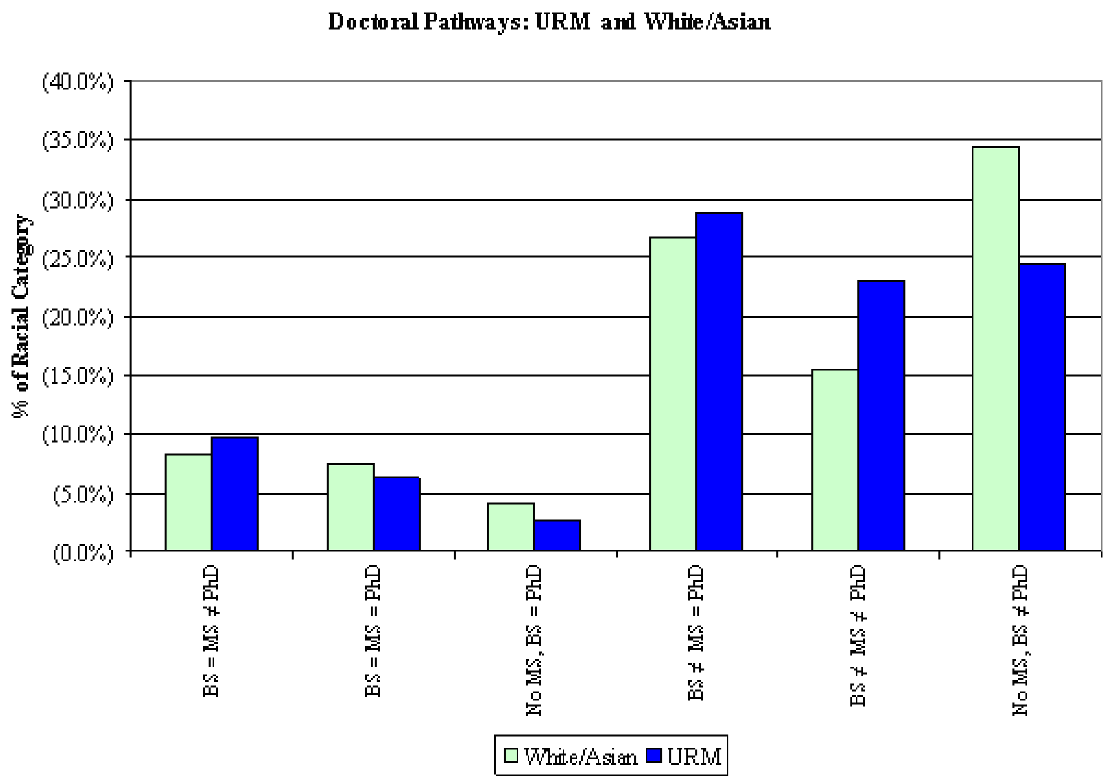
3. *There is a need for additional "training grant" opportunities through NSF to support the basic research training of Master's and PhD students*. The NSF IGERT[14] program is a very good example of a competitive and effective training grant program, with an emphasis on interdisciplinarity and on emerging new STEM sub-fields (such as the Vanderbilt-Fisk IGERT in nano-scale science and engineering). The IGERT program does not generally support graduate student training in more established areas of STEM research; there is an ongoing need for graduate students including URM PhD students to receive training and development in these established fields. Examples of standing training grant programs exist at other Federal agencies, such as NIH, that could serve as templates for the development of a more general training grants program through NSF. Indeed, the model of NSF's own Research Experiences for Undergraduates (REU) program, which is a general training grants program at the baccalaureate level, could be fruitfully applied at the post-baccalaureate, Master's, and PhD levels. In lieu of such training grants, Vanderbilt has so far committed $2M in institutional funds to support training of Fisk-Vanderbilt Master's-to-PhD Bridge students.

Mr. Chairman, thank you again for the opportunity to testify before the Subcommittee today. I look forward to answering the Subcommittee's questions and working together to broaden participation in the STEM fields.

[14] Integrated Graduate Education and Research Traineeships (IGERT) is an NSF-wide program.

Appendix A: Additional comments and supporting material for the Fisk-Vanderbilt Master's-to-PhD Bridge Program

MSIs (including HBCUs, HSIs, and TCUs) represent large—and largely untapped—pools of URM talent in STEM. For example, the top 15 producers of African American physics baccalaureates in the US are all HBCUs, and just 20 HBCUs were responsible for producing fully 55 percent of all African American physics baccalaureates in the US between 1998 and 2007[15]. In comparison to majority institutions, which in 2006 produced on average 9.0 URM bachelor's degrees per institution per year in physics,



The graph shows comparisons between URMs and White/Asian students, based on different permutations of the educational pathway to the PhD. An equal sign indicates degrees earned from the same institution. The fourth and sixth comparisons from the left show the "traditional" paths to the PhD, in which the student earns the bachelors degree from institution A, and either receives both the masters degree and the PhD from institution B or else forgoes the masters degree entirely. The fifth comparison from the left shows the case for earning the bachelors degree at institution A, a "terminal" masters degree at institution B, and PhD from institution C. URMs are much more likely to take this latter path than non-URMs. Adapted from Lange (2006), based on analysis of 80,739 PhDs earned in STEM fields, 1998 to 2002.

[15] AIP Statistical Research Center, Enrollment and Degrees Survey.

computer science, and engineering, MSIs produced on average 36.1 URM degrees per institution per year in these disciplines (data from NSF WebCASPAR). Moreover, these institutions are successful at placing students in PhD programs. For example, among the US baccalaureate-origin institutions of African American STEM PhD recipients for the years 1997-2006, the top 8, and 20 of the top 50, were HBCUs[16].

The number of MSIs with research-active faculty, and that offer advanced STEM degrees, has undergone dramatic growth. The growth of MSI Master's degree programs in particular is striking. For example, between 1987 and 2006, the number of MSIs offering Master's degrees in the physical sciences or engineering increased by 79 percent, and the number of URMs earning Master's degrees from these institutions increased correspondingly by 533 percent (from 119 URM degrees in 1987 to 753 in 2006; data from NSF WebCASPAR). Consequently, as shown in the chart below, URMs who earn PhDs in STEM fields are about 50 percent more likely than their non-URM counterparts to have earned a "terminal" master's degree (i.e. not a master's degree earned as part of a PhD program) before eventually transitioning to a PhD program[17]. Thus the Master's degree is a critical, and previously poorly understood, stepping stone for many URMs in STEM. Moreover, the transition from the Master's to the PhD is therefore a critical educational juncture at which students without suitable mentoring and guidance may be lost from the STEM PhD pipeline.

<u>Fisk-Vanderbilt Master's-to-PhD Bridge Program Facts & Figures</u>

- In 2006, U.S. institutions awarded to Black U.S. citizens 12 PhDs in physics (out of 637 U.S. citizen PhDs; 1.9%) [data from NSF]. The average per PhD-granting institution in the U.S. is 1 minority PhD in biology, physics, materials science, and astronomy every 2, 5, 9, and 13 years, respectively.
- The *Fisk-Vanderbilt Bridge program* is on track to award *10 times* the U.S. institutional average number of minority PhD recipients in astronomy, *9 times* the average in materials science, *5 times* the average in physics, and 2 times the average in biology (the biology track was newly added in 2007). Our most recent incoming cohort alone includes more minority students in astronomy than the current annual production of minority PhD astronomers for the entire U.S.
- Our *Bridge* students have been awarded the nation's top graduate fellowships from NSF (GRF and IGERT) and NASA (see Table 1 below).

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[16] Burrelli, J., & Rapoport, A. 2008, "Role of HBCUs as Baccalaureate-Origin Institutions of Black S&E Doctorate Recipients," NSF 08-319.

[17] Lange, S. E. 2006, "The Master's Degree: A Critical Transition in STEM Doctoral Education", Ph.D. Dissertation, University of Washington.

Syverson, P. 2003, "Data Sources", Graduate School Communicator, XXXVI, 5

- Extramural grants received to support the *Bridge* program—support for graduate students, faculty, and related undergraduate research—now exceed $25.1M (see Table 2 below).
- Vanderbilt and Fisk now provide significant institutional support in the form of tuition waivers, RA stipends, and administrative support (see Table 2 below).

Table 1: Fisk-Vanderbilt Master's-to-PhD Bridge Program Students to Date

Student	Ethnicity/ Gender*	Admit Year	Undergraduate Institution	Discipline	Current Institution / Status
S. Babaloloa	A/M	2004	University of Ilorin, Nigeria	Materials	UA Huntsville (faculty)
T. LeBlanc	H/M	2004	UMET, Puerto Rico	Astronomy	Vanderbilt (NASA Fellow)
J. Harrison	A/M	2004	Chicago State Univ.	Materials	Case Western (IGERT fellow)
H. Jackson	A/F	2004	Fisk University	Physics	Wright State (USAF Co-op)
J. Rigueur	A/M	2004	Fisk University	Physics	Vanderbilt (IGERT fellow)
V. Alexander	A/M	2005	Florida A&M Univ.	Physics	Dropped out, status unknown
J. Bodnarik	W/F	2005	USAF Academy	Astronomy	Vanderbilt (NASA Co-op)
M. Harrison	A/F	2005	Xavier University	Materials	Vanderbilt (IGERT fellow)
J. Isler	A/F	2005	Norfolk State Univ.	Astronomy	Yale (NSF graduate fellow)
E. Jackson	A/M	2005	Norfolk State Univ.	Materials	Vanderbilt (IGERT fellow)
J. Jones	A/F	2005	Grambling State U.	Materials	Vanderbilt (IGERT fellow)
T. Yan	H/M	2005	UMET, Puerto Rico	Biology	Vanderbilt
L. Zambrano	H/F	2005	UMET, Puerto Rico	Astronomy	Dropped out (now at UTB)
D. Foster	A/M	2006	UMBC	Astronomy	Vanderbilt
A. Ruffin	A/F	2006	Tennessee State U.	Physics	Oak Ridge National Lab
D. Campbell	A/M	2006	Rhodes College	Physics	Vanderbilt
R. Santos	H/M	2006	UMET, Puerto Rico	Physics	Dropped out, status unknown
E. Walker	A/F	2006	Alabama A&M U.	Materials	Vanderbilt (IGERT fellow)
J. Cooper	A/F	2007	Rust College	Biology	U Chicago
D. Gunther	W/F	2007	Austin Peay State	Materials	Vanderbilt
L. Palladino	W/F	2007	Hofstra U.	Astronomy	Vanderbilt
C. Mack	A/M	2007	UNC Chapel Hill	Astronomy	Vanderbilt
A. Parker	A/M	2007	Austin Peay State	Materials	Vanderbilt
E. Morgan	A/F	2007	Tennessee State U.	Astronomy	Vanderbilt
F. Bastien	A/F	2008	U. Maryland	Astronomy	Vanderbilt
L. Jean	H/F	2008	U. New Hampshire	Biology	Vanderbilt
M. Richardson	A/M	2008	Fisk University	Astronomy	Vanderbilt
S. Haynes	A/F	2007	Tennessee State U.	Astronomy	Fisk (MS expected 2010)
F. Colazo	H/M	2008	Fisk University	Astronomy	Fisk (MS expected 2010)
B. Kamai	N/F	2008	U. Hawaii	Astronomy	Fisk (MS expected 2010)
J. Harris	A/F	2008	Grambling State U.	Astronomy	Fisk (MS expected 2010)
S. Lawrence	A/F	2008	Clark U.	Biology	Fisk (MS expected 2010)
S. Satchell	A/F	2008	Saint Paul's U.	Biology	Fisk (MS expected 2010)
B. Cogswell	A/F	2009	Florida State U.	Physics	Fisk (MS expected 2011)
M. Williams	A/M	2009	Morehouse Univ.	Astronomy	Fisk (MS expected 2011)

*Ethnicity/Gender: H=Hispanic, A=African American, N=Native Hawaiian, W=White, F=Female, M=Male.

Table 2: Funding Received to Date Supporting Bridge Students and Faculty

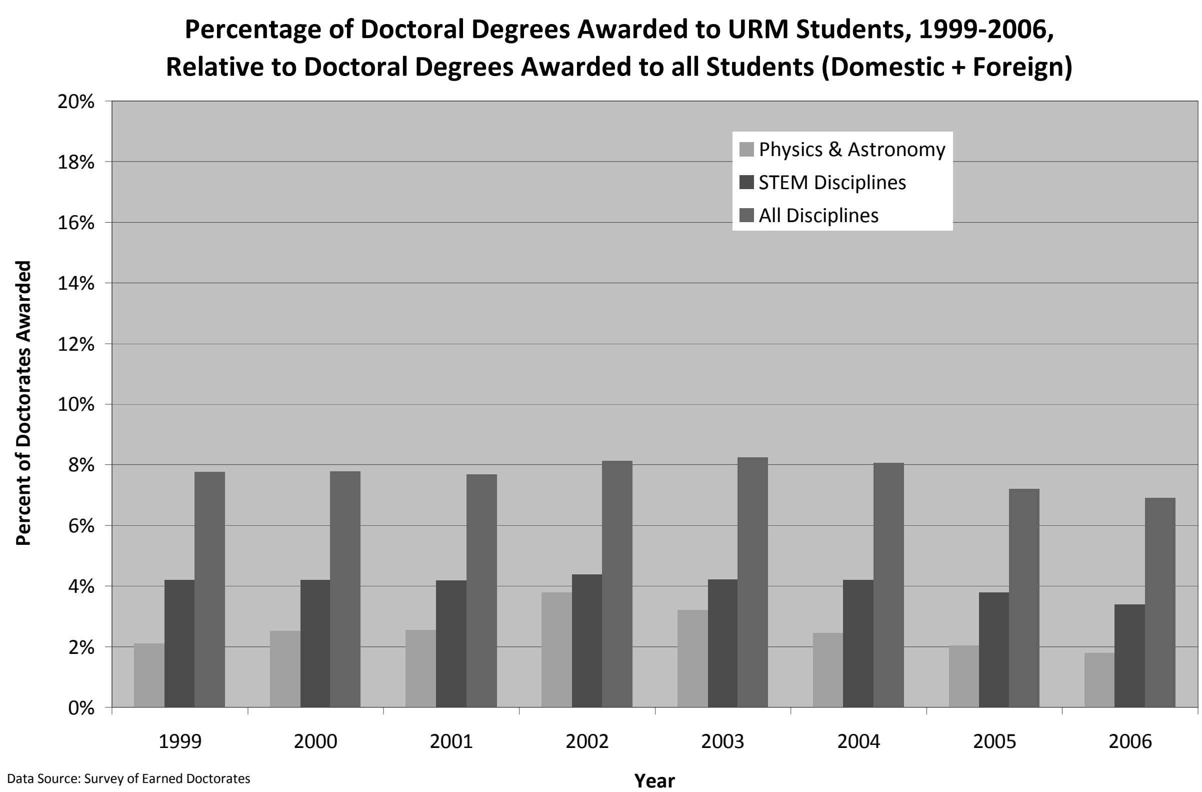
Agency	Program	Years	Lead Faculty (PI in boldface)	Amount
NSF	CAREER	2004-09	**K. Stassun (Vanderbilt)**	$1M
NASA	MUCERPI	2004-07	**A. Burger (Fisk)**, K. Stassun (Vanderbilt), E. Collins (Fisk), D. Ernst (Vanderbilt), S. Morgan (Fisk)	$800K
NSF	CREST/Materials Sci.	2004-14	**E. Collins (Fisk)**, A. Burger (Fisk), W. Lu (Fisk), S. Morgan (Fisk), R. Mu (Fisk)	$9.4M
DoE, DHS, DoD, NASA	Materials Science	2004-09	**A. Burger (Fisk)**	$3.5M
NSF	REU	2004-10	**E. Collins (Fisk)**, A. Burger (Fisk), S. Morgan (Fisk)	$600K
NSF	REU	2007-10	**D. Ernst (Vanderbilt)**, K. Stassun (Vanderbilt)	$300K
NSF	PAARE (AST)	2008-13	**K. Stassun (Vanderbilt),** A. Burger (Fisk), K. Holley-Bockelmann (Vanderbilt), M. Watson (Fisk)	$2.2M
NSF	CAREER	2009-14	**K. Holley-Bockelmann (Vanderbilt)**	$1.1M
NSF	I-Cubed	2009-14	**K. Stassun & R. McCarty (Vanderbilt)**, S. Rosenthal (Vanderbilt), E. Collins (Fisk)	$1.25M
DoEd	GAANN	2009-12	**K.Stassun,** D. Ernst (Vanderbilt), E. Collins (Fisk)	$900K
Vanderbilt Provost	VIDA[18]	2007-12	**K. Stassun (Vanderbilt)**	$2M
Vanderbilt A&S Dean	Biological Sciences[19]	2008-11	**D. Webb (Vanderbilt)**, J. Ike (Fisk), K. Stassun (Vanderbilt)	$150K
Fisk Provost	Physics/ Biology[20]	2004-14	**E. Collins (Fisk)**, S. Morgan (Fisk), J. Ike (Fisk)	$937K

[18] Vanderbilt Office of the Provost provides support for stipend/tuition for 4 Bridge students per year and a full-time program coordinator.
[19] The Dean of Vanderbilt Arts & Science provides seed support for 1 Bridge student per year in Biological Sciences (stipends + tuition).
[20] Fisk provides full tuition waivers for approximately 6 Bridge students per year in these Master's degree programs.

Appendix B: Additional comments and supporting material for Challenges to Broadening Participation in STEM

The very low number of underrepresented minorities (URMs) earning doctoral degrees in STEM disciplines is a problem in need of focused attention and rapid improvement. Individuals who exit the higher education STEM pipeline with baccalaureate degrees are in an excellent position to join the national STEM workforce with fulfilling and gainful employment. However, it remains a critical national interest to sustain a vital pipeline of individuals earning doctoral degrees in STEM. These are the best and brightest of our national brain trust: the future leaders of our world-class laboratories, the future principal investigators of federally funded R&D initiatives, the future teachers, mentors, and role models for subsequent generations of America's explorers. It matters, therefore, that these future STEM leaders reflect the "face of America."

Graduate STEM programs in the US have become increasingly effective in the training of STEM leaders for the rest of the world. Indeed, in many STEM disciplines, the proportion of all PhDs awarded to non-US citizens or permanent residents now exceeds 50 percent. As one example relevant to one federal agency (NASA), in 2008 there were 265 PhDs awarded by US institutions in aerospace, aeronautic, and astronautical engineering, of which 121 were awarded to US citizens and permanent



residents; that is, less than half of all PhDs awarded in these NASA-related disciplines are now being awarded within the domestic US STEM workforce[21]. More generally, 44 percent of all STEM PhDs are awarded by US institutions to US citizens and permanent residents[21].

To be sure, graduate students from other countries contribute greatly to the intellectual community at an institution like Vanderbilt, and bring much to the institution in terms of diversity. At the same time, however, large segments of the US population remain grossly underutilized. Over the period 1999-2006, US citizen URMs represented on average just 4 percent of all STEM PhDs awarded by US institutions (see chart above), whereas these groups comprise more than 30 percent of the PhD-age population of the US. Foreign students earned almost five times as many PhDs in 2006 than did URM citizens of the US. As noted by the Woodrow Wilson Foundation report, *Diversity and the PhD*: "educating the world's students while neglecting significant groups of the national population is a vast inequality at the highest academic level".

Low as is the overall representation of URMs in STEM fields, some disciplines prove particularly challenged. In general the physical sciences show the most severe underrepresentation of URMs. For example, in physics and astronomy the proportion of PhDs awarded to URMs in 1999-2006 averaged just barely over 2 percent, again compared to the more than 30 percent that URMs represent in the PhD-age population of the US. In 2008, US institutions awarded to Black US citizens just 15 PhDs in physics (out of 905 US citizen PhDs; 1.7%) [NSF Web-CASPAR]. Of course, PhDs are earned one individual at a time, each within a department at one institution. It is at this level of granularity that the challenge of broadening participation must be met. For example, in physics the statistics translate into an average of 1 URM PhD per PhD-granting institution every 5 years. In materials science, it is 1 URM PhD per institution on average every 9 years. In astronomy, it is 1 URM PhD per institution on average every 13 years.

One consequence of this very low URM PhD production rate is that there continues to be a very small number of URM STEM faculty at major research universities to serve as mentors and role models for the next generation of URM STEM PhDs. Taking astronomy as an example, a recent survey of all 51 astronomy and astrophysics PhD-granting programs in the US counted a total of just 17 individuals who identify as URMs among the full-time faculty (2 percent of all astronomy and astrophysics faculty)[22]. These PhD-granting programs today collectively award approximately 4±1 URM PhDs per year (data from American Institute of Physics), an average per PhD-granting institution of 1 URM PhD every 13 years[23]. Over the past

[21] Data source: Survey of Earned Doctorates (NSF/NIH/USED/NEH/USDA/NASA).
[22] Nelson, D., & Lopez, L. 2004, "The Diversity of Tenure Track Astronomy Faculty," American Astronomical Committee on the Status of Minorities in Astronomy, Spectrum Newsletter, June 2004.
[23] Stassun, K.G. 2005, "Building Bridges to Diversity", Mercury, 34 (3), 20

20 years this represents a slight increase in absolute number from 3±1 URM PhDs in 1988. The corresponding fraction of URM PhDs has been roughly flat at 2-4 percent of the total[24], while the proportion of URMs in the US population grew by 33 percent during this same time period (from 20.9 percent in 1988 to 27.0 percent in 2008; data from US Census). Over the past decade, the proportion of URM PhDs in physics and astronomy has been a factor of 2 smaller than in all other science and engineering (STEM) fields, and a factor of 4 smaller than in all fields. On average about 3 percent of the STEM workforce turns over each year. To achieve parity in the number of URMs entering the stream of permanent astronomy and astrophysics positions, and assuming similar attrition rates among URM PhDs as for astronomy and astrophysics PhDs as a whole, the number of URM PhDs would need to increase from 5 per year to approximately 40 per year, an eight-fold increase. At this pace, the field overall could achieve parity in 30 to 35 years.

Inside Higher Ed (3/11/2010, Jaschik)[25] reports that a study from Cornell University's Higher Education Research Institute "finds a statistically significant relationship between [URM] students who plan to be a science major having at least one [URM] science instructor as freshmen and then sticking to their plans. The finding could be significant because many students (in particular members of URM groups) who start off as science majors fail to continue on that path—so a change in retention of science majors could have a major impact." Joshua Price, who authored the report on the study, said, "These results suggest that policies to increase the [URM] representation among faculty members might be an effective means of increasing the representation of [URMs] who persist and ultimately graduate in STEM fields."

The mentoring and training of URM STEM PhDs is not shared equally among PhD-granting institutions. Indeed, fully one-third of all URM STEM PhDs in the US are produced by just 27 institutions. As shown in the table below, these 27 institutions represent two distinct groups of institutions: (1) The few MSIs that award PhDs (such as Howard University, University of Puerto Rico, Carlos Albizu University), and (2) the very top-ranked PhD-granting institutions (such as University of Michigan, University of California Berkeley, Harvard University). In comparison, the overwhelming majority of PhD-granting programs in the US on average produce single-digit numbers of URM STEM PhDs, or none at all. These PhD-granting programs, representing broadly the second-tier of research universities, are currently underutilized for broadening participation of URMs in attaining STEM PhDs.

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[24] These fractions are relative to US citizen and permanent resident PhDs only. Since foreign students account for approximately 50% of all physics and astronomy PhDs awarded in the US (Ref: Survey of Earned Doctorates), the true fraction of PhDs earned by URMs is a factor of 2 smaller.

[25] http://www.insidehighered.com/news/2010/03/11/race

Engaging URM individuals from a broader base of "applied" STEM backgrounds could substantially, and quickly, expand the pool of qualified individuals in areas of the "pure" disciplines that are likely to experience growth in the coming decade. For example, the development of new instruments for high-energy physics experiments, for space-based astrophysics missions, for climate-change research, etc., will require technical expertise from a variety of engineering disciplines, including systems engineering and design, and innovations in detector technologies stemming from materials science. Similarly, the increasing importance of high-performance computing and informatics-based approaches—for large scale simulations, for data-intensive surveys, for data-mining infrastructures across all STEM disciplines—will require expertise that may be tapped from the ranks of computer science graduates.

In 2006, for example, URMs earned a total of 17,813 baccalaureate degrees in

STEM Doctoral Degrees Awarded to Underrepresented Minorities (American Indian, Black, Hispanic)

	Institution	2003-2007
	All institutions	9,677
1	Carlos Albizu University	323
2	Howard University	219
3	University of Michigan-Ann Arbor	201
4	Nova Southeastern University	199
5	University of Puerto Rico-Rio Piedras Campus	192
6	University of Florida	162
7	University of California-Berkeley	143
8	Stanford University	123
9	University of California-Los Angeles	114
10	CUNY Graduate School and University Center	108
11	Carlos Albizu University-Miami Campus	103
12	Ponce School of Medicine	103
13	Purdue University-Main Campus	98
14	The University of Texas at Austin	97
15	University of Maryland-College Park	96
16	Alliant International University	90
17	Harvard University	90
18	Texas A & M University	89
19	University of California-San Diego	86
20	University of North Carolina at Chapel Hill	86
21	Michigan State University	85
22	George Mason University	82
23	Pennsylvania State University-Main Campus	81
24	Georgia Institute of Technology-Main Campus	81
25	University of Arizona	80
26	California School of Psychology, Los Angeles	78
27	University of Illinois at Urbana-Champaign	77

STEM doctoral degrees awarded by leading institutions, by race/ethnicity of U.S.-citizen and permanent-resident underrepresented minority graduates: 2003–07. SOURCE: National Science Foundation, Division of Science Resources Statistics, special tabulations of U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, 2003–07.

physics, computer science, and engineering [data from NSF WebCASPAR]. In comparison, 3,598 (20.2 percent) of these earned a master's degree, and 292 (1.6 percent) went on to earn a PhD. Thus the pool of URMs with relevant STEM training is substantial, but an overwhelming majority of these individuals currently exit the higher education pipeline with a bachelor's degree. The opportunity to pipeline URM STEM baccalaureates into advanced degrees in STEM disciplines is large.