Development of an Earth and Space Science-Focused Education Program at Howard University

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ABSTRACT

We have developed a curriculum at Howard University that educates and prepares students, especially underrepresented minorities, for careers in Atmospheric, Earth and Space Sciences. One of the main objectives of the current initiative has been to provide introductory Earth & Space Science courses at the undergraduate level through the Department of Physics & Astronomy. These courses enhance student learning by including astronomical observing and laboratory demonstration opportunities at the Howard University Observatory. Intermediate-level courses in Atmospheric and Space Science have also been designed, and will serve as a bridge toward the graduate-level courses currently being offered by the M.S./Ph.D.-granting Howard University Program in Atmospheric Sciences (HUPAS). HUPAS is the first and only program at a Historically Black College or University (HBCU) that offers a terminal graduate degree (M.S. or Ph.D.) in Atmospheric Sciences. Currently, a total of 23 graduate students are enrolled in HUPAS, which include 14 African-Americans and 6 Hispanic-Americans, and 3 international students from Mexico, Barbados and Madagascar; and the gender breakdown is 13 females and 10 males. To the best of our knowledge, this is the largest number of African/Hispanic students enrolled in a graduate atmospheric science program in the U.S.

INTRODUCTION

Chartered by Congress in 1867, Howard University is a comprehensive, research-oriented historically Black private university in Washington, D.C., which aims to provide an educational experience of exceptional quality to students of high academic potential and with particular emphasis on making available opportunities to traditionally underrepresented minorities. It is the only predominantly African-American university to be designated a Research I university by the Carnegie Commission on Higher Education. Indeed, Howard University is one of only 88 universities to be so designated. Howard University has awarded more Ph.D. degrees to African-American students than any other university in the country.

Earth system science and space science are two of the most rapidly expanding fields that will impact the teaching and learning of science, mathematics and technology in the 21st century (see American Association for the Advancement of Science, 1993; and The National Academy of Sciences, 1996 and 2000). Keeping that in view, and against heavy odds, a few select institutions are developing new geoscience programs (Anderson et al., 2006). The growing use of space-based remote sensing for studies in Earth science, and of space science missions dedicated to the studies of other planetary atmospheres, has greatly increased the commonality of purpose in gathering data between these previously diverse fields. Earth science and space science are twin sciences that combine many of the physical sciences and engineering disciplines - physics, chemistry, biology, aerospace engineering, and meteorology - in a multidisciplinary environment. In view of the fact that the demographics of the U.S. population is undergoing a radical change, it is critical for the long-term health of the Earth and space sciences programs, and for science and technology in general, to broaden participation by including hitherto underrepresented minorities in these areas (see American Association for the Advancement of Science, 1993; and The National Academy of Sciences, 1996 and 2000; Private/Personal Communication, 2004, AIP, Roman Czujko). It is important to remove barriers that inhibit minority participation in the Earth and space sciences. In order to level the playing field, there is an urgent need to train a future workforce in these dual areas that is drawn from a broad-based talent pool of scientists and engineers that is inclusive rather than exclusive. In order to realize this goal of broadening minority participation, (i) we are developing Earth and space science-related academic capabilities at Howard University and (ii) fostering long-term partnerships and exchange programs in education and research between Howard University and the Space Science Division of the Naval Research Laboratory in Washington, DC, and between Howard University and the Space Science Data Operations Office of the NASA Goddard Space Flight Center in Greenbelt, MD. The purpose of the present manuscript is to inform readers in the field of Geoscience Education about Howard University's efforts to improve instruction in the Earth and Space sciences and enhance student learning through laboratory demonstrations, astronomical viewing opportunities, and invited colloquia by distinguished scientists. A major goal of the current effort is to increase minority participation at the undergraduate level, especially among African-Americans and Hispanic Americans, so that they are better prepared to pursue a graduate degree in the Howard University Program in Atmospheric Sciences (HUPAS), and in course of time be part of a growing pool of well-qualified earth and space scientists who will fulfill the nations needs in these areas. Here, we summarize our efforts and demonstrate to the readership that the educational and research infrastructure is in place at Howard University, and we are well on our way towards achieving the important goal of producing well-qualified minority students who can be future leaders in the fields of Earth Science and Space Science.

Freshman Year	Sophomore Year	Junior Year	Senior Year
Fall: 3 Freshman English 3 Gen Physics for S&E I 1 Gen Physics S&E I Lab 4 Calculus I 1 Phys. Ed. (Swimming) 4 Foreign Language** 1 Freshman Orientation 17 SEMESTER TOTAL	**Fall**: 3 Foreign Language** 4 Calculus III 3 Philosophy 1 Phys. Ed. (Activity) 3 Core Requirement* (Div-B) 3 Speech 17 SEMESTER TOTAL	**Fall**: 3 Core Requirement* (Div-A) 3 Physical Mechanics I 4 General Chemistry*** (Div-D) 3 Core Requirement* (Div-A) 3 Exp. Phys. I WRTG # (or Exp. Phys. I #) 16 SEMESTER TOTAL	**Fall**: 3 Elective (or Optics) 3 Quantum Physics I 3 Elect. & Magnet. I 3 Core Requirement (Div-C) 3 Elective 0 Comprehensive Examination 15 SEMESTER TOTAL
Spring: 3 Freshman English 3 Physics for S&E II 1 Physics S&E II Lab 4 Calculus II 1 Phys. Ed. (Health) 4 Foreign Language** 16 SEMESTER TOTAL	**Spring**: 3 Foreign Language** 4 Differential Equations 3 Core Requirement (Div-C) 1 Phys. Ed. (Activity) 3 Intro Modern Physics 1 Physics S&E Lab III 15 SEMESTER TOTAL	**Spring**: 3 Core Requirement* (Div-A) 3 Physical Mechanics 4 General Chemistry*** (Div-A) 3 Core Requirement* 3 Elective (or Exp. Phys. II) 16 SEMESTER TOTAL	**Spring**: 3 Thermodynamics 3 Quantum Physics II 3 Elect. & Magnet. II 3 Core Requirement* (Div-B) 4 Elective 16 SEMESTER TOTAL 37 TOTAL PHYSICS HRS. 128 TOTAL HRS

Table 1. Sequence of Courses for Physics Majors to Earn a Bachelor's Degree in the College of Arts and Sciences at Howard University. * One African Studies Course is required and may be used as a Div-A or Div-B requirement. ** French, German or Russian: students required to demonstrate competency at the -004 level. No more than 2 courses in a single department can be used to satisfy Area requirements. These courses are recommended for students who plan to pursue graduate studies in physics. Other electives may be taken to satisfy graduation requirements for physics students following other areas of specialization. * General Chemistry is recommended as the Div D core requirement for the physics major. # The Course Experimental Physics I WRTG (021-703) satisfies the college writing requirement.**

HOWARD UNIVERSITY PROGRAM IN ATMOSPHERIC SCIENCES (HUPAS)

Today, African-, Hispanic- and Native-Americans represent more than 25% of the U.S. population (Greico and Cassidy, 2001). Yet, fewer than 15% of all bachelor's degrees are earned by African- or Hispanic-Americans, and their representation among geoscience bachelors is only 5% (U.S. Department of Education, 2004). The U.S. Census data indicate that the U.S. population of minority groups is projected to increase significantly (by 30-50%), and collectively approach majority status around the year 2050 (U.S. Census Bureau, 2004). An under-representation of minorities in the sciences and engineering is bound to have negative consequences for the communities of these minority groups and more significantly for the nation as a whole. At the highest degrees of educational attainment, namely the conferring of the Ph.D. degree, traditionally underrepresented groups are very poorly represented. Recent National Science Foundation (NSF) data show that 21,028 Ph.D.s were conferred in the geosciences over a 30-year period (1973-2002), and only 117 (0.6%) and 294 (1.4%) were earned by African-Americans and Hispanic-Americans, respectively (Analyses conducted by the AIP Statistical Research Center on data collected by the NSF Division of Science Resources Statistics and provided by NSF in an on-line database called WebCASPAR). In the discipline of atmospheric sciences, minorities have an even smaller representation than all the geosciences at the bachelors level and a somewhat (insignificantly) higher representation at the Ph.D. level (cf. WebCASPAR). The immediate impact of such under-representation is the lack of diverse faculty and scientists in the classrooms and research laboratories, which in turn translates to a small number of visible mentors and role models for the minority student population. It unfortunately propagates the stereotypical image of what a representative college professor and research scientist should look like in the everyday workforce.

Howard University is actively working to increase the numbers of African-Americans and Hispanic-Americans in atmospheric science, since the implementation of the Howard University Program in Atmospheric Sciences (HUPAS) in 1998-99. HUPAS provides an educational and research environment for students to develop expertise in the atmospheric and space sciences and to prepare them for career opportunities in these expanding fields. A major theme of the program is to emphasize comprehensive solutions to atmospheric problems by coupling field measurements, laboratory experiments and atmospheric modeling.

HUPAS is the first and only program at a Historically Black College or University (HBCU) that offers a terminal graduate (M.S. or Ph.D.) degree in Atmospheric Sciences. HUPAS is an interdisciplinary program with faculty members drawn from the Departments of Chemistry, Physics and Mechanical Engineering. The faculty members have expertise in the areas of atmospheric chemistry (air quality and aerosols), radiative transfer, cloud microphysics, turbulence, climate dynamics and modeling. The program is a discipline within the Graduate School of Arts & Sciences (GSAS) and represents Howard University's long-term commitment to goals shared by NASA and the previously funded Center for the Study of Terrestrial and Extraterrestrial Atmospheres (CSTEA) at Howard University. Currently, the NOAA Center for Atmospheric Sciences (NCAS) supports a majority of the HUPAS students. NCAS has also provided funding to the Howard University Atmospheric Observatory (HUAO) in Beltsville, Maryland, which is a world-class research facility devoted to atmospheric measurements (that are meteorological, chemical and radiative in nature); and it also serves as an instrument development test-bed for advancing and applying remote-sensing technology to a broad range of applications that focus on

Freshman Year	Sophomore Year	Junior Year	Senior Year
Fall: 3 Freshman English 3 Physics for S&E I 1 Physics S&E Lab 4 Calculus 1 Phys Ed 4 Foreign Language 1Freshman Orientation Total Credit Hrs. 17	**Fall:** 3 Foreign Language 4 Calculus III 3 Philosophy 1 Phys Ed 3 Core Requirement (Div B) 3 Speech 1 Computer Programming & Numerical Computation Total Credit Hrs. 18	**Fall:** 3 Core Requirement (Div-A) 3 Physical Mechanics I 4 General Chemistry Div-D 3 Core Requirement (Div-A) 3 Exp Phys. I 3 Intro to Earth & Space Science I Total Credit Hrs. 19	**Fall:** 3 Atmospheric Physics I 4 Inter Earth & Space Science I 3 Quantum Physics 3 Core Requirement (Div-C) 3 Elective (Programming) 0 Comprehensive Examination 1 Current Topics Total Credit Hrs. 17
Spring: 3 Freshman English 3 Physics for S&E II 1 Physics S&E Lab 4 Calculus II 1 Phys Ed 4 Foreign Language Total Credit Hrs. 16	**Spring:** 3 Foreign Language 4 Differential Equations 3 Core Requirement (Div-C) 1 Phys Ed 3 Intro Modern Physics 1 Physics S&E Lab 1 Weather Forecasting Total Credit Hrs. 16	**Spring:** 3 Core Requirement* (Div-A) 3 Electricity and Magnetism 4 General Chemistry (Div-A) 3 Thermodynamics 3 Intro to Earth & Space Science II Total Credit Hrs. 16	**Spring:** 3 Atmospheric Physics II 4 Inter Earth & Space Science II 3 Core Requirement* (Div-B) 3 Remote Sensing I 3 Elective 1 Current Topics Total Credit Hrs. 17

Table 2. Suggested Sequence of Course Requirements for Completing a Bachelor's Degree in Physics & Astronomy in the College of Arts and Sciences at Howard University (Major: Physics and Proposed Minor: Earth and Space Science).

probing the state of the lower atmosphere. NCAS has also facilitated and funded an opportunity for faculty at Howard University to be the lead in a Trans-Atlantic cruise aboard the NOAA-RHB research vessel for comprehensive investigations relating to properties of the Saharan dust. In addition, faculty and students at Howard University are expected to actively participate in the African Monsoon Multidisciplinary Analysis (AMMA) international field experiment in West Africa during the Summer of 2006.

The graduate Program in Atmospheric Sciences offers a core course structure based upon three distinct academic tracks, namely (i) Atmospheric Physics, (ii) Atmospheric Chemistry, and (iii) Geophysical Fluid Dynamics. HUPAS offers both the M.S. and Ph.D. degrees in Atmospheric Sciences. Students are required to take 9 core credits, with an additional 15 hours in elective courses, in order to satisfy requirements for the M.S. degree. For the Ph.D. degree, they must take a minimum of 12 core credits, and an additional 24 hours in elective courses. Under appropriate guidance provided by suitable faculty advisors, students entering the program combine courses in atmospheric science with courses from other disciplines (physics, chemistry or mechanical engineering) and select a research topic appropriate to their interest and career needs; and may have external dissertation committee members drawn from nearby research centers, such as NASA-GSFC and NOAA. HUPAS offers courses related to Earth and other planetary atmospheres - but the emphasis has been on the Earth's atmosphere. To improve Howard University's capabilities in Earth and space science education and research, we are enhancing the curriculum to include Earth and space science related topics. Two new undergraduate Earth and Space Science courses are currently being offered (as outlined in Box 1), so as to better prepare students for the HUPAS program. Since Howard University does not currently have an undergraduate program in Atmospheric Sciences, enhancing the curriculum to include such Earth and Space Science education courses can only serve to increase the pool of undergraduate students from the Howard University population applying and being accepted by HUPAS.

There are currently 23 M.S./Ph.D. students enrolled in the HUPAS program; with the first Ph.D. graduates expected during the 2005-2006 school year. The ethnic breakdown of these students is as follows: 14 African-Americans, 6 Hispanic-Americans, and 3 international students from Mexico, Barbados and Madagascar. The gender breakdown of this student body is as follows: 13 females and 10 males. To the best of our knowledge, this is the largest number of African/Hispanic-Americans in a graduate atmospheric science program in the U.S. (including both majority and minority institutions). HUPAS graduate students have been recruited from HBCUs from a variety of disciplines, such as mathematics, physics and chemistry. The current crop of HUPAS graduate students has 2 students who earned their undergraduate degrees at Howard University. Students are also sought at National Conferences; and specifically we have targeted the meetings of the National Society of Black Physicists (NSBP) and the American Meteorological Society (AMS).

MINORITY UNIVERSITY EDUCATION AND RESEARCH PARTNERSHIP IN EARTH AND SPACE SCIENCE WITH S.M.A.R.T., INC. AND THE NAVAL RESEARCH LABORATORY, SPACE SCIENCE DIVISION

Science, Mathematics, Aerospace, Research, and Technology (S.M.A.R.T.), Inc. (an affiliate of the DC Space Grant Consortium) and the Space Science Division of the Naval Research Laboratory (NRL) serve as partners with the Department of Physics and Astronomy, Howard University, in this initiative by (a) providing a course instructor (Dr. George Carruthers - a co-author of this paper) for undergraduate students in Earth and Space Science, at the introductory and intermediate levels, at Howard University; and (b) providing opportunities for student summer employment and hands-on activities at the Naval Research Laboratory. Dr. George Carruthers of NRL and S.M.A.R.T. has earlier taught courses in Earth & Space Science for DC Public Schools science teachers,

EARTH & SPACE SCIENCE I AND II
2 Semester Course, 3 credits each (including laboratory sessions)

Pre-requisites: High school physics and mathematics, including Algebra and Trigonometry; co-enrollment in college physics and calculus recommended

First Semester
Physics 030 - Earth & Space Science - I

I. Introduction to Earth and Space Physical Science
1. Introduction and Overview
   a. Objectives of the Course
   b. Overview of Earth & Space Science
   c. Overview of Remote Sensing
2. The Size and Distance Scale of the Universe
3. Properties of Matter
   a. Fundamental properties of matter: solids, liquids, gases
   b. Fundamental properties of matter: atoms, molecules, subatomic particles
   c. Structure of atoms and molecules; quantum mechanical interpretation
   d. The atomic nucleus; nuclear reactions and radioactive decay
4. Forms of Energy
   a. Potential Energy and Kinetic Energy
   b. Newton's Laws of Motion and Gravity
   c. Electric and Magnetic Fields; Effects on Charged Particles
   d. Electromagnetic Radiation
   e. Gravitational and Electromagnetic Potential Energy
   f. Heat and Pressure Energy of Gases; Thermodynamics
5. Optics and Remote Sensing
   a. Refractive Optics
   b. Reflective Optics
   c. Diffraction Gratings
   d. Spectrometers and Spectrographs
6. Spectroscopy and Remote Sensing
   a. Types of Spectra
   b. Black Body Radiation
   c. Spectral Line Radiation
   d. The Hydrogen Atom and Its Spectrum
   e. Atomic Spectroscopy
   f. Molecular Spectroscopy
   g. Spectroscopic Remote Sensing Measurement Techniques
7. Introduction to Orbits and Space Flight
   a. Newton's Laws of Motion and Gravity
   b. Sub-orbital trajectories and hands-on demonstrations
   c. Orbits and deep-space trajectories
   d. Kepler's Laws of Orbital Motion
   e. Astronomical Coordinate Systems and Orbital Elements
   f. Space Flight and Rockets

II. Origins: How Did It All Begin?

1. In the Beginning: The Origin and Evolution of the Universe
2. The Energy Sources of Stars; Elemental Abundances
3. Origin of the Solar System
4. Formation and Early History of Earth
5. Geologic Time and Dating of the Rock Record
6. The Chemistry and Origin of Life

III. The Solid Earth

1. Rock and Mineral Types
2. Large Scale Structure of the Earth
   a. Plate Tectonics
   b. Volcanoes and Earthquakes
   c. Continental Drift and Orogenisis
3. The Earth's Seasons

IV. The Earth's Hydrosphere and Cryosphere

1. The Earth's Hydrosphere
   a. Characteristics of the Oceans and Sea Floor
   b. Properties of Sea Water
   c. Circulation and Waves in the Sea
   d. The Earth's Tides
2. The Earth's Cryosphere
   a. Glaciers and Ice Ages

V. The Earth's Atmosphere

1. The Structure and Composition of the Atmosphere
2. Thermal Properties of the Atmosphere
3. Effects of Solar Input and Earth's Rotation
4. Meteorology: The Study of Weather
5. Climatology: Long Term Trends
6. Aeronomy: The Middle and Upper Atmosphere
7. The Ionosphere

VI. The Near-Earth Space Environment

1. The Sun and Its Effects on Earth's Upper Atmosphere and Ionosphere
2. The Solar Wind and Effects on Earth's Magnetosphere and Plasmasphere
3. The Magnetosphere
4. The Plasmasphere and Radiation Belts
5. The Polar Auroras

Second Semester
Physics 031 - Earth & Space Science - II

I. The Moon and the Earth-Moon System

1. Introduction
2. Phases of the Moon and Eclipses
3. The Moon: Structure and Composition
4. Observing the Moon
5. Exploring the Moon
6. Future Prospects

II. The Sun

1. Structure of the Sun
2. Energy Sources and Evolution of the Sun
3. Observational Description of Sun; Advances Due to Space Missions
4. Effects of the Sun and Solar Variability on Earth and Its Atmosphere

III. The Solar System: Major Planets and Satellites, and Minor Members

1. Mercury
2. Venus
3. Mars
4. Jupiter and the Galilean Satellites
5. Saturn and Titan
6. Uranus and Neptune
7. Pluto and Charon; the Kuiper Belt
8. Asteroids and Comets
9. Meteoroids, Meteors, and Meteorites

IV. The Stars

1. The Nature of Stars other than Our Sun
2. Star Formation Processes
3. Classification of Stars: Spectral Types and the Hertzsprung-Russell Diagram
4. The Evolution of Stars
5. How Stars Die

V. The Interstellar Medium

1. Properties, Composition, and Distribution of Interstellar Material
2. Gaseous Nebulae
3. Interstellar Dust
4. Remote Sensing Measurements of the Interstellar Medium

VI. Galaxies and The Universe

1. The Structure of Our Galaxy
2. The Nature of Galaxies other than Our Own
3. The Universe and Cosmology
4. New Developments; Future Space- and Ground-Based Programs

Relevant Textbooks

The textbooks in Earth Science and Space Science/Astronomy listed under References are only a few of a great many that have been printed in recent years. There are also many textbooks on specific subfields of Earth science and space science, such as volcanology, solar astrophysics, planetary science, and cosmology.

Box 1. Outlines of the two current earth and space science course offerings at Howard University.

We feel that if we are able to implement the course sequence given in Table 2 (through the Department of Physics & Astronomy), so that the Earth and Space Science courses become required electives for an Atmospheric Physics track and satisfy the degree requirements for the College of Arts & Sciences, then the current Earth and Space Science course offerings have the potential for good enrollment and can have a permanent place on the course listing of the Department of Physics & Astronomy. If successful, this model can be extended to include the Departments of Chemistry and Mechanical Engineering. It is anticipated that the introductory and intermediate level Earth and Space Science courses cited here will serve as a bridge to the

Box 2. Sequence of courses for physics majors and a proposed earth and space minor HUPAS graduate coures.

supported by NASA's Initiative to Develop Education in Astronomy and Space Science (IDEAS) and the DC Space Grant Consortium (DCSGC).

EARTH AND SPACE SCIENCE COURSE OFFERINGS

The primary objective of the current courses (see Box 1) is to provide an introduction to Earth and Space Science, and related areas of physical science, for college students planning to major in these fields (or related areas of engineering), or to DC public school teachers as background material for teaching these or related subjects to pre-college students. Other objectives include: (a) providing background for more advanced courses in Astronomy, Astrophysics, Atmospheric Science, Geology, Oceanography, and other sub-fields of Earth & Space Science, or for related areas of Aerospace Engineering; and (b) introducing other educational resources, including books and periodicals, videos, CD-ROMs, and relevant World Wide Web sites. A rich storehouse of related information is available through the extensive list of References.

The currently offered Earth and Space Science courses include, in the first semester, reviews of the basic physics topics relevant to remote sensing, as well as to the field of Earth Science (including atmospheric science and the near-Earth space environment). The second semester covers the Moon, Sun, solar system, stars, galaxies, and cosmology. Box 1 provides outlines of these Earth and Space Science I and Earth and Space Science II courses. The introductory level courses have college-level introductory physics and calculus as pre-requisites, but the first course has been modified to accommodate students with lesser mathematics and physics backgrounds by placing more emphasis on Part I of the course outline (as given in Box 1). The sequel Earth and Space Science II course has the introductory course, or an equivalent Earth and Space Science course from another institution, as a pre-requisite. Currently, we are also in the early stages of developing intermediate-level Earth and Space Science courses that would bridge the gap between the current introductory-level courses and the graduate-level HUPAS courses (or other related major fields). Two such courses that we have developed outlines for are as follows: (1) An intermediate-level course in Atmospheric Science, focusing on Earth and Planetary Atmospheres; and (2) a course in the Near-Earth and Solar System Space Environment (that includes the topic of "Space Weather"). Since there is no single textbook available that covers all the Earth and Space Science topics, and in any case these fields are changing so rapidly that textbooks become out of date very quickly, the courses are based on annotated PowerPoint presentations (that can be relatively easily modified and/or updated based on current events). As is well known, for example, Solar System Exploration is perhaps the most rapidly changing of these topics to date. The courses have also made extensive use of images and data accessed, via the Internet, from the Space Telescope Science Institute, the Jet Propulsion Laboratory, and NASA Centers, among others. We intend to continue and expand this trend in our Introductory, as well as Intermediate, Earth and Space Science courses.

FACILITIES

In addition to the Howard University Atmospheric Observatory (HUAO) in Beltsville, MD, described earlier, which is used for atmospheric measurements and weather-related activities, we also utilize the Howard University Astronomical Observatory located on top of Locke Hall (on the main campus). It is a telescopic observatory equipped with a 12-inch aperture Meade Schmidt-Cassegrain telescope for night sky viewing, with a microprocessor-driven clock drive, along with atmospheric monitoring equipment. The telescope is housed in a large dome, and is installed on a vibration-free pier. There is room in the dome for supporting computer and maintenance equipment. In addition, there are several smaller, portable telescopes, including 6-inch Newtonian telescopes assembled by astronomy students, and we have recently acquired a CCD camera for both observatory and classroom use. Classroom facilities and a planetarium are also located in the penthouse of Locke Hall. All astronomy classes currently are also taught there, allowing students easy access to the observatory when weather conditions permit. Observation and instrument facilities include a solar telescope with videotaping capability (which we used to provide public viewing of the June 2004 transit of Venus) and a stand-alone solar spectrograph with public viewing capabilities (both built with student participation), which are being used in the current effort. The August 2003 and November 2005 Mars oppositions to Earth were viewed using the 12-inch aperture Meade Schmidt-Cassegrain telescope. Such public viewing of rare events spark the students' imagination and afford once-in-a-lifetime opportunity to witness Nature's grandeur first hand. To quote NASA on the extremely rare transit of Venus in front of the Sun: "On June 8, 2004, starting at sunrise on the East Coat of North America, you will see the planet Venus as it moves across the face of the early morning sun. The last time humans witnessed this event was on December 8, 1882, when it was watched by millions of people across the world, from the crowded streets of Bombay to the deserts of the American southwest." We have learned that when students participate in such fascinating activities, and they feel a sense of ownership through the building of instruments that facilitates such involvement and furthers their true education, they learn more through an exciting combination of the inquiry teaching approach and a research perspective (Basaga et al., 1994; The National Academy of Sciences, 2000; Anderson and Smith, 1987).

OUTCOMES AND GOALS

The outcome of our Earth and Space Science Education curriculum enhancement, over the next few years, is being assessed to determine what students know and how they learn optimally in the classroom by adopting a systems approach and encouraging critical thinking (The National Academy of Sciences, 2001; Gautier and Rebich, 2005; Perkins, 2004; McConnell et al., 2005). Each semester we monitor enrollment, student performance, and document responses through an evaluation questionnaire (Libarkin et al., 2005) that we have prepared and are continually improving to obtain useful and constructive feedback from the students and teachers taking the course. In addition, in Fall 2005, we had one undergraduate student and three D.C. public school teachers enrolled in the Earth and Space Science I PHYS 030 course complete an online evaluation by visiting the web site http://www.educationdesign.biz /survey.html developed by David Reider, Program Evaluator of the Earth System Science Education for the 21st Century (ESSE 21) project effort. We highlight some of the outcomes and goals of our concerted efforts.

In Fall 2004, 3 Howard University undergraduate students (2 Physics majors and 1 Electrical Engineering major) were registered for the PHYS 030 course, while a fourth student audited the course. In Fall 2005 and Spring 2006, we have had a total of 10 students registered for the two Earth and Science courses; 4 in Fall 2005 and 6 in Spring 2006. Of these registrants, there were 1 and 2 undergraduate students, enrolled in Fall 2005 and Spring 2006, respectively; the remainder were high school teachers from DC public schools (see below). We seek to increase our undergraduate enrollment 2-3 fold in these courses by improved advertising and by including these introductory and intermediate-level courses as electives for Physics majors as part of an existing Atmospheric Physics track under the Applied Physics area of concentration. In the long run, we are attempting to develop an Earth & Space Science minor (see Table 2, Box 2) option for Physics majors that will also include coursework in Computer Programming and Numerical Computation, Weather Forecasting and Atmospheric Physics, besides the Introductory- and Intermediate-level Earth and Space Science courses. Such efforts will, in turn, improve our present enrollment of 2 students (out of a total of 23 in HUPAS) who received their undergraduate degrees from Howard University and gained entry into HUPAS for their graduate degrees. Our current efforts aimed at enhancing the Earth and space science instruction and including it in an Atmospheric Physics track is geared towards reaching out to more undergraduates in these fields and recruiting them to HUPAS. We anticipate that a sizeable number of students (goal of 6-8 per semester) enrolled at Howard University, not only from the Department of Physics and Astronomy, but other science and engineering departments as well, will become better educated in the subject of Earth System Science and Space Science. Further, we expect that some (about 50%) of these students will seek advanced degrees in the HUPAS program.

DC Public School teachers are being provided the opportunity to take one or more of these courses, either during the regular school year, or in special summer sessions. Indeed, in Fall 2005, we had 3 D.C. public school teachers registered for the Earth and Space Science I (PHYS 030) course, and 4 again in Spring 2006 for the sequel Earth and Space Science II (PHYS 031) course. These courses serve to satisfy the certification and continuing education requirements for the DC public school system. The teachers taking these Earth and Space Science courses have enthusiastically indicated that much of the material and handouts they received is being used by them in designing and teaching courses in their respective high schools (Owen et al., 2004). Our goal is to be able to attract 4-5 public school teachers per semester by getting the word out and being in regular communication with the Principals of the DC public schools.

The facilities of the Howard University Observatory and Planetarium, and of the Space Science Division of NRL (in summer internships), are being used for "hands-on" educational activities involving students (and high school teachers) taking the above courses, and by pre-college students (including those working on science fair projects). An added dimension to the course offering has been provided by eminent guest lecturers. For example, a lecture on the fascinating topic of Space Weather was given in Fall 2005 by James L. Green, Chief of the Space Sciences Data Operations Office, NASA Goddard Space Flight Center. Two other lectures related to Earth and Space Science were given to students through the Department of Physics and Astronomy Wednesday Colloquia series, namely Mesoscale Analysis Techniques (by Roger Wakimoto of the National Center for Atmospheric Research) and Measurements of Solar Actinic Flux and Atmospheric Photolysis Rates (by William Stockwell of Howard University's Chemistry Department). Such colloquia and seminars continue on a regular basis during the academic year and are listed on the web site: http://www.physics1.howard.edu.

The contents of these new courses are being developed in transportable and modular electronic format, so that they can be readily exported to other institutions, and/or be used on Internet World Wide Web pages conducive to distance learning.

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