NAE Grand Challenges and Academic Culture in Engineering Education at NC State

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Abstract – The National Academy of Engineering "Grand Challenges" are serving as an excellent framework to organize elements of academic culture in the College of Engineering at NC State University. This paper describes the Engineering Challenges, why they are important in the current engineering education climate, and how NC State has embraced them as a mechanism to create a culture of success.

Keywords: National Academy of Engineering, Grand Challenges for Engineering in the 21st Century, engineering education, academic culture.

INTRODUCTION

The College of Engineering at NC State University has adopted the *NAE Grand Challenges for Engineering in the 21st Century* as a framework to advance the strategic objectives of college. This strategy includes various elements and operations within the unit, from engagement to student recruitment, curriculum development to faculty hiring, and more.

Strategically this approach is informed by the Grand Challenges, as well as reports such as *Changing the Conversation*, and *Engineering in K-12 Education*. This paper and presentation will describe the motivation for using the NAE Grand Challenges to change the academic culture and approach to engineering education at NC State. This model should be of interest to both large and small engineering colleges.

NAE GRAND CHALLENGES

In 1998 the National Academia of Engineering (NAE), in collaboration with the American Association of Engineering Societies (AAES) and National Engineers Week, engaged in a process to identify the most important engineering contributions from the 20th century. The result of that work was captured in a book, entitled *A Century of Innovation: Twenty Engineering Achievements that Transformed Our Lives* [Constable,1]. This was an important work in that it served as a review of the engineering technologies from the 20th century that had broad impacts on society. The top five from the list included electrification, the automobile, the airplane, water supply and distribution, and electronics. An important goal of this initiative was to emphasize the incredible impact that engineering technologies have on the quality of life on Earth, and the role of engineering in our society.

In 2006, the National Academy of Engineering, at the request of the National Science Foundation (NSF), established an 18-member blue ribbon panel of international experts to identify a set of challenges faced by humankind in the 21st century that engineering has an important role in solving. This initiative was not focused on indentifying specific and isolated technologies, rather the goal was to focus on larger societal concepts—showing the explicit linkage and role of the engineering discipline in contributing to, and solving, such challenges. Dr. William Perry, committee member and former US Secretary of Defense described the initiative as "the focus of our Grand Challenge study was not just thinking about what could be invented but was rather more focused on what needed to be developed." [Perry, 2] Dr. Charles Vest, President of the National Academy of Engineering talks of the Challenges as being "game changers" that when solved will offer a "positive prosperous future." [Vest, 3] This initiative served to orient public attention to the role of engineers in society, but also has served as an organizing framework within engineering.

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The output of the initiative was the identification of challenge areas known as the *NAE Grand Challenges for Engineering in the 21st Century*. [NAE, 4] The final list of grand challenges constituted fourteen distinctly different areas, where engineering and engineering solutions, together with contributions from other fields could become "game changers." Table 1 lists these.

Table 1: The NAE 14 Grand Challenges for Engineering in the 21st Century

· Make solar energy economical	· Provide energy from fusion	· Develop carbon sequestration methods
· Manage the nitrogen cycle	· Provide access to clean water	· Restore and improve the urban infrastructure
· Advance health informatics	· Engineering better medicines	· Reverse-engineer the brain
· Prevent nuclear terror	· Secure cyberspace	· Enhance virtual reality
· Advance personal learning	· Engineering the tools of scientific discovery	

The Grand Challenges, when taken as a list, seem to be constituted by fourteen distinctly different challenge areas. However, their formation was much more structured than what may appear. In considering the question of "What are the great challenge areas for engineering and mankind in the next century" the NAE committee anchored their thoughts around four key themes necessary for humanity to flourish—sustainability, reducing vulnerability, health, and joy in living. The framework and development of the challenges is described in Table 2.

Table 2: Organizing themes for NAE Grand Challenges

Sustaining Life on Earth: A first order question to be addressed is what issues in our contemporary world threaten the very existence of the human race? What things, left unsolved, undermine our ability to occupy this planet indefinitely? These questions, which address the issue of sustaining life on Earth, led to the identification of several of the Grand Challenges. Among these are issues related to clean water and solving the energy issue.

Living Secure from Threats: After humankind has sustained life on the planet, we need also to guarantee that we can be secure from threats. What are the things that represent such threats today and into the future? Grand Challenges such as preventing nuclear terror and securing cyberspace developed from this mindset.

Promoting Healthy Living: Once life has been sustained and we are secure from threats, it is important that issues related to healthy living are addressed. Challenges such as advancing health informatics and building better medicines are example areas.

Living and Learning with Joy: Finally, now that we are alive, safe, and healthy, higher level challenges that add joy and depth to human existence and understanding become important. Example Challenges such as those involving personal learning, tools of discovery, and virtual reality fit this category.

As such, the NAE Grand Challenges can perhaps best be thought of as a collection of challenge areas that stem from concerns related to sustaining life on earth, living secure from threats, promoting healthy living, and living and learning with joy rather than fourteen un-connected themes. It should be noted that the NAE did not explicitly rank or group individual Challenges into categories. Because of the comprehensive and fundamental nature of several of the challenges, many can not be classified under single unifying themes. This is why the NAE chose not to group the Challenges. However, this paradigm may be helpful in understanding and explaining the Challenges better.

Although the *NAE Grand Challenges for Engineering in the 21st Century* initiative was not the first to use "grand challenge" language to identify important problems[5,6], the effort has been noted broadly. For example the *Strategy for America* Innovation Plan (US Executive Branch) is informed by the NAE Grand Challenges. [7]

NATIONAL TRENDS AFFECTING ENGINEERING

As the world is changing and becoming flatter [8], the constraints and rules concerning engineering work and engineering education have changed too. Marketplaces of producers, consumers, and education that did not exist ten years ago are thriving today. The changing playing field and leveling of opportunity, have brought tremendous challenges to the winners of the former status quo—such as the United States. However, at the same time, these changes represent opportunities to re-examine and re-engineer a strategy to leverage strengths for success in the new paradigm.

Lower production costs initially led Corporate America to downsize, outsource, and offshore operations in many manufacturing sectors. As a result, plants closed and much of the manufacturing base in many US industries was lost. At the same time, the expanded functionality of communication and information technologies established a dynamic where new markets could be accessed on a worldwide scale. These locations became places to expand business and overall demand, not simply locations to manufacture goods. China and India together account for 37% of the world's population [OECD, 9], and have been popular places for investment by many worldwide companies.

Education Changes

During this same period of time, national trends in education in the United States have been dipping compared to the rest of the world. Degree attainment; rankings in skills such as reading, science and mathematics; and overall student interest in STEM (science, technology, engineering and science) careers has decreased compared to world-wide competitors. A review of student preparation in the K-12 system in critical skills is falling, as is teacher preparation and training. Consider the following:

- In international standardized tests involving students from 30 nations, United States fourteen-year-olds rank 25th in mathematics and 21st in science. [10]
- In tests *within* the United States, little improvement has been observed over the past 40 years. This is in spite of a sevenfold increase in inflation-adjusted spending per student since World War II. [10]
- Ninety-three percent of United States public school students in fifth through eighth grade are taught the physical sciences by a teacher without a degree or certificate in the physical sciences. [10]
- Sixty-nine percent of United States public school students in fifth through eighth grade are taught mathematics by a teacher without a degree or certificate in mathematics. [10]
- According to the ACT College Readiness report, 78 percent of high school graduates did not meet the readiness benchmark levels for one or more entry-level college courses in mathematics, science, reading and English. [10]
- Among high school seniors average scores in the National Assessment of Educational Progress have declined during the most recent decade for which data are available in science. [10]
- The World Economic Forum ranks the United States 48th in quality of mathematics and science education. [10]
- In South Korea, 38% of all undergraduates receive their degrees in natural science or engineering. In France, the figure is 47%, in China, 50%, and in Singapore 67%. In the United States the corresponding figure is 15%. [11]
- Of the 4 million first university degrees in science and engineering awarded worldwide in 2006, 21 percent were earned by students in China, compared with 11 percent by students in the United States. Science and engineering account for approximately one third of bachelor's degrees awarded in the United States, versus 63 percent of those in Japan, 53 percent in China, and 51 percent in Singapore.[12]
- In the age category 55-64 the US ranks 2nd in tertiary degree attainment of OECD countries, for the 25-34 age category the rank is 11th. [13]
- Among students who began enrollment at a 4-year school in 2003-2004 only 50% had received a degree at that institution in 6 years [14].
- The World Economic Forum ranks the United States 48th in quality of mathematics and science education [10]

Thus, it seems that at the same time that the "world" was expanding in terms of competitiveness for goods and services, the relative quality of the education system in the US was losing ground compared to international

competitors. Especially troubling are indications that US K-12 students are losing ground in science and mathematics competencies, fundamental building blocks for careers in STEM disciplines.

Students in Engineering
In addition, there is evidence that student interest in engineering as a field of study has been declining over the past decade plus. For example, an ACT-backed study entitled "Maintaining a Strong Engineering Workforce' found: [Noeth, 15]

- A drop in the number of high school seniors planning to study engineering, from 8.6 percent in 1992 to 5.5 percent in 2002; (and below 5% in 2006 [13])
- A decrease in the percentage of students interested in engineering who had taken college preparatory courses in high school;
- A drop in the number of female ACT test takers considering engineering careers;
- A gap between aspirations of racial/ethnic minority test takers, as indicated by expressed interest in engineering, and their relevant preparation with more than basic coursework.

The drop in interest in female and racial/ethnic minority students presents an even more important challenge, as engineering attempts to expand its historical diversity base. Many reasons have been suggested for the decline in student interest, some ideas include [16]:

- *The curriculum is difficult:* involves hard work with long difficult path
- *The curriculum is densely packed:* has little flexibility, dense pre-requisite streams
- *Other paths to good jobs are easier:* compensation levels and paths easier elsewhere
- *Engineers are treated as commodities by employers:* associated with job layoffs, loss in company loyalty
- *Traditional entry level jobs are being off shored:* few new BS job opportunities exist
- *Media reports indicate instability:* focus on loss of jobs and economic downturns sways parents/students away

Resulting Conclusions
These effects have led many to question the future place of the US in the global marketplace, and its ability to continue as a nation grounded on innovation and technological development. Several national-level committees, panels, and advisory groups have, over the course of the last decade, studied these dynamics and offered commentary on the status of engineering and engineering education in the United States[10,11,17-23]. A summary of findings includes:

> *Having reviewed trends in the United States and abroad, the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength.* [21]

> *If one extrapolates these trends, it becomes clear that our nation faces the very real prospect of losing its engineering competence in an era in which technological innovation is key to economic competitiveness, national security, and social well being. Bold and concerted action is necessary to sustain and enhance the profession of engineering in America–its practice, research, and education. It is the goal of this report both to sound the alarm and to suggest a roadmap to the future of American engineering.*[11]

> *…with tightening of global linkages, new challenges and opportunities are emerging as a consequence of rapidly improving technological capabilities in such nations as India and China …* [22]

> *Science and technology have been and will continue to be engines of US economic growth and national security. Excellence in discovery and innovation in science and engineering (S&E) derive from an ample and well-educated workforce – skilled practitioners with two- and four-year degrees and beyond, researchers and educators with advanced degrees, and precollege teachers of mathematics and science. The future strength of the US S&E workforce is imperiled by two long-term trends: (1) Global competition for S&E talent is intensifying, such that the United States may not be able to rely on the international S&E labor market to fill unmet skill needs; (2) The number of native-born S&E graduates entering the workforce is likely to decline*

unless the Nation intervenes to improve success in educating S&E students from all demographic groups, especially those that have been underrepresented in S&E careers. [18]

The National Science Board (Board) has issued several reports expressing concern about long-term trends that affect U.S. workforce capabilities in engineering, including the dependence on international students and workers; the declining interest on the part of U.S. citizens in engineering studies and careers; weakness in the K-12 science, technology, engineering, and mathematics (STEM) education system; and demographic trends that are unfavorable to increasing citizen participation rates in these fields. [23]

In the opinion of many, the US has several important challenges in the next decade which emphasize the critical nature of the state of events. The closing statements from the *Rising Above the Gathering Storm Revisited* report capture the sentiment: [10]

Today, for the first time in history, America's younger generation is less well-educated than its parents. For the first time in the nation's history, the health of the younger generation has the potential to be inferior to that of its parents. And only a minority of American adults believes that the standard of living of their children will be higher than what they themselves have enjoyed. To reverse this foreboding outlook will require a sustained commitment by both individual citizens and by the nation's government…at all levels. The Gathering Storm is looking ominously like a Category 5…and, as the nation has so vividly observed, rebuilding from such an event is far more difficult than preparing in advance to withstand it.

ENGINEERING EDUCATION ACTIONS

Based on the call-to-action resulting from the national trends, many important initiatives are underway to improve engineering and engineering education. Such influences have focused engineering education on:

- Developing K-12 student competency and interest in engineering through a more active role in the K-12 pipeline,
- Changing the way that we orient students to careers in engineering,
- Rethinking strategies for attracting, retaining and graduating students in engineering,
- Developing alternate pathways to degree attainment (especially first generation and non-traditional students), and working to smooth students transitions, and
- Changing public perception of engineering as a discipline.

The National Science Board report *Moving Forward to Improve Engineering Education* identified three key challenges for engineering education: [23]

- *Responding to the Changing Global Context of Engineering.* Engineering degrees must ensure technical and analytical fundamentals, in addition to skills in innovation, communication, cultural sensitivity, systems thinking, and leadership among others. Students must to be prepared for broader careers such as marketing and management. Duderstadt [11] adds "To compete with talented engineers in other nations with far greater numbers and with far lower wage structures, American engineers must be able to add significantly more value than their counterparts abroad through their greater intellectual span, their capacity to innovate, their entrepreneurial zeal, and their ability to address the grand challenges facing our world." Additionally, 21st-century engineers must be "technically competent, globally sophisticated, culturally aware, innovative and entrepreneurial, and nimble, flexible, and mobile." [10]
- *Perceptions of Engineering*. Engineering struggles to attract enough students especially those with the diverse backgrounds needed. Engineers are associated by the public with "things" and not people—with defense and economic growth not helping the world, and improving the quality of life and the environment. Thus, engineering attracts students strong in math and science interested in "things," and not students with interests in working on teams to solve challenging complex problems. Duderstad [11] adds "Students … although many have the aptitude and interests to major in engineering, they view it as a dead end profession, subject to this commodity treatment and associated with too many risks, in contrast to broader professions such as law, medicine, and business. The same ambiguity characterizes public perception, with images of large rooms of

rows upon rows of engineers working on narrow elements of large systems such as airplanes or automobile platforms until the next round of layoffs. Particularly during these days of economic stress, these images are more prevalent than those of master engineers creating the highly innovative products and systems that address critical human needs while adding economic value.

- *Retention of Students in Engineering.* Engineering must do a better job of keeping and graduating a higher percentage of students who initially express an interest in the engineering degree path. Currently engineering programs graduate only 50-60% of such students in six years. Women and minority students leave engineering programs, where there are far too few peers, at higher rates. Many schools have found successes with student engagement such as undergraduate research, cooperative education, and other experiences.

THE NC STATE ENGINEERING STRATEGY

At NC State, the strategy to address many of the issues that exist for engineering and engineering education are built on the NAE Grand Challenges in the context of two other important NAE reports—*Changing the Conversation* and *Engineering in K-12*. A short summary of each report is given below.

Changing the Conversation, Messages for Improving Public Understanding of Engineering [24]:
This report is the product of the NAE Committee on Public Understanding of Engineer, and builds on the 2002 NAE report *Raising Public Awareness in Engineering.* [25] Overall the initiative was mean to study and recommend improvements for how engineering is messaged, talked about, and received by the general public in the US. This is thought of as an important effort to "sustain the US capacity for technological innovation," "attract young people to careers in engineering," and "Improve technological literacy."

Specific goals of the project included the identification of a limited number of messages likely to improve public understanding of engineering, to test such messages across constituent groups, and to disseminate the results. Conclusions include:

- There is a wide and public view linking engineering with aptitude and interest in mathematics and science. Although this associate does exist, this linkage does not improve the appeal of the discipline.
- Age and gender influence perception of engineering. Older individuals associate engineering with jobs, and thus perceptions are sensitive to media stories involving workforce and the economy. Girls tend to be positively affected when engineering is associated with "people," whereas boys focus on engineering being represented by "things." Girls are less confident then boys that engineering can be a rewarding career choice, and one that "helps people."
- On the whole the public does not perceive engineers as "nerds" as popularized in the Dilbert cartoon, although this perception is very pervasive internally to the engineering community.
- There are few significant ethnicity-based differences in the way the engineering profession is perceived.

Implications: This report has made us much more aware of the intended and unattended messages that we send when interacting with constituents of all kinds. From this report we have adapted our messages and tailored effects to the audiences that we are interacting with. This is especially true related to gender-specific audiences.

Engineering in K-12 Education, Understanding the Status and Improving the Prospects [26]:
This study presents the final report of the Committee on K-12 Education, a group charged by the National Academy of Engineering and National Research Council. The study investigated the nature, purpose, and known and potential effects of teaching STEM (science, technology, engineering and mathematics) in elementary and secondary schools across the US. Improving K-12 engineering (STEM) education is related to challenges that face the US in a competitive and interconnected world related in terms of jobs, security, and quality of life perspectives. The initiative is meant to study improving K-12 engineering education as a means to attract and retain students in engineering careers, and for the purpose of training a technologically savvy citizenry.

Findings of the report include:

- The current STEM education structure does not reflect the natural and potential interconnectedness of the subjects, and existing curricula do not currently explore these connections,
- Considerable value exists in student motivation, learning and achievement in STEM by increasing engineering in K-12 education,
- There is potential value in student gains in math and science learning when taught through the lens of engineering,
- Teacher preparation in K-12 engineering is far behind that of other STEM disciplines.

Implications: The results of this report have confirmed the extensive involvement in K-12 engineering engagement activities in the College. For example, Dr. Liz Parry, Coordinator, K-20 STEM Partnership Development in the College of Engineering at NC State and current chair of the K-12 Division of ASEE, is substantially involved at the national level is addressing this issue. We view these activities as "seed planting" in terms of pipelines issues, but also respect the technology literacy implications that early exposure to engineering.

Strategic Dimensions of the Culture
As it relates to interactions with constituents at all levels, the Academic Affairs Office in the College of Engineering utilizes the construct of the *NAE Grand Challenges for Engineering in the 21st Century* to:

- Communicate the wonder, opportunity, and excitement of careers in the engineering fields,
- Illustrate the breadth of problem types that engineers work on,
- Emphasize the systems-thinking construct needed to develop solutions to solve these problems,
- Reflect on the historical role of the engineering disciplines compared to the modern and developing role for engineers on multi-disciplinary teams,
- Restate the need for engineers to obtain 21st century skills related to communication, leadership, and cultural, humanities, and ethical sensitivities,
- Provide opportunities for students to gain in-depth experiences in Challenges areas, as a mechanism to prepare them for engineering careers broadly, and to prepare them to be the future innovators to help solve these challenges.

In addition, informed by *NAE Changing the Conversation* report we seek:

- To be sensitive to the intended and unintended messages of formal and informal communications with constituents,
- To be mindful that how messages are perceived and can be fragmented, especially along age and gender categories,
- In communicating with constituents, to make the linkage between "engineering messages" that tested well across groups, such as "Engineers Make a World of Difference," "Engineers Creative Problem Solvers," "Engineers Help Shape the Future," and "Engineering is Essential to our Health Happiness and Safety" and the Grand Challenges.

In addition, informed by *NAE Engineering in K-12* report we:

- Continue to engage resources in the K-12 engineering education challenges, and use the Challenges as a framework for work in this space,
- Use the NAE Grand Challenges as a means to communicate in K-12 engagement activities for the purpose of exciting, attracting and retaining students' interests in engineering,

Implementing the Culture
Below are examples of the many ways that the College of Engineering implements this culture:

Extension and Engagement: The Office of Academic Affairs in the College of Engineering has substantial involvement in extension and engagement activity, especially related to K-12 students and teachers. We utilize the NAE Grand Challenges within the following extension and engagement activities in the College:

Engineering Summer Camps: Each summer of the College of Engineering offers summer camps at the elementary and middle schools levels. These include camps on the NC State campus, as well as camps coordinated at other locations throughout the state. In the camps students experience engineering through hands-on and creative activities—where the curriculum, messages, and communications are informed by the Grand Challenges. Examples include elementary students exploring solar energy through building a sun jar that "captures" energy during daylight hours through a solar cell and uses that energy to light an LED and create a night light, middle school students exploring the energy content of various fuels, middle school students creating earthquake-resistant buildings and testing them on a shake table, elementary students exploring the difficulties involved in providing clean water by designing water filters, and all ages exploring issues associated with health by designing and testing heart valves.

NAE K-12 Partners Program: The NAE K-12 Partners Program [27] was created by the College of Engineering at NC State and the Pratt School of Engineering at Duke University to promote the Grand Challenges in K-12 education. Schools, classes and/or individual students become partners by linking to Partner Sites and implementing the 5-Part Make It Happen Plan. Through the plan students and teachers implement a Grand Challenge-based project with their students, where the students are learning about the Challenges overall and specific broad elements of any chosen Challenge. They then share what they've learned with others at the school of in the community—teaching them about what they've learned. Lastly students are asked to incorporate something is individual, creative and innovative related to the project in the context of the Challenge.

The mission of the program is to "create an awareness of and involvement in the NAE Grand Challenges for the K12 community in order to (1) strengthen the STEM pipeline; (2) develop technical literacy and motivation needed to be successful as a society in solving Grand Challenges; (3) educate the populace on the engineering mindset and the role of engineering in addressing Grand Challenges and improving the quality of life." [26]

The College co-founded the program, serves a leadership role on the national office, and works to grow the program through direct involvement with teachers and students. In addition we work hard to create a multiplier effect by establishing Partner Sites at colleges of engineering across the US who outreach with K-12 entities in their location to implement the Grand Challenge framework at their schools.

The Engineering Place: The Engineering Place [27] is the umbrella program that administers K-12 activities, including those previously discussed, in addition to many other outreach activities that are informed and influenced by the Grand Challenges. As the mission of the programs is "to attract and retain a diverse engineering population by creating a continuum of opportunities for North Carolina K-20 students and educational professionals that broadens perspectives and enhances experiences in the disciplines of engineering," the platform of the Grand Challenges provides a contextual basis for many activities that naturally illustrate the breadth of real-world engineering. This application-based approach goes far toward exhibiting the true, integrated nature of the field. Family STEM nights include activities that allow kids and parents to investigate alternative energy, urban infrastructure and the carbon cycle. A class for pre-service elementary teachers focuses on the grand challenges as examples of engineering applications, specifically referring to real-world problems like the needs engendered by the earthquake and subsequent events in Haiti. The Engineering on the Road program takes examples of activities of this sort into classrooms all over the state of North Carolina.

Wake/NCState Early College High School: NC State is partnering with Wake County Public School [29] to open an early college high school in fall 2011 with a focus on the NAE Grand Challenges as a means of addressing STEM. Using the Grand Challenges as a platform for presenting STEM in a high school setting lends relevance to the curriculum that has been proven to have a positive effect on student achievement and retention. The 14 Grand Challenges contain issues relevant to many aspects of the Standard Course of Study (SCOS) used to construct daily lessons in K-12 schools in North Carolina. Using the Grand Challenges as a platform for teaching demonstrates how the subjects taught in K-12 schools can be used to make real substantive differences in the world. Addressing the Grand Challenges covers not just science and engineering, but also social studies, math, the arts and language arts Because engineering is both a set of professions and a design and problem solving approach that applies across whatever course of study that a student might choose

to focus on, the Engineering Grand Challenges are a platform that can be used in a STEM high school to provide relevance and urgency to the study of all subjects, regardless of a student's post secondary plans.

Engineering Research: The Office of Academic Affairs in the College of Engineering is active in seeking sponsored research monies to advance the goals of the unit. In many cases the research agenda in these grants relates to student learning, effects of outreach, teacher training elements, etc. We are using the Grand Challenges specifically in many of these research efforts. Two such examples include the following:

RAMP-UP: Recognizing Accelerated Mathematics Potential in Underrepresented Populations (RAMP-UP) is an NSF sponsored research project supported through the GK-12 program (#0338162), The GK-12 Program supports graduate students in collaborating with teachers in their classrooms to bring the results of the graduate students' research to the K-12 students. Grand Challenge themes are very present in the work of this grant. As an example, a RAMP-UP graduate student (PhD student in mechanical engineering) developed energy-related activities that helped elementary and middle school students explore solar energy, urban infrastructure and sustainability concepts. These activities included a trip to a 1 MW solar farm to see what large-scale power generation looks like.

NIH Grant: A grant funded by the National Institutes of Health worked specifically with two North Carolina elementary schools as they became engineering magnets and now is being used to assess the impact of this transition on student achievement. Coupled with a Congressional earmark, these schools have now been joined by four others. These elementary schools use engineering as a basis for teaching the Standard Course of Study in North Carolina. The students keep engineering notebooks and use the Museum of Science Boston Engineering is Elementary definition for the engineering design process during the entire school day. The students are introduced to the NAE Grand Challenges as a part of the engineering curriculum.

Student Recruiting: The Office of Academic Affairs in the College of Engineering is responsible for recruiting and enrollment management for the College. We utilize the NAE Grand Challenges in the following student recruiting activities:

Summer Camps: Each summer the College of Engineering operates a dozen high school summer camps for rising 9^{th} through 12^{th} grade students. In one regard these camps are K-12 outreach activities, yet at the same time they represent recruiting events. A very high percentage of students who attend these camps will apply for admission in the College after high school. As is the case with the elementary and middle school camps the curriculum, messages, and communications are informed by the Grand Challenges. Examples include the Biological Engineering workshop where students learned about engineering design used to improve and protect water quality. Participants experienced several facets of environmental engineering, including: measuring the impacts of storm water treatment practices, assessing stream health, and examining water flow through natural and man-made systems. In the computer science workshop students learned about game programming, tied directly to the challenge of enhancing virtual reality, and in the civil engineering workshop the students worked directly with issues associated with restoring urban infrastructure by making and breaking concrete and asphalt samples, building life-size trestle bridge and visiting construction sites.

Recruiting Programs: Recruiting is an important function in the College, not only to attract top students to our programs but also to properly message engineering to prospective students and parents. With that in mind, our Director of Undergraduate Engineering Enrollment Management oversees many programs and activities focused on informing and recruiting future students. Examples of these include:

- Regional Receptions: Fall semester evening receptions held throughout the state. Provide an opportunity to interact with prospective students and parents, and connect with alumni in the region.
- Spend-A-Day: On campus daily-long events involving students and parents. Held in spring as a yield event for students with higher admissions profiles. One of these events is targeted at women in engineering, providing an opportunity to use gender targeted messaging themes.

- Information Sessions: Thrice-weekly sessions held on campus for students, parents and visitors. Special larger sessions are held during times of peak campus visits including spring breaks and other times.
- Open House Sessions: Fall and spring semester Open House events where several thousand students, parents and visitors are on campus.
- Visitation Days: groups from schools, student organizations and other units often visit campus as part of field days, vocational development, or for other purposes.

In all of these programs and interactions we present the NC State Engineering message, and opportunities on our campus, that are tied directly to the Grand Challenge themes. We have developed handouts and display materials which link NC State Engineering to the Challenge themes. It is our goal in these interactions to educate constituencies about engineering and the NC State opportunities utilizing the strategic dimension of the NAE Culture as described above.

Other Activities: The College also hosts groups and events on ad-hoc bases. These provide future opportunities to advance the strategic dimensions of the College around the NAE Grand Challenges. Examples include:

- FIRST: The College promotes and partners with *NC FIRST* (For Inspiration and Recognition in Science and Technology) both at the FRC and FLL level for several events.
- Future Cities: The College partners with PENC (Professional Engineers of NC) and hosts the annual regional competition of the Future Cities Competition.
- JETS: The College has partnered with JETS (Junior Engineering Technical Society) to host a JETS TEAMS competition in the spring of 2011. The theme for the TEAMS competition in 2011 is energy and the global need for diversification, efficiency, security and ecological sustainability.

Student Success & Curriculum: The NAE Grand Challenges have been implemented in several ways in processes and courses at NC State.

New Student Orientation (NSO): New Student Orientation [, held the summer previous to students coming on campus, provides an opportunity for the College of emphasize strategic dimensions around the Grand Challenges. We use sessions during NSO to iterate on:

- The excitement of engineering: the great problems engineers work on
- Engineering today versus yesterday: the multi-disciplinary nature of engineering work
- Choosing a major in engineering: many engineering majors work on Challenge areas (such as energy, security or healthy living)
- Opportunities to prepare to be solvers of Grand Challenges: talk about skills and experiences necessary to position oneself

E101 Course: All first semester engineering students are required to be enrolled in E101: Introduction to the College of Engineering and Problem Solving. [As part of the course students student the Grand Challenges as a formal part of the course. They are asked to consider each of the challenges in the context of their own personal interests and the research going on at NC State. Each student is giving a copy of a publication describing the Challenges in detail.

Through the study of the Grand Challenges in the course students' misperceptions about engineering are changed and challenged. For instance many students think that in order to work on "Topic X" or in "Field X" or for "Company X" that they must graduate with a degree in "Degree Program Y." The NAE Grand Challenge framework helps students understand that many engineering disciplines work on the same types of problems, in the same companies, and in the same fields. This is an important concept not only from a broad engineering education perspective, but as a means to counter students' self-limiting attitudes as they choose their major.

Matriculation Process: Students at NC State are admitted into the First Year Engineering Program. Those that persist matriculate into one of our 17 ABET accredited engineering programs sometime during the first four

semesters. Capacity limits and student performance historically block some students from their intended engineering major. This results in student frustration and in some cases students leaving engineering altogether. Many students have an emotional connection to a discipline. They came to NC State to be an XYZ engineer, and if they think that anything short of that is a failure on their part. If the messages about engineering at NC State has been delivered (and heard) well at NSO and in the E101 course, students will be more open to thinking broadly about the engineering disciplines and their personal and career aspirations. We have found the NAE Grand Challenge framework as a positive way to have orient conservations with students and their parents.

NAE GC Scholars Program: [30] The College has recently established a NAE Grand Challenge Scholars Program at NC State. The program encourages and recognizes NC State students who will be solvers of the Grand Challenges in the future. NC State GC Scholars undertake requirements in each of the following components: Research, Interdisciplinary Curriculum, Entrepreneurship, Global Awareness, and Service Learning. This program provides students the opportunity to thread experiences during their time on campus around the NAE Grand Challenges.

Faculty Hiring & Research Thrusts: The dean of the College, Dr. Louis Martin-Vega has been very active in promoting the concept of the Grand Challenges. When discussing his strategic approach for leading and directing resources in the College he makes reference to a matrix with row-headers made of the engineering disciplines in the College and column heads of strategic thrust areas such as those in the NAE Grand Challenges. Referencing current sponsored research in the College, as well as this matrix, he points to the inter-connected nature of modern engineering work. He speaks to the need to make investments in the body of the matrix—across disciplinary boundaries—emphasizing hiring and resource allocations in strategic thematic areas versus in strict disciplinary frameworks. This strategy has allowed the College to compete very successfully in faculty hiring competition, as well as in with large-scale research proposals.

NAE Grand Challenge Summit Series: [31] The College of Engineering at NC State and the Pratt School of Engineering at Duke University collaborated to sponsor the Raleigh, NC Regional Grand Challenges Summit in February. This event (see: http://www.grandchallengesummit.org/raleigh-summit) attracted regional, national and international leaders to the NC State campus and Raleigh area to learn about the Grand Challenges, with special focus on engineering better medicines, preventing nuclear terror, and providing energy from fusion. Sponsorship of this event was consistent with our leadership role in the region and within the engineering education community around the Engineering Grand Challenges.

CONCLUSION

Challenges exist in the global marketplace of the world today that did not exist a decade ago. In the US, factors around education, engineering, and competitiveness have led to an unprecedented call for change. The College of Engineering at NC State University has adopted the *NAE Grand Challenges for Engineering in the 21st Century* as a framework to advance the strategic objectives of college in response to that call. Themes around the Grand Challenges have informed the style and content of our interactions with constituencies, our perspectives on faculty hiring, the opportunities we provide for our students, our research enterprise, and many other facets or operation within the college.

We are using the Grand Challenges to change the academic culture within the College for the better.

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