Leveraging the NASA Administrator's Fellowship Program (NAFP) to Enhance Graduate Chemical Engineering Education at Howard University

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Abstract

This paper addresses the enhancement of graduate education at Howard University's Department of Chemical Engineering brought about through leveraging of the National Aeronautics and Space Administration's (NASA) Administrator's Fellowship Program (NAFP). The paper describes NASA's education framework and outlines the enhancement of graduate chemical engineering education in the department through enhanced elective course offerings, expanded research opportunities and networking to broaden research and employment opportunities for undergraduate and graduate students, concluding with the critical role NASA has in promoting and impacting engineering and science graduate education.

"To inspire the next generation of explorers...as only NASA can" is the NASA education program's mission. This "can-do" concept guides all NASA's programs and activities and requires a diverse pool of talented scientists and engineers. The NASA NAFP Fellow and the Department of Chemical Engineering at Howard University have worked together to make this a model of successful educational program enhancement.

Introduction

Throughout history, NASA has played a critical role in promoting engineering and science education at colleges and universities. NASA has accomplished its educational objectives by following a well-established structure and leveraging its resources to accomplish program goals. NASA has notably committed to education since its creation in 1958. This strong commitment has been continuously reflected in the agency's Strategic Plan, in which education is viewed as important as space exploration. NASA's national education program is devoted to "inspire the next generation of explorers". This education program is carried out through NASA Headquarters as well as all NASA Field Centers. To further promote a direct interaction among educators, students, and personnel, NASA provides information, materials, and services to the larger education community through a multifaceted dissemination network.

NASA's Education Program

Through its dedication and continuous effort, NASA has become one of the most significant government agencies dedicated to education. NASA has established a comprehensive education program to serve its customer, the education community in the nation. Additionally, NASA has developed an evaluation mechanism as a tool in assessing educational outcomes. This well-defined framework was initiated in 1994 and has since provided guidance to NASA on establishing program goals and evaluation indicators. A detailed description of the framework is provided in the *NASA Implementation Plan for Education 1999-2003*[1].

As stated in the plan, NASA's Office of Human Resources and Education, NASA's Office of Equal Opportunity Programs, NASA's five Strategic Enterprises, and all NASA's Field Centers have responsibility in implementing the education program. The Office of Human Resources and Education has Agency-wide responsibility for NASA's Education Program to establish policy, goals, objectives, and for evaluation. The Office of Equal Opportunity Programs has the responsibility for NASA's policy related to minority institutions of higher education. All NASA Strategic Enterprises and Field Centers are responsible for ensuring a close coordination with the Office of Human Resources and Education in implementing the education program.

NASA's education customer is the informal and formal education community, including museums, science and technology centers, and nonprofit education organizations that support the formal education community and provide significant educational activities for learners of all ages. Most of these organizations are major community, regional, or national resources for science education. The formal education community is divided into the following levels based on grade: K-4, 5-8, 9-12, community college, undergraduate, graduate, and postdoctoral. Tailored to customer needs, NASA has created a comprehensive education program containing a portfolio of activities directed toward education at all levels.

Six education program categories comprise the NASA education program and define the way in which NASA content is delivered to the informal and formal education community. The program categories are stated as follows:

1. Teacher/Faculty Preparation and Enhancement: To provide professional development experiences for K–12 educators and higher education faculty.
2. Curriculum Support and Dissemination: To develop, utilize, and disseminate science, mathematics, technology, engineering, and geography instructional materials for the development of higher education curricula.
3. Support for Systemic Improvement of Education: To use NASA's unique assets to support local, state, regional, and national science, mathematics, technology, engineering, and geography education efforts through collaboration.
4. Student Support: To use NASA's mission, facilities, human resources, and programs to provide information, experiences, and research opportunities for students in the areas of science, mathematics, technology, and geography.
5. Educational Technology: To provide technology products and services to enhance the education process.

6. Research and Development: To involve primarily graduate students and faculty who make substantive contributions to NASA.

Elements of mathematics, science, and engineering education are vital to the success of NASA's challenging mission. NASA has provided numerous education opportunities for students at the undergraduate level and above, with a goal to fulfill the continuing needs of the aeronautics and space effort. In the past, various NASA programs have provided opportunities, especially for underrepresented universities, by increasing the number of highly trained scientists and engineers in aerospace, space science, space applications, and space technology.

Under NASA's education program, internships and research opportunities in science and engineering fields are available for both students and educators. For students, examples of these opportunities include NSIP (Elem-High School), SHARP (High School), SHARP Plus (High School), USRP (Undergraduate), GSRP (Graduate Study), and RRAP (Post-doctorate). For educators, opportunities include NEW (Pre-college) and NFFP (University). Additionally, there is a unique research opportunity for both educator and NASA career employees in the NASA Administrator's Fellow Program (NAFP).

NAFP Program

The NAFP program provides opportunities for both NASA employees and the Mathematics, Science, Engineering, and Technology (MSET) faculty of Minority Serving Institutions (MSIs). The NAFP program is designed to enhance the professional development of the participants. Furthermore, NAFP program assists NASA by increasing the ability of the participating MSIs to respond to its overall research and development mission. The NAFP has been successfully implemented since 1997, with participants from all NASA Centers, Jet Propulsion Laboratory, and MSIs, which are listed in Tables 1 and 2, respectively.

NASA has actively sought out qualified individuals and organizations from under-represented groups and encouraged them to be involved in its activities. As NASA strives to achieve diversity in education, NAFP is an excellent vehicle in providing talented employees to MSIs and attracting MSI faculty who are representative of America's diversity. As shown in Table 2, the NAFP has engaged MSIs which cover a wide geographical area.

Table 1: NAFP Participating Centers

NAFP Participating Centers	
• Ames Research Center	• Johnson Space Center
• Dryden Research Center	• Kennedy Space Center
• Glenn Research Center	• Langley Research Center
• Goddard Space Flight Center	• Marshall Space Flight Center
• Jet Propulsion Laboratory	• NASA Headquarters
	• Stennis Space Center

The NAFP fellowship provides NASA career employees an opportunity to contribute their expertise to historically black colleges and universities (HBCU's) and other minority institutions (MI's) as teachers and researchers for one academic year. Following academic

service, the NAFP Fellow spends the next 9 to 13 months on developmental assignments at NASA Headquarters, NASA Centers, and other appropriate organizations. The total length of the program for NASA employees is 18-22 months. During this period, their NASA salary and benefits are continued and their status as NASA employees retained.

Table 2: NAFP Participating Institutions

NAFP Participating Institutions, 1997-2003		
• Alabama A & M University	• Lincoln University	• Spelman College
• Alcorn State University	• Morgan State University	• Tennessee State University
• Bennett College	• New Mexico State University	• Texas Southern University
• Cheyney University	• Norfolk State University	• Tuskegee University
• Elizabeth City State University	• North Carolina A & T University	• University of Puerto Rico - Arecibo - Rio Piedras - Humacao - Mayaguez
• Essex County College	• Oakwood College	• Xavier University
• Florida A & M University	• Prairie View A & M University	
• Hampton University	• Salish Kootenai College	
• Howard University	• Shaw University	
• Institute of American Indian Arts (IAIA)	• Southern University and A& M College	

Through their experiences at the universities and in other developmental assignments, NAFP fellows gain valuable insights to help guide future NASA initiatives. By participating in developmental activities, NASA employees enhance their own technical, research, and management skills and are thus able to better assist NASA in meeting its science and technology goals. This interaction of ideas and experiences enables NASA to expand its working relationships and gain an understanding of how best to communicate and disseminate information on its technologies to the various MSIs.

NAFP MSET faculty fellows spend 12 months conducting research at NASA Headquarters, NASA centers, government agencies, in the private sector, or at other appropriate organizations. MSET faculty may also pursue other developmental assignments over the course of the fellowship. The participation of faculty scientists, mathematicians, and engineers is intended to increase the basic research and management capability of the schools. This can allow the schools to become involved in science and technology areas of interest to NASA and other government entities.

NAFP provides mid-career MSET faculty opportunities to conduct research at NASA centers or other large institutions. The NAFP research disciplines, as shown in Table 3, encompass a wide range of engineering and science fields vital to NASA's missions. These experiences will improve their professional careers and better position their home institutions to participate in NASA's mission. It enables the recipients to compete in the mainstream, peer-reviewed research programs of NASA. NAFP faculty fellows are also provided opportunities to interface with high-level NASA and government officials, to participate in NASA's R&D programs, and to learn about innovative scientific and engineering research methods.

Table 3: NAFP Research Disciplines

Research Disciplines	
• Engineering Disciplines - Aerospace - Chemical - Computer - Electrical - Industrial - Material Science - Mechanical - Nuclear - Systems	• Agronomy • Astrophysics • Biology • Botany • Chemistry • Computer Science • Environmental Toxicology • Mathematics • Pharmacology • Physics • Structural Mechanics

NAFP selection is competitive with only six NASA employees and six MSI faculty chosen each year. Selected participants begin as a cohort and then proceed to specific NAFP assignments. There have been seven cohorts formed since the beginning of the program in 1997. As shown in Table 4, 57 fellows, including 33 NASA career employees and 24 MSI faculty, have participated in the NAFP program[2]. A total of 31 MSIs, including 22 HBCU's, seven Hispanic-Serving Institutions (including one community college), and two Tribal Colleges and Universities have actively participated in the program.

Table 4: NAFP Follows

Participation Rates	NASA Employees	MSIs Faculty	NAFP Fellows
Cohort 1 (1997 – 1999)	6	2	8
Cohort 2 (1998 – 2000)	5	1	6
Cohort 3 (1999 – 2001)	2	5	7
Cohort 4 (2000 – 2002)	6	2	8
Cohort 5 (2001 – 2003)	4	6	10
Cohort 6 (2002 – 2004)	4	5	9
Cohort 7 (2003 – 2005)	6	3	9
Grand Total	33	24	57

The NAFP focuses on professional development, academic enrichment, community outreach, and preparation of students for graduate and postgraduate studies and careers in NASA-related fields. The NAFP is regarded as a highly effective education vehicle with remarkable results and is the NASA Administrator's signature professional development program substantively "impacting the education and workforce pipeline." [2].

NAFP fellows have engaged in the classroom to motivate students in pursuing careers in science, math, and engineering. In the lecture area, NAFP fellows have taught over 30 courses at MSIs. NAFP fellows have performed outreach activities in over 20 elementary schools, secondary schools, and youth groups across the United States and Puerto Rico. NAFP fellows

have developed or enhanced over 50 courses across several curriculum areas, including the first fully accredited, four-year engineering bachelor's degree to be offered at a tribal college.

In the research area, NAFP fellows have served as mentors to students and faculty at MSIs. NAFP fellows have developed or initiated student research opportunities at NASA Centers and NAFP fellows have authored or co-authored more than 24 technical papers. Moreover, NAFP fellows initiated, monitored, or developed several NASA-related collaborative programs that established useful working relationship for future collaborations.

NAFP Program at Howard University

Howard University in Washington, D. C. has been actively involved in the NAFP program through the years. The university has not only encouraged faculty to engage in the program but also has served as a hosting institution for NASA career employees. In this instance, the Cohort 7 NAFP Fellow (Chen) selected Howard University's Department of Chemical Engineering as the locus for his NAFP Fellow's academic service, and the Chair of the Department (Tharakan) served as the Technical Monitor to the NAFP Fellow. This model of exchange proved invaluable in enhancing the contributions of the Fellow to departmental graduate education and research as well as to the Fellow's professional development.

The Department of Chemical Engineering at Howard University

The Department of Chemical Engineering is housed in the College of Engineering, Architecture and Computer Sciences (CEACS) at Howard University, the largest HBCU in the country. The department offers an undergraduate program leading to the Bachelor of Science in Chemical Engineering (BSChE), and a graduate program of coursework and research leading to the Master of Science (MSChE). The undergraduate program is accredited by the Accreditation Board of Engineering and Technology (ABET). The department combines contemporary coursework with a research-oriented faculty to deliver a quality engineering education at the cutting edge of the broad array of chemical engineering technologies. The Department is one of six departments in CEACS, with the others including Systems and Computer Sciences, Civil Engineering, Mechanical Engineering, Electrical and Computer Engineering, as well as a School of Architecture and Design. The department currently has five full-time faculty and two adjuncts serving a student population comprising 90 undergraduate and 16 graduate students.

All members of the regular departmental faculty are members of the Howard University Graduate School of Arts and Sciences and active in research; however, the small faculty size only affords the granting of MSChE degrees. Further resources will need to be committed by the University in order to support a doctoral program. The MSChE at the Department is a research based program that requires 24 credits of coursework and six credits of thesis research that culminates in a thesis and a Master's thesis defense. Coursework includes 12 credits of core courses and 12 credits of electives that permits the student to tailor their educational training to their thesis research focus. Elective sequences comprise courses offered by Faculty in their research specialty and courses offered within the College and University that have directly complemented and enhanced the student's graduate education. Graduate Faculty of the department and their research specialty are shown in Table 5.

Table 5: Department Faculty and Research Specialty

	Research Specialty
FACULTY	
John P. Tharakan, Ph.D., California, San Diego, 1986 *Professor & Chair*	Bioreactor & bioseparation, bioenvironmental remediation research, environmental biotechnology, environmental justice & education.
Mobolaji E. Aluko, Ph.D., California, Santa Barbara, 1984 *Professor*	Dynamics of reacting systems, applied mathematics, ceramic and electronics materials processing, process control.
Joseph N. Cannon, Ph.D., P.E., Colorado, 1971 *Professor*	Transport phenomena in biomedical and environmental systems, engineering education.
Ramesh C. Chawla, Ph.D., Wayne State, 1978 *Professor*	Environmental engineering-air, water, and hazardous waste: pollutant monitoring and control; reaction kinetics and mass transfer in environmental systems.
William E. Collins, Ph.D., Wisconsin-Madison, 1990 *Associate Professor*	Polymer science, biomaterials, biomedical engineering, tissue engineering.
ADJUNCT FACULTY	
Robert J. Lutz, Ph.D., Pennsylvania, 1971 *Adjunct Professor*	Biomedical research, drug delivery, biofluid mechanics.
Philip Chen, Ph.D., Maryland (College Park), 1985 *Adjunct Assistant Professor*	Heat transfer, spacecraft contamination engineering, material science.
Kenneth Ekechukwu, Ph.D., Warsaw, 1990 *Adjunct Assistant Professor*	Process control, coal science and mineral processing.

The small size of the faculty reduces the capability to offer graduate core and elective courses while simultaneously maintaining a quality undergraduate curriculum, meeting ABET requirements and providing required undergraduate student support services. Regular department faculty teach all the core graduate courses and this requirement limits the number of elective courses that can be offered. The Department is always on the lookout for mechanisms by which elective course offerings can be expanded and diversified beyond the research expertise of regular faculty. The NAFP Fellow's program offers the department the expertise and resources of the NAFP Fellow to enhance elective course offerings and diversify the research areas that graduate students have the opportunity to engage in.

The NAFP Fellow's teaching and research plan at Howard University were developed through close discussions with departmental faculty and the Technical Monitor and it is consistent with NAFP's objectives aimed at emphasizing NASA employee's professional development and fostering cooperative efforts between the Department and NASA. The plan that was developed consisted of four thrusts: teaching, research, mentoring, and outreach. With these objectives, Howard University, and, most importantly, the students at Howard, benefited from the NAFP initiative.

Teaching

The NAFP Fellow was able to expand the departmental elective offering from one a year to three a year. Potential lectures included spacecraft engineering theory and applications, not normally considered as regular chemical engineering elective courses. Based on the Fellow's expertise and experience, and through assessment of student interest, two electives were added to the Departmental elective schedule. These included Advanced Heat Transfer (Fall 2003) and Spacecraft Contamination Engineering (Spring 2004).

Heat transfer is an important component of the core chemical engineering course of advanced transport. The advanced Heat Transfer course permitted the department to offer students the opportunity to study heat transport at an advanced level with specific applications to spacecraft engineering. At Howard University, the Advanced Heat Transfer course was taught using a variety of books that covered different subjects, and a link to spacecraft heat transfer was added to demonstrate its space applications. Topics covered included steady state and transient conduction, thermal and hydrodynamic boundary layer concepts, free and forced convection, and radiation heat transfer. The course used heat transfer principles to understand thermal behavior of systems, to illustrate the development of governing equations, to investigate the influences of system parameters on steady or transient response of the system, to provide basic tools used in thermal system design, and to expose students to heat transfer applications in space-related areas.

Spacecraft contamination engineering influences spacecraft operations because contamination can degrade the physical properties of thermal and optical systems. The presence of contaminants in the field-of-view affects sensor's operations. Without proper contamination control, contamination induced degradation will render millions of dollars worth of instruments useless. Over the past decade, the NAFP Fellow (Dr. Chen) has spearheaded spacecraft contamination engineering projects at NASA, leading a contamination engineering team that grew from a small team of 12 to more than 36 NASA scientists, engineers and on-site contractors.

The purpose of the spacecraft contamination engineering course is to build on fundamental knowledge from physics and chemical engineering and expand into more advanced topics in contamination control. Topics such as fundamental physics of molecules and particles, space environments, generation of contaminants, contaminant transport phenomena, surface interactions, analytical modeling, spacecraft subsystems impact, cleanroom operations, contamination monitoring and measurements, contamination removal, and on-orbit mitigation will be covered. Students are required to identify, formulate and solve spacecraft contamination

engineering problems using a combination of physics and chemistry. The course also emphasizes practical applications to spacecraft systems.

Mentoring

A constructive interaction with young students is mutually rewarding to the students and the NAFP fellow, realized through the mentoring process. The presence of the NAFP Fellow in the Department offers the students an opportunity to discuss chemical processes, process control techniques, and process design guidelines from the perspective of NASA. The NAFP Fellow provides further enhancement to the department's research and education goals by advising chemical engineering students in gas kinetics, fluid dynamics, and environmental sciences with specific applications to spacecraft design. Through the mentoring process, students in the Department are exposed to NASA's cutting-edge technologies. In addition to the two elective courses, the NAFP Fellow enhanced the department's undergraduate education opportunities by mentored independent study for individual students. Students were guided to perform literature reviews, study engineering concepts, designs, and operations while focused on a particular topic of mutual interest. A final report is required, including presentation of the independent study projects. With this independent study course offering, the department enhances its ability to provide chemical engineering students with valuable hands-on experience in NASA areas of science, technology and engineering.

Research

The NAFP Fellow also enhanced the research capability of the faculty and the department and provided graduate students with the exposure to space-related research. Potential research areas included spacecraft analysis, environmental science study, materials outgassing, and spacecraft contamination. The independent study mentoring provided by the NAFP Fellow included research with students and faculty. A point of contact and framework for engagement with NASA was provided by the presence of the NAFP Fellow, who encouraged students and faculty to get involved in space research and provided all relevant information to engage in NASA research and funding opportunities. The NAFP Fellow utilized professional workshops, meetings, conferences and publications to further increase student and faculty awareness of space technology. The engagement generated enough public awareness of NASA's missions and created the potential for further exchanges between Howard and NASA.

Outreach

Outreach activities initiated and facilitated by the NAFP Fellow will assist Howard University in becoming familiarized with NASA's mission and in receiving NASA specific technology. Current NASA technologies and research activities are brought to the attention of students and faculty at the department. Besides providing students with technology, the NAFP Fellow also brings the message of NASA employment opportunities to Howard University. In addition, by enabling and leading tours of NASA's test facilities, covering thermal vacuum chambers, spacecraft vibration test area, and cleanrooms – including the largest clean room in the United States, the range of science, engineering and technology opportunities at NASA are brought alive to the students.

Conclusion

The model of interaction and exchange between the NASA NAFP Fellow and the Technical Monitor at the Department of Chemical Engineering at Howard University has been successful in enhancing departmental graduate elective course offerings, in expanding the research areas available to graduate students and faculty, and in exposing students to the research and education possibilities beyond what could be provided by the regular faculty of the department. With the critical assistance of the Technical Monitor and the close interaction between the NAFP Fellow and the departmental faculty and staff, substantial progress has been made towards fulfilling the mission of the NAFP program while serving the needs of the department.

"To inspire the next generation of explorers...as only NASA can" is the NASA education program's mission. Under NASA's education framework, the successful implementation of NAFP and various NASA education programs will be useful in promoting engineering and science college education. NAFP greatly enhances NASA's outreach by connecting to highly qualified minority faculty and students at MSIs. Although housed in the Department of Chemical Engineering, the Fellow's outreach will spread to the whole of Howard University and Howard students' interests in science and engineering and space exploration will be expanded. This public awareness is vital to NASA's future, both in increasing public support as well as attracting minority students to NASA. NAFP provides NASA with the means of directly networking with some of Howard University's brightest students.

In the end, the NAFP Fellow, the Technical Monitor and the Department benefited tremendously from the exchange and interaction, with each gaining valuable insights into space-related chemical engineering education and research. Through the course of the program, the Fellow was able to enhance his own technical, lecturing, and research skills to better assist NASA in meeting science and technology goals. For Howard University and the Department of Chemical Engineering, the benefit of NAFP was equally substantial, providing expertise and resources to help minority students succeed in science and engineering and bringing NASA expertise to the campus.

Acronyms

ABET: Accreditation Board of Engineering and Technology
BSChE: Bachelor of Science in Chemical Engineering
CEACS: College of Engineering, Architecture and Computer Sciences
GSRP: Graduate Student Researchers Program
HBCU: Historically Black Colleges and Universities
MI: Minority Institution
MSChE: Master of Science in Chemical Engineering
MSET: Mathematics, Science, Engineering, and Technology
MSI: Minority Serving Institution
NAFP: NASA Administrator's Fellowship Program
NASA: National Aeronautics and Space Administration

NEW: NASA Educational Workshops
NFFP: NASA Faculty Fellowship Program
NSIP: NASA Student Involvement Program
RRAP: Resident Research Associateship Program
SHARP: Summer High School Apprenticeship Research Program
USRP: Undergraduate Student Research Program

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Biography

JOHN THARAKAN received his PhD in Chemical Engineering from the University of California, San Diego, California in 1986. After conducting research on protein purification and plasma fractionation for the American Red Cross for four years, he joined the faculty of Howard University's Department of Chemical Engineering in 1990, and has been Chair since 2002. His research interests include bioprocess and bioseparations engineering and bioenvironmental and bioremediation engineering.

PHILIP CHEN received his PhD in Chemical Engineering from the University of Maryland, College Park, Maryland in 1985. He has since been associated with NASA Goddard Space Flight Center. He serves as the senior contamination technical staff at the Thermal Engineering Branch. He was selected as the Fellow of the NASA Administrator's Fellowship Program in 2003.