The Howard University Program in Atmospheric Sciences (HUPAS): A Program Exemplifying Diversity and Opportunity

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ABSTRACT

This paper discusses experiences and lessons learned from developing an interdisciplinary graduate program (IDP) during the last 10 y: The Howard University Graduate Program in Atmospheric Sciences (HUPAS). HUPAS is the first advanced degree program in the atmospheric sciences, or related fields such as meteorology and earth system sciences, instituted at a historically black college or university or minority-serving institution (MSI). The PhD program in atmospheric sciences was implemented in 1996 as a direct result of synergies between overlapping interests in initiating interdisciplinary programs within the Howard University Graduate School, and within a National Aeronautics and Space Administration (NASA)–funded university research center to produce greater institutional depth and breadth of research in the geosciences. The development of HUPAS has revitalized a significant segment of the Howard University research community, leveraged a significant level of funding for research and training, raised the visibility of the university in a vibrant area of research, and made a great impact on the national statistics for the production of underrepresented minority (URM) advanced degree holders in the atmospheric sciences. Though the HUPAS program is still in its infancy with respect to many well-established programs in atmospheric sciences and meteorology, it has benefited from a number of federal, state, and academic partnerships, which have led to increasing capacity development, improved resources for students, and research infrastructure enhancements. Specific examples of successful partnerships among HUPAS and federal funding agencies such as NASA and National Oceanic and Atmospheric Administration have been critical cornerstones in the development process. The student recruitment and retention strategies that have enabled the success of this program and statistics of student graduation during the last decade are discussed. Entering its tenth year, HUPAS has apparently overcome many of the pitfalls that plague the development of IDPs that draw their faculty from existing, traditional departments. It is hoped that the approaches and lessons learned and discussed in this paper may be illuminating and useful for others to emulate in the development of a similar IDP programs in atmospheric and other earth and environmental sciences, especially at MSIs and at institutions with small- to medium-sized graduate enrollments. [DOI: 10.5408/10-180.1]

Key words: atmospheric sciences, HUPAS, interdisciplinary graduate programs, NCAS, Howard University

INTRODUCTION

Since its inception in 1867, Howard University has promoted a mission to train underrepresented minority (URM) students in many disciplines and fields of study. The first and second PhD graduates from Howard University were in chemistry (1958), and though only 50 y in existence, the Howard University Graduate School remains among the top 10 producers of URM PhDs for the nation, as well as many international communities, in science, technology, engineering, and mathematics (STEM) fields. One of the important reasons for this success has been focused recruitment of highly motivated and well-prepared undergraduate students from minority-serving institution (MSIs) in a variety of STEM fields. In particular, many of these students might not have selected atmospheric sciences as a first choice for graduate study or may not have succeeded in majority institution graduate programs because of environment, lack of support, or personal factors.

The motivation for the establishment of an academic (degree-granting) program in atmospheric sciences at Howard University began with recognition of the adverse effects resulting from a failure of national education programs in atmospheric sciences to attract a large pool of talent from the pool of URM STEM undergraduates (Williams et al., 2007). Recent National Science Foundation (NSF) data show that between 1998 and 2005, African Americans and American Indians trailed all other racial groups enrolled in graduate programs in science and engineering (see Table I). The numbers for earth, atmospheric, and ocean sciences are even more dismal (note that these statistics are further discussed in Fig. 1). In 2006 , according to the NSF reporting, there were only 11 African American graduate students enrolled in historically black colleges and universities in atmospheric sciences nationwide.[1] In stark contrast, and this will be discussed in a later section, in 2006 alone, there were nine African Americans enrolled in Howard University Graduate Program in Atmospheric Sciences (HUPAS). Despite the

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[1] Table 53: Graduate students in science, engineering, and health fields in historically black colleges and universities, by detailed field, citizenship, and race/ethnicity of U.S. citizens and permanent residents (NSF, 2008).

TABLE I: Graduate students in science and engineering fields of study (2002–2005).[1]

Ethnic/Racial Group	2002	2003	2004	2005
White	9,799	9,963	10,342	10,120
Black	266	270	261	262
Hispanic	413	484	537	507
American Indian/Alaskan Native	81	63	67	61
Asian/Pacific Islander	355	363	436	415

[1]Source: Table 15. Graduate students in science, engineering, and health fields in all institutions, by field, citizenship, and race/ethnicity of U.S. citizens and permanent residents, 1998–2005 (National Science Foundation, 2008).

small absolute numbers, this is indeed a very significant success story in the development of the HUPAS program.

The main objectives of this article are to highlight the success of the atmospheric sciences graduate program at Howard University and discuss the lessons learned in the development of this program. We will describe four critical factors that have contributed to the program's success. These factors are discussed in next section. Additional lessons associated with some of the challenges encountered during the development of the HUPAS program are discussed in the subsequent section. The paper is concluded with a brief discussion on recommendations for future directions of the program. It is hoped that these lessons will provide some benefits to build interdisciplinary graduate programs at MSIs and other similarly situated academic institutions.

LESSONS LEARNED: CRITICAL FACTORS IN THE SUCCESS OF HUPAS

During the first 10 y in the development of the HUPAS program at Howard University, we learned that the following four factors are most critical to the program's success. These factors are:

- stakeholder support in seminal developments,
- demonstrable production and potential for growth,

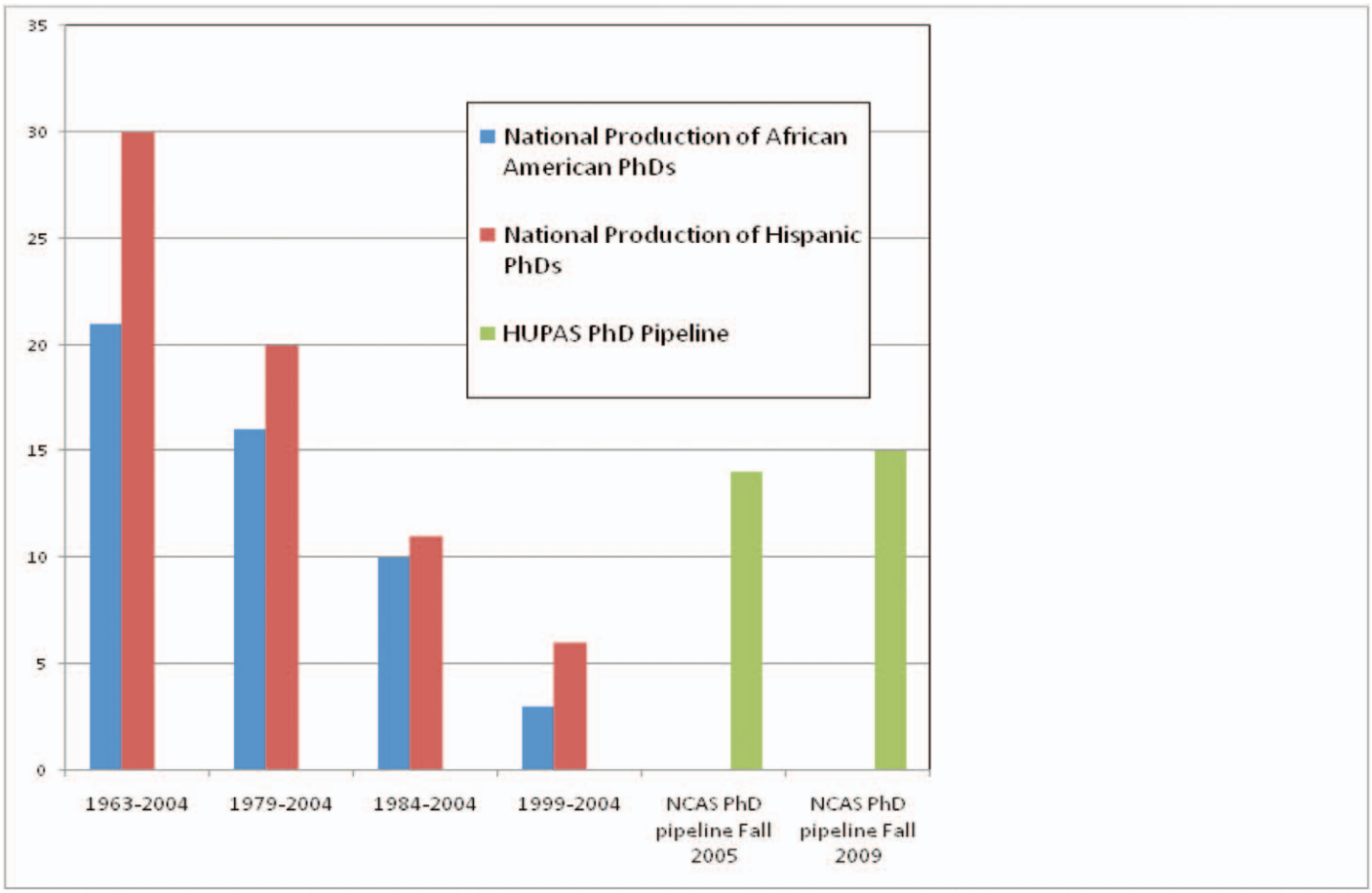

FIGURE 1: (Color online) Statistics of HUPAS PhD degree production as compared to the NSF indicators for the total U.S. PhD degree production in atmospheric sciences. NCAS = NOAA Center for Atmospheric Sciences.

- university investment, and
- research program and recruitment strategies.

We suggest that these fundamental elements are transferable to institutions of similar administrative philosophy and history.

Stakeholder Support in Seminal Development

The national statistics as shown in Table I were used to present a case for establishing an interdisciplinary academic program at Howard University capable of attracting students to a particularly nondiverse area of geosciences—atmospheric sciences/meteorology—and meeting national workforce needs in this area. The proposal received considerable encouragement from the National Aeronautics and Space Administration (NASA) through an external advisory panel review for the Center for the Study of Terrestrial and Extraterrestrial Atmospheres (CSTEA; Morris and Thorpe, 1996). CSTEA was initiated through a research grant designed to stimulate research and training in support of NASA missions in earth and space sciences through investment and support of intellectual capital in the faculty and students at historically black colleges or universities (HBCUs). The research projects at CSTEA involved faculty from a variety of academic departments (physics, chemistry, biology, electrical engineering, mechanical engineering) of two colleges (College of Arts and Sciences, and College of Engineering). In an effort to move the center toward a unifying theme, as well as to ensure relevance in the student education, several training programs (summer institutes, technical workshops, and advanced courses) were developed to link the research projects more closely with NASA's mission. These training programs provided the main impetus for the establishment of HUPAS, which was developed as a logical progression from the summer internship and recruitment programs to meet the unique needs for research within NASA's Goddard Space Flight Center (GSFC) facility and the larger scientific community in atmospheric sciences.

The full proposal for the graduate program in atmospheric sciences was developed over a 2 y period (1996–1997) and vetted amongst the faculty at Howard University, within the CSTEA technical review committee, and among several independent reviewers in atmospheric sciences programs nationwide. The final version was presented to the Howard University Board of Trustees in the fall of 1997. It was approved for implementation as a degree-granting graduate program in 1998. HUPAS thus became one of the first two interdisciplinary programs sanctioned by the Howard University Board of Trustees—the other being materials sciences. HUPAS is distinguished from the Materials Sciences Interdisciplinary Program by its ability to grant advanced degrees directly. HUPAS remains a graduate school program with three "parent" departments: chemistry, mechanical engineering, and physics and astronomy. Each of these departments aligns roughly with a core subspecialty of atmospheric sciences: atmospheric composition and chemistry, atmospheric fluid dynamics, and atmospheric thermodynamics and radiation, respectively. A program director serves as the administrative focal point for the program and is usually a tenure-track faculty member teaching HUPAS courses from one of the three parent departments. This position rotates among the active faculty teaching in the program (about every 2 y). The program director chairs the executive committee of HUPAS, which is composed of one active faculty member from each parent department, the sitting chair of each parent department, and one at-large member (seven members).

The development of HUPAS began modestly in 1996 with a new graduate elective course offered in the Department of Chemistry—Atmospheric Chemistry I. This course was followed by other courses, such as Planetary Atmospheres, Atmospheric Chemistry II, and Atmospheric Physics, over the next 3 y. While these courses were being developed and offered, efforts were made to develop the graduate program in tandem. By 1998, five tenure-track faculty had been hired that could teach courses in HUPAS: one in the Department of Chemistry, three in the Department of Physics and Astronomy, and one in the Department of Mechanical Engineering. These faculty formed the initial core academic staff to support the program. Each faculty person had a primary appointment in either the College of Arts and Sciences or in the College of Engineering (Mechanical Engineering), and all had additional appointments in the Graduate School. All HUPAS courses were initially cross-listed as graduate courses in the parent departments of each faculty member. This encouraged students from the parent departments to enroll in HUPAS courses as electives and provided some justification for the HUPAS workload for faculty in each department.

The NASA funding was ultimately supplemented with other federal and private-sector grants. The core funding for CSTEA (and therefore HUPAS) was continued for two 5 y cycles, ending in 2002. The center funding was extended beyond 2002 on a limited basis in order to allow completion of degrees for students (the majority of whom were in non-HUPAS courses of study) still in the pipeline in 2002. In 2001, HUPAS faculty successfully competed for a cooperative agreement with the Department of Commerce, through the National Oceanic and Atmospheric Administration's Educational Partnership Program (EPP; Robinson et al., 2007). Through this funding, a cooperative science center (CSC) called the NOAA Center for Atmospheric Sciences (NCAS) was established at Howard University (Morris et al., 2007). This center has contributed significantly to the recruitment and production of graduates in the atmospheric sciences and other related fields. Indeed, it provided the financial continuity as the NASA core funding for CSTEA was phasing down. During this time, the university maintained its commitment of 12 graduate fellowships under the CSTEA umbrella and an additional commitment (although at a reduced number, five) to the new NCAS Center as part of the university match for the program. In addition, the university committed to hire two tenure-track faculty in support of HUPAS. This provided an important source of support in the continued development of the academic program. The details of the hiring were negotiated at the departmental level, and hires were eventually made in the Department of Chemistry (2006) and in the Department of Physics and Astronomy (2009).

The core funding provided through NOAA has buttressed the growing funding portfolio of the HUPAS faculty to one that is now quite diverse and includes multiple federal, state, corporate, and private sources. As mentioned already, HUPAS has greatly benefited by its partnership with the NOAA Educational Program (EPP), which provides

TABLE II: Summary of Program Statistics through 2009.

Total Number of Required Course Credit Hours	32
Average Time to complete MS	2.6 years
Average Time to complete PhD	5.5 years
Current Number of Faculty	7
Current Enrollment (full time)	20
Average Annual Incoming Class Size	4
Average Annual Enrollment	16
Total Number of Graduates as of December 2009 (MS/PhD)	15/11
Matriculation Rate	80%
Current PhD Pipeline	7

significant funding for NCAS at Howard University (Robinson et al., 2007). NCAS, a consortium led by Howard University, consists of four major MSI partners: Howard University, Jackson State University (JSU), the University of Puerto Rico at Mayaguez (UPRM), and the University of Texas at El Paso (UTEP); and two minor institutions: the State University of New York at Albany (SUNYA), and the University of Illinois at Urbana-Champaign (UIUC). NCAS has significant research collaborations with NOAA and NASA GSFC. NCAS has developed significant research relationships with NOAA National Centers for Environmental Prediction (NCEP), the Air Resources Laboratory (ARL), and the National Environmental Satellite Data Information Services (NESDIS). For further details about the NCAS program, the reader is referred to Morris et al. (2007).

During the fall of 2008, with the success of HUPAS, the University Research Center (URC) at Howard University was established with funding provided by a grant from NASA, which is further contributing to the growth of the program. With an initial grant for a period of 5 y (2008 to 2013) from NASA, the URC was established to enhance HUPAS in education and research projects that are aligned with the NASA mission in atmospheric and earth sciences. This proved to be another important factor for the continued development of the program. In addition, leveraged through the NOAA core funding, several research programs have also benefited from smaller grants awarded to HUPAS faculty from various sources (e.g., NSF, Maryland Department of Environment, U.S. Department of Energy, and the Environmental Protection Agency [EPA] for cloud aerosols and solar radiation measurements and air-quality research, to be discussed in the following sections). Table II gives a brief summary of the overall structure of HUPAS as of December 2009.

Demonstrable Productivity and Growth Potential

HUPAS has made an unprecedented impact on the national scale in its first 10 y of existence, as evidenced by the national statistics for minority PhDs in the atmospheric sciences.

The national impact of the development of the HUPAS PhD pipeline can be seen even more clearly in Figure 1, which compares HUPAS PhD degree students' production to those obtained from the NSF indicators for the total U.S. production of African American PhDs.

Over the lifetime of the program, 34 students who received either full-time or significant part-time support from the NASA and NOAA centers were awarded the PhD degree, and 37 students were awarded the MS degree in atmospheric sciences, chemistry, physics, mechanical engineering, or electrical engineering. Many of these graduates are working as full-time employees of NASA and NOAA, employees of NASA and NOAA contractors, or have positions in academics conducting research in areas of interest to both agencies.

In Figure 2, the current enrollment and PhD pipeline of HUPAS over its lifetime is shown. The dividing vertical lines segment the first 15 y of the program into three phases roughly corresponding to pre-PhD production, i.e., program spin-up (left-hand panel), the current phase of initial PhD production (middle panel), and the projection for the following 5 y (right-hand panel). For example, 10 PhDs from underrepresented groups have graduated from HUPAS in the last 3 y. On the other hand, NSF indicators report only 51 PhD degrees from these same groups in the 30 y period

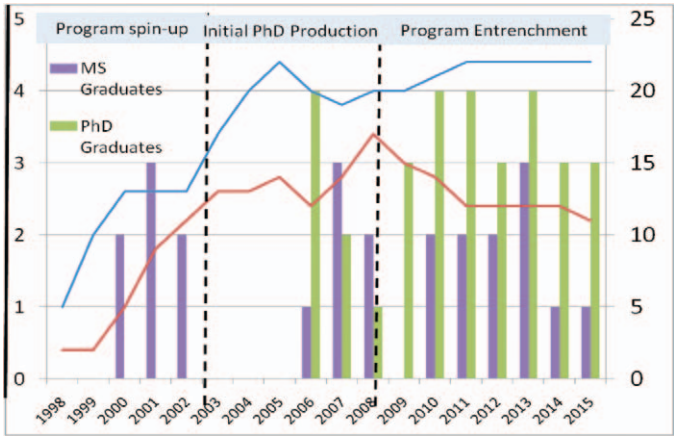

FIGURE 2: (Color online) The development of HUPAS over its first 11 y and a 4 y projection (the first 15 y). The blue and red lines indicate the annual enrollment and PhD pipeline, respectively, and they are plotted against the ordinate axis on the right. The PhD pipeline is defined as the total number of students enrolled full time as PhD students in HUPAS. The annual graduates are plotted against the left ordinate axis.

between 1973 and 2003. More specifically, between 1973 and 2003, only five African American females earned PhDs in atmospheric sciences. In contrast, HUPAS produced four African American female PhDs in atmospheric sciences between 2006 and 2009 and has two more in the pipeline—matching the national output in our third PhD class. Similarly, NSF statistics reports only three Hispanic females earning their PhD in atmospheric sciences between 1973 and 2003. On the other hand, HUPAS has produced one Hispanic female PhD in 2006 and has three more in the pipeline—exceeding the national production over a 30 y period. These numbers do not include precandidacy students currently enrolled in HUPAS.

The number of students in the current HUPAS PhD pipeline is comparable to the national output of African American and Hispanic PhDs over the last decade. The number of current African American PhD students (five) exceeds the national production over the period of 1998–2008. This is a remarkable result and provides a strong justification for the university investment in HUPAS as a national resource for domestic talent.

Since the 1998–1999 academic year, student enrollment in HUPAS has grown from five students to 19 (400% increase). HUPAS-affiliated faculty have raised over US$30 million in external grants to conduct atmospheric science research involving graduate students from a variety of departments . In fact, funding acquired by HUPAS efforts has been used to support the research and/or education of seven graduate students in chemistry, twelve graduate students in physics, and four graduate students in mechanical engineering. NCAS funds have also supported numerous undergraduate interns in various departments at Howard.

Over the past decade, HUPAS has become one of the fastest growing and most successful graduate programs at Howard. HUPAS has reached a steady-state enrollment of near 20 students annually. It is by far one of the most diverse atmospheric sciences graduate programs in the nation, with students of African American, Hispanic American, African, Caucasian, Caribbean, and Latin American ethnicities.

During the program spin-up phase (1998–2003), the enrollment and the PhD pipeline increased largely as a function of aggressive recruiting and ample support packages through the early NASA funding. This is seen in Figure 2, which shows a distinctive rise in enrollment in the beginning phase and a leveling of the PhD pipeline numbers over the period 2001–2008, coinciding roughly with the start of the NOAA funding and the recruitment of selected MS graduates into the PhD program. The absence of graduates during the 2003–2005 time frame during the second phase (middle panel) is due to the fact that the initial students recruited into HUPAS obtained their MS degrees before transferring to the PhD program. Other students recruited during the 2001–2003 period entered the PhD program directly, and given a 4–6 y matriculation period for doctoral degrees, would not have been eligible for graduation during this time. In the third phase (far-right panel, 2008 and beyond), the HUPAS PhD pipeline (dark-blue line) is observed to fall off as PhD graduates exit the pipeline. This drop is not precipitous as it simply indicates a move toward a steady-state number from an initial "front-loading" of the PhD program. Based on current enrollment numbers and the statistics compiled over the past 7 y, the steady-state enrollment of HUPAS is projected to be between 18 and 23 students per year, with an average entering class of 3–5 students per year. The HUPAS PhD pipeline is expected to average 8–10 students annually, with an annual PhD production to reach a steady-state level of 3–5 graduates in the next 5 y.

Figure 3 provides breakdowns of the demographics of the current program enrollment by gender, ethnicity, and undergraduate institution. While the program relies heavily on attracting students from MSIs (75% of enrollment), one quarter of the students come from majority institutions. This is essentially reflective of the aggregate pipeline, with a small fraction (~1%) coming from international institutions. The ethnicity and gender plot is strong evidence for our claim as one of the most diverse programs in the nation.

An understated but key aspect of the growth potential is internal advocacy. We have found that it is critical for the interdisciplinary graduate program to promote its benefits to the contributing departments, schools or colleges, and to the university community on a regular basis. This includes both formal representation at faculty meetings as well as informal advocacy within the general academic community. Newsletters highlighting the contributions of departments to interdisciplinary graduate program (IDP) success, the creation and research activities (especially publications and joint presentations) of novel interdisciplinary teams and projects that span academic stovepipes, and invitations to co-develop classes, co-advise students, and participate in transdisciplinary programs must be an active part of the IDP development. This encourages support through a broadening of the stakeholder base and reduces tensions and misinformed perceptions associated with competing for the same or constrained budgets.

University Investment

The core funding from CSTEA was used to recruit junior faculty with expertise in atmospheric sciences for the purposes of organizing and aligning research projects with those of the NASA Goddard Laboratory for Atmospheres and to develop the graduate program in atmospheric sciences at Howard University.

The initial funding to start HUPAS included matching costs contributed from the Howard University Graduate School for graduate assistantships (stipends and tuition) to support students recruited to work on NASA-relevant research funded by CSTEA, and other resources leveraged from this center grant, including costs to support a computer laboratory, conference travel, and limited recruitment materials.

The university commitment at key levels of the department, college, and provost were involved in facilitating and maintaining faculty hiring commitments in support of the IDP. This involved lobbying administrators with compelling arguments for the benefits to each department and college (College of Arts and Sciences and the College of Engineering, Architecture, Systems and Computer Sciences).

HUPAS faculty hires represented 24% of the total hires made in these four parent departments during its 16 y of development, that is, two of 12 hires in chemistry, three of 10 hires in physics, and one of three hires in mechanical engineering. Table III shows the evolution of the faculty component of HUPAS from 1994 to the present time. The full-time faculty number has been steadily increasing during

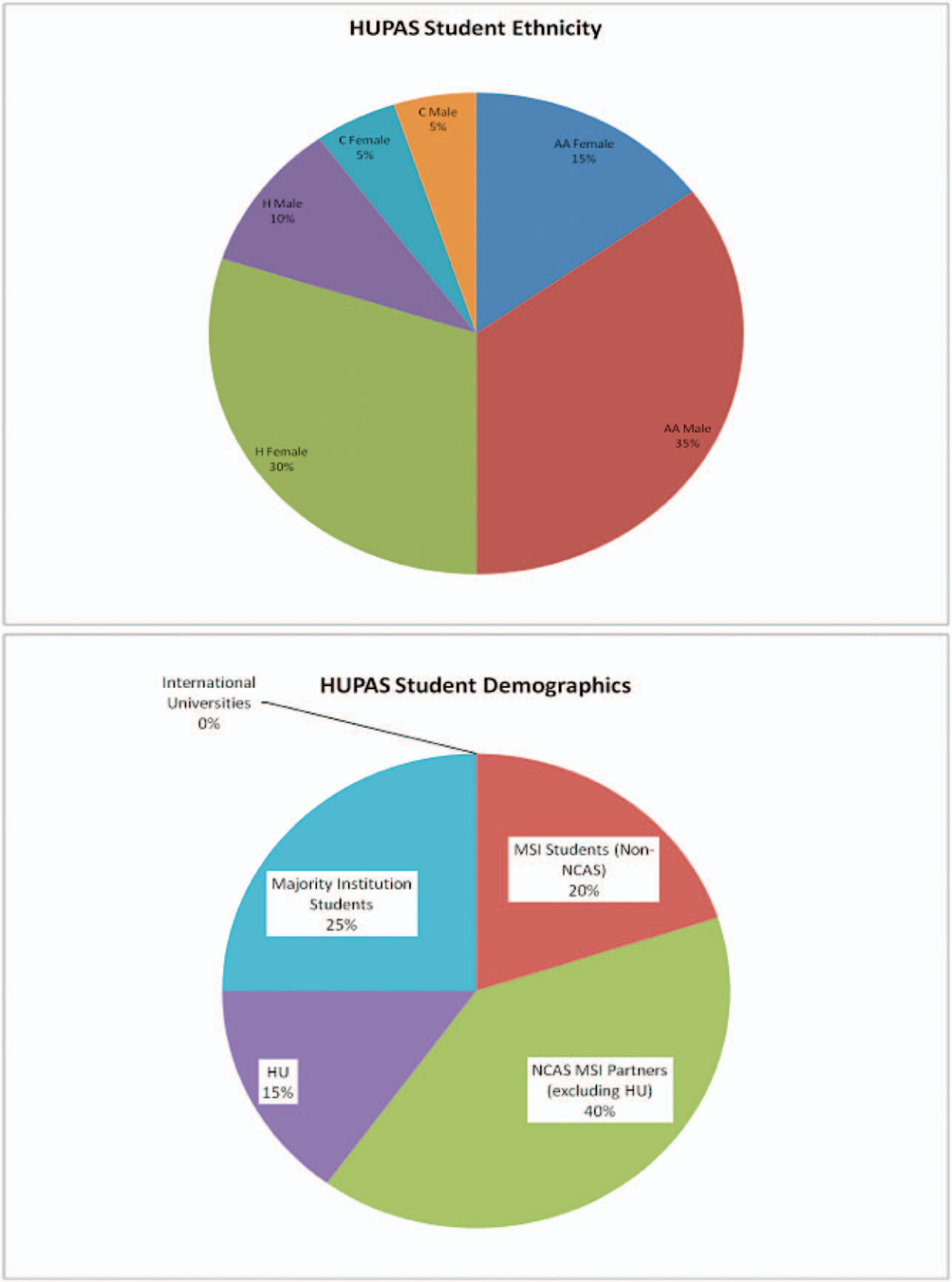

FIGURE 3: (Color online) Program demographics for academic year 2009: Pie chart of HUPAS student ethnicities and gender (top), and pie chart of the distribution of HUPAS student home institutions (bottom). C = Caucasian, AA = African American, H = Hispanic.

TABLE III: Faculty development and student enrollment statistics over the lifetime of the program.

Academic Year (AY)	Number of Full-time Faculty	Number of Adjunct Faculty	Number of Courses Offered (Average per AY)	Number of Students Enrollment (Average per AY)
1994–1996	1	0	2	0
1997	3	0	3	0
1998	5	3	6	6
1999–2001	3	4	6	10
2002–2005	4	4	5	18
2006–2008	6	1	6	20
2009–present	7	0	6	19

the recent decade, totaling seven faculty members at the present time, and on the average per academic year, the HUPAS faculty teach about five to six courses. Further, the student enrollment number has also been steadily increasing during the recent years, totaling nearly 20 students for the average academic year.

In a relatively short period after implementation, Howard University sought to become elected to full membership in the University Center for Atmospheric Research (UCAR) in October 2000. UCAR is the general academic sanctioning body and resource center for atmospheric sciences programs with respect to best practices for curriculum and research strategies. The university has maintained its membership and major participation in UCAR, and Howard faculty continue to serve on key UCAR committees. The key result of this venture has been twofold. Full membership allowed HUPAS faculty access to decision-making and visibility on a national level with peer and future peer programs and elevated the visibility of the program within the university as part of an elite group of academic programs nationally. Membership to UCAR comes at a cost (about $10,000). By making this commitment to join the group, the university tacitly agrees to support activity to maintain status, i.e. the IDP in atmospheric sciences.

THE RESEARCH PROGRAM AND RECRUITMENT STRATEGIES

Research Program

The successes of HUPAS are attributable to the persistence and strength of the academic structure discussed in this section, and strong faculty research programs and effective student recruitment strategies. The HUPAS faculty and graduate students have been involved in three primary areas of activity: (1) field observational programs, (2) numerical modeling for weather and climate studies, and (3) air-quality research. The field observational programs are integrated in such a way as to provide support for the weather and climate and air-quality studies. The early research efforts within the NASA center were relatively unfocused and covered a broad range of topics, from semiconductor research to satellite dynamics. As the center matured with increasing tenure-track faculty having specific expertise in atmospheric sciences, the scope of research narrowed to focus more specifically on tropospheric processes, instrument development and deployment, and atmospheric modeling. The NOAA funding enabled a greater focus on weather and climate applications, and this funding has also been a critical resource for enhancing the capacity of the academic program.

As a notable example, the Howard University (HU) Beltsville campus facility, once an underutilized 0.441-km^2 (109-acre) tract of land in Maryland that has episodically been used for an astronomical observatory, animal research, and the site of a beamline project in the mid-1990s, has been developed into a world-class instrument test-bed and measurement facilities for atmospheric aerosol, cloud properties, and radiation measurements. The site facilities include a Raman light detection and ranging (Lidar), a 30-m meteorological and flux measurement tower, a wind profiler, a Doppler radar, a variety of passive radiometers for both short-wave and long-wave radiation measurements, and an EPA photochemical assessment monitoring (PAM) facility for air-quality measurement sponsored by the Maryland Department of Environment. This facility has been a hub of collaborative activity for projects with NASA, NOAA, EPA, and the Department of Defense (DoD). These projects involve satellite data validation, instrument validation and intercalibrations, atmospheric verifications of forecasts from National Weather Service (NWS)/NCEP numerical weather and climate models, and extensive boundary-layer case studies. NASA and NOAA interests provide the central context for many of the HUPAS students' thesis research, and connect the students with professional researchers nationwide, which enhances the visibility of the program within the scientific community. It should be noted that the establishment of the HU Beltsville atmospheric observation facilities was instrumental in successfully leveraging a research grant from NASA to establish a University Research Center at Howard University starting in the fall of 2008, as mentioned earlier.

Other important research programs that HUPAS faculty and graduate students have participated in are several field observational experiments, the major one being the AERosols and Oceanographic Science Expedition (AEROSE) experiments onboard the NOAA ship *Ron Brown*, which occurred for 6 yr from 2004 and 2006 through 2010. AEROSE is a series of maritime and land-based observational campaigns designed to investigate critical aspects of the microphysical and microchemical evolution of air mass outflows from Africa and their downstream impacts on atmospheric chemistry, climate, and human health (Morris et al., 2006). During the summer 2006, HUPAS faculty and students also participated in the field observations (a surface site near Dakar) program of the NASA component of the African Multidisciplinary Monsoon Analysis (NAMMA)

campaign. NAMMA was designed to investigate the genesis of tropical storms and hurricanes that affect the life, livelihood, and economy of the United States (Zipser et al., 2009).

The observational programs involve a significant number of HUPAS faculty and students and provide an effective recruitment tool for the graduate program. After a screening and interview process, a select few potential students are invited to participate in summer intensives, research cruises of short and long duration, and remote observation programs. These research opportunities are also offered to students and scientists seeking collaboration or field experience as part of HUPAS outreach strategy. To date, over 40 students, 15 collaborating scientists, and six international scientists have participated in field campaigns. Approximately 40% of the students currently enrolled in HUPAS have participated in at least one field research activity prior to or during their tenure in the graduate program. Many of the research results have been documented in scientific literatures and presented at international and national scientific meetings (Morris et al., 2006; Nalli et al., 2006; Min et al., 2009).

Recruitment Strategies

As with many successful graduate programs, the most effective vehicle for increasing matriculation rates has been found to be the mentoring and retention programs. To this end, the Graduate School of Arts and Sciences at Howard University established an Office of Retention Mentoring and Support. In addition, typically, each HUPAS faculty member conducts a regular group meeting during which both peer-to-peer mentoring and faculty–student mentoring are facilitated. All graduate students are also mentored by a committee that includes other faculty members at HUPAS, the NCAS distinguished scientist, and, often, and scientists from NASA and NOAA, to ensure reasonable progress in their research. HUPAS faculty members also serve as advisors for the graduate student organization for students enrolled in atmospheric sciences and American Meteorological Society (AMS) student chapters at the various institutions.

However, the bulk of the recruitment is targeted and prescribed by a three-tiered rubric involving strategic partnerships with other academic institutions, summer workshops, and sponsored field research experiences. To this end, NCAS has played a very significant role and contributed substantially to the recruitment of graduate students into HUPAS. The three-tiered system designed at NCAS to supplement the regular recruitment for HUPAS at Howard University has been quite effective (Morris et al., 2007). The first component of the three-tiered system was initiated through funding leveraged off of the CSTEA grant. These were summer internship programs that were linked to a specific suite of "feeder" schools. The "feeder" concept consisted of identifying and partnering with MSIs that had a strong record of producing high-quality undergraduates in the physical sciences and selectively identifying students from these programs with high potential for success in graduate school (Williams et al., 2007). The latter was determined via involvement of faculty at the feeder institution and academic advisement regarding course selection in the undergraduate curriculum. The summer internship programs were designed to attract junior and senior undergraduate students with demonstrated potential to participate in research at NASA, NOAA, and HU facilities in collaboration with teams of civil servants, HUPAS faculty, and graduate students. The NCAS allows for extended linkages across the five partner institutions as well as partnering with institutions within the other CSCs. This broadens the targeted recruitment efforts and helps to ensure a steady pool of recruits for a modest-sized graduate program.

The second component involves summer workshops on atmospheric instrumentation and data analysis, meteorological modeling, and remote sensing and analysis for advanced undergraduates and first-year graduate students. These workshops are conducted on a rotating basis amongst the NCAS partnership schools: Jackson State University, the University of Texas at El Paso, the University of Puerto Rico at Mayaguez, and Howard University. In addition to providing instruction on skills critical for atmospheric sciences research, they introduce students to the various graduate programs and opportunities at the host institutions. The workshops are open to all students, but first preference is given to students enrolled in NCAS partner institutions and academic partners of other NOAA CSCs.

The third component is composed of summer internships and at-sea training programs for undergraduates in an effort to attract them to HUPAS. As described earlier, this has proven to be one of the most effective recruitment tools for the program.

In addition, it should be specially noted that HUPAS is the primary sponsor of the "Colour of Weather" mixer events hosted by NCAS at Howard University at the AMS annual meetings over the last few years. These events have provided a unique recruitment opportunity for HUPAS and have been elevated to a level of national recognition. These formerly ad hoc events are now co-sponsored by the AMS, and they are featured diversity activities at the annual conference. The reader is referred to Joseph et al. (2008) for a brief summary of the event that took place at the 2008 AMS annual meeting held in New Orleans.

Traditional recruitment strategies are also employed in that HUPAS faculty regularly participate in outreach activities in the form of short presentations and seminars, in booths for dissemination of outreach materials, and in one-on-one engagement conducted at various professional meetings such as the AMS annual conferences and American Geophysical Union (AGU) annual meetings. Moreover, HUPAS faculty ensure participation in professional meetings with high attendance from underrepresented groups, i.e., NSBP (National Society of Black Physicists), NSHP (National Society of Hispanic Physicists), SACNAS (Society for the Advancement of Chicanos and Native Americans in the Sciences), and NOBCChE (National Organization for the Professional Advancement of Black Chemists and Chemical Engineers).

CURRENT AND FUTURE CHALLENGES

Despite the successes of the program, there are several features of its current implementation that require improvement in order for the program to thrive. One of the major challenges for HUPAS (and one shared by many developing interdisciplinary academic programs) is faculty workload. At present, participating faculty receive no official credit or

compensation for participation in the program at any level (departmental, college, or provost). The lack of workload recognition coupled with an entrenched traditional view of academic disciplines in the physical sciences as a stovepipe science inherently lead to conflicts and the risk of de-incentifying the program. The risk of imposing inordinate teaching loads on motivated faculty is substantial and ultimately deadly, unless the workload in each academic unit is recognized. Another factor common to IDPs is that, when faculty are being evaluated for tenure, a narrow set of disciplinary criteria that do not account for the current practices within the applied area of research is applied, and this tends to negatively bias the review. Once again, this may pressure untenured faculty into overcompensating by teaching large introductory courses and accepting overloads at the expense of quality instruction. A sense of departmental ownership is the key. Implementation of a fair workload policy within each department that does not penalize faculty who are doing active research and/or who are teaching within IDPs is tantamount to IDP sustainability. Cross-listing IDP (HUPAS) courses in departments, where appropriate, and publicizing the courses broadly are necessary parts of the internal promotion strategy that all IDPs must execute. In general, students should be encouraged to take a suite of courses that will enhance their academic training and prepare them for success in a rapidly evolving technical landscape. This includes, but is not limited to, IDP courses. It is essential that as new courses are developed, they can be developed in such a way as to incorporate inter- and transdisciplinary teams to teach courses that appropriately span multiple disciplines and attract faculty to join in the IDP. This team-building activity extends the relevance of the program in the traditional departments.

Institutional support for interdisciplinary teams and efforts should be programmatically encouraged by the administration through granting of release time, resource allocation, cost-sharing, and other more innovative means for fostering success.

Recommendations for Future Directions

The potential for a larger HUPAS enrollment and its further growth are only possible by continued university investment in the program. The current trend within the university is to foster the growth of interdisciplinary programs, rather than create new departments. Thus, to be successful within this framework, the academic institution must provide:

- A workload policy that incorporates enough flexibility for IDP development and sustainability. Such a workload policy might incentify interdisciplinary programs and instruction programmatically through the granting of release time, resource allocation, cost-sharing, and other more innovative means. For example, indirect funding generated from large interdisciplinary grants could be reinvested in providing administrative and resource support for IDPs.
- Dedicated program "faculty lines," i.e., tenure-track Full Time Employees hired to provide primary instruction and research in HUPAS. New hires could apply for joint appointments with the IDPs and traditional departments and, thus, not be subject to overly contentious dual-workload issues.
- Administrative support and space commensurate with the demonstrated enrollment and recruitment levels and faculty productivity. Currently, the required administrative processing is borne by overextended faculty, and this makes routine management of the program less effective than it would be given adequate staffing. Common space for the program is also critical for student satisfaction and for program identity. In order to ensure healthy interactions with departments, the common space should be one that fosters interactions among both students and faculty.
- Resources to support international students and enhance the diversity of the program. One of the features of HUPAS that we continue to champion is the diversity balance of the program. The university can contribute to this by aiding in the support of international students, who cannot be supported with the same pool of federal funds used for domestic students. Their presence enhances the preparation of scientists with enhanced perspectives on global implications and interconnectivity of atmospheric sciences research in a way that cannot be captured in their absence.

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