

## A Breakthrough Mission of Vital Importance

How the National Defense Education Program helps build a workforce

Standing outside a classroom during a summer training conference in Maryland, a visitor is enveloped by the noise of enthusiastic middle-school teachers and U.S. Department of Defense (DoD) engineers on break. They're building partnerships to make math and science come alive in schools near civilian defense research labs across the country. The sound is music to the ears of DoD officials. The gathering, or another like it, may be seen one day as having played a small but key role in producing a breakthrough in developing America's 21st-century workforce. Sessions such as this are being funded all or in part by the new National Defense Education Program (NDEP).

### A Fresh Approach

It's well-documented that the U.S. workforce is losing its math and science edge, and sincere and serious steps have been undertaken to address the STEM (Science, Technology, Engineering and Math) issues behind this problem. Numerous agencies and programs throughout the country are involved. NDEP, however, is the first comprehensive effort by the U.S. Department of Defense to step into the mix with funding and grassroots participation by its own technical workforce. The effort is aimed squarely at nurturing both leading-edge research today and developing future lab scientists and engineers tomorrow.

At the elementary-, middle-, and high-school levels (K-12), the idea is to bring defense scientists and engineers into the K-12 classroom to partner with teachers to show students the excitement and real-world relevance of science and math. Along the way they solve problems via exercises such as building and programming robots to cleaning mock pollution-damaged reefs or designing balls with the right type of bounce to clear an obstacle course. For college and beyond, DoD offers scholarships, internships, fellowships, and research grants.

### Meeting Objectives

NDEP must be aggressive to meet the congressional objectives behind its mission. Among them are awarding 1,000 innovative scholarships by 2013, demonstrating DoD involvement in K-12 education programs by 2010 in 25 states, and awarding 50 amazing five-year research fellowships by 2013. This website, [www.ndep.us](http://www.ndep.us), plays a part in the effort.

Launching the NDEP website in 2008 was fitting. It was the 50th anniversary of the National Defense Education Act of 1958, a congressional action spurred by the launch of Russia's Sputnik satellite. While historical comparisons are not meaningful, this effort is nevertheless an appropriate honor to the initiative that cemented the United States' place as a technological powerhouse the world has never seen, providing its citizens a broad increased standard of living.

Anchoring the website is LabTV, a first-ever video look at the non-classified work of civilian scientists and engineers inside defense labs across the nation. "Kids today aren't learning science and math the way I did growing up," says Robert McGahern, director of K-12 programs for NDEP. "Today we need to reach students who have grown up with the Internet and we are competing with the wide variety of other new and exciting media content at their fingertips. That's why you'll see fun and educational videos on the new LabTV." The site also will explain

the NDEP mission and serve as a source of regularly updated information for teachers and scientists, as well as a forum to collaborate on ways to advance STEM (Science, Technology, Engineering, and Math) learning. A portion of the site devoted to students provides more information about science and math programs, competitions, and scholarships.

### The NDEP History

The growing awareness of the need to bolster the commitment to the type of long-term, high-risk research only a noncommercial government-sponsored program can provide was crystallized by the terrorist attack of Sept. 11, 2001. The impact of that attack was analogous to the national reaction when Sputnik was launched and Congress responded with the passage of the National Defense Authorization Act in 1958. The terrorist attack of 2001 was similar in that it motivated Congress to address the technical challenges posed by emerging threats to the nation's security. Certainly there already had been a lot of debate on whether we are educating the number of students we need who are qualified for technical jobs.

There also were existing federal programs addressing the problem, in particular those sponsored by NASA, the Department of Energy, the National Science Foundation, and the Department of Education. But none of those were geared specifically toward developing interest in Department of Defense laboratories. And the DoD is facing a stark reality: Its Apollo generation is ripe for retirement.

A report by the Association of American Universities projects at least 13,000 military civilian lab scientists will retire in the next decade. This comes at a time when the Department of Labor projects an 11 percent increase in engineering jobs between 2006 and 2016, upping the competition for skilled workers. The demand for highly skilled professionals is reflected in high salaries and low unemployment. In April 2008, the National Science Foundation reported the median annual salary for an engineer working for the federal government was \$86,000. In the physical sciences the pay was \$81,000 and in mathematics \$79,000.

The Department of Defense is the largest federal employer of scientists and engineers and the largest federal sponsor of research and development. The overall unemployment rate of scientists and engineers in the United States dropped from 3.2 percent in 2003 to 2.5 percent in 2006, according to data from the National Science Foundation (NSF) Scientists and Engineers Statistical Data System (SESTAT). This was the lowest unemployment rate measured by SESTAT since the early 1990s. It continued a trend of lower unemployment rates for scientists and engineers compared with unemployment rates in the rest of the U.S. economy. For defense labs the situation is even tighter since they can only employ U.S. citizens. In 2003, the National Science Foundation reported that 58 percent of the engineering doctorates awarded in the United States went to non-citizens. And while S&E college graduate programs are growing, more than half of the students who enrolled in 2003 were foreign-born. A year later, science and engineering doctorates awarded to temporary residents were up 9 percent, compared with 2 percent for U.S. citizens. These trends have only become more pronounced.

Seeking to bolster the military's future STEM workforce, Congress in 2005 authorized the Science, Mathematics, And Research for Transformation (SMART) program. SMART uses DoD dollars to fund the college education of science and engineering students who are U.S. citizens.

In exchange, the students take paying summer internships in defense labs and agreed to work for a DoD lab for one year for each year of college support. SMART has been a hit. Qualified students apply in large numbers each year, with the best gaining acceptance. Of the first 30 SMART scholars, all got jobs in defense labs and remained DoD employees after their service requirement expired. This experience has repeated all the way through the current SMART class.

“After they have fulfilled their service requirement, we would like to hear them say to you, ‘I want more,’” says Laura Adolfie, the director of the DoD STEM Development Office, which has primary responsibility for the NDEP program. “Maybe they don’t stay at the place they are, but they do stay in the DoD community. Or maybe they go out and are part of the larger DoD enterprise. The burden is on us to create a program that will meet their needs as well as the needs of the laboratories.”

Impressed with the response to SMART, Congress approved an expanded version, which became NDEP.

### Highest Levels of Research

A lot of the strength of the United States is attributable to its technological prowess, much of which developed out of government-funded science research. “Specialized defense technologies often have little or no applicability to commercial products,” the American Society for Engineering pointed out in a 2004 report. “Unlike the situation during World War II or even the Vietnam era, the DoD market is now often too small to justify a significant investment of scarce capital. For instance, Intel stopped making customized chips for the military because it was expensive and the volumes were too small.”

The American Association for the Advancement of Sciences notes that federal basic research funding in the physical sciences and engineering is flat and has declined as a percentage of gross domestic product over the past 30 years. Yet that research, and the people behind it, is critical in times of crisis. Seeking to address that need at NDEP is the National Security Science and Engineering Faculty Fellowship (NSSEFF), a program overseen by Adolfie.

NDEP funded eight NSSEFF fellows in 2008 and 10 fellows in 2009 and raised the maximum grant amount to \$850,000 per year for five years. Each of the winners is a college educator who had presented a DoD-relevant proposal vetted by a team of scientists and government officials. The winners come from universities around the country and the titles of their proposals sound like the stuff of science fiction: “Exploring Dissimilar and Nanomaterials Integration as a Platform for New Medium and Long Wave Infrared Device Functionality,” “Engineering Proteins for Anti-Viral Applications,” “Functional One-Dimensional Structures Based on On-Wire Lithography,” “Fusion and Interference from Multiple and Massive Disparate Data Sources,” “Managing Acoustic Communications in High-Stress Settings,” and “High Strain Actuators for Miniaturized Actuators and Self-Powered Sensors.” Adolfie, who monitors each scientist’s progress, has high expectations not only for the final efforts —

“We expect a dynamite report,” she says with a laugh — but also for the professional relationships that will develop among the scientists themselves and the DoD researchers with whom they will come in regular contact. “They will feel comfortable with each other and keep

up with and teach each other,” she says. “We want them to share ideas and collaborate.” Eventually the program will issue 10 grants a year, giving it about 50 NSSEFF researchers under the umbrella at any one time.

### Out of the Comfort Zone

Supporting innovative programs like SMART and NSSEFF is comfortable territory for the government and military officials involved. The applicants, whether students or professors, are adults, often peers. But these efforts primarily fuel individuals and programs already in the pipeline. Addressing the K-12 student pool in a way that would expose them to the Defense Department labs, potentially inspiring them to pursue a DoD career path, was an unmet challenge.

The folks at NDEP knew they had to reach deeper and try to groom the workforce of the next decade and beyond. Initially the bulk of the focus is on the middle-school students, those in sixth through eighth grades, with more to be added as the program matures. Experts say middle-school students are at a game-changing age where they will need to embrace math and science -- or likely vanish as a potential STEM employee. From groundwork laid by programs like N-STAR, the Virginia Demonstration Project, and Materials World Modules pioneered by Northwestern University, NDEP administrators are building a STEM learning platform that can be customized by teachers and school districts to fit distinct needs.

The Virginia Demonstration Project was started in 2005 by the Navy’s Office of Naval Research and became the NDEP model for bringing scientists and engineers into the classroom for STEM programs. Working with the College of William and Mary, the VDP involves both classroom activities and summer camps designed to make science and math learning fun. By 2009, 40 Navy scientists and engineers had logged more than 1,500 classroom hours in 21 middle schools in four public school systems and one DoD school in Virginia.

“We are getting a really good response from the teachers,” says Bob Stiegler, a Navy engineer who has been involved with VDP from the beginning. “The indication is we have impacted the Standards of Learning test scores. They just did an assessment with the Maryland program and the overwhelming response was the students really absolutely love the engineers being in the classroom.” The engineers also help teach the students practical skills.

“The solution might not always be mathematical,” McGahern says. “Sometimes it is learning to work backwards, to draw a list or to make a picture. All these skills can help you solve other things later in life.” This hands-on approach promotes better retention among students. “Rather than just getting the answer from a textbook where they answer equation six in chapter four, the kids learn and remember the answer better,” McGahern says.

The K-12 effort is not without its challenges. Some school districts were concerned that the program is designed to recruit students to join the military, but they have since realized that the majority of DoD scientists are civilians and that their concerns were unfounded. School districts also face pressure to have their students perform well on standardized tests and fear devoting time to new programs.

“They typically have their plate full of requirements and their normal first participation is a summer program that doesn’t risk anything going on in a classroom,” McGahern says. “Once they see how this works and the feedback from teachers and students that ‘Yes, this is pretty cool,’ the schools start getting behind it before their boards and working to include it as part of the standard curriculum.”

While teachers often are initially concerned the program will represent more work and not help improve test scores, they change their minds after they have completed a session. When Jason Kremar, an engineer with the Naval Surface Warfare Center in Dahlgren, Va., first started with the program the teachers were volunteers. As the program became institutionalized, some of the new teachers were hesitant. “You get teachers who had been teaching for several years and now you are telling them to do something different,” Kremar says. “What we do to alleviate that is we are a very adaptable program. If they have a week, or one Friday a week for nine weeks, we can do it that way too. When the teacher gets involved and sees it is not an add-on, it is something they would be teaching anyway, that helps a lot.”

Enthusiasm for the program within a school can be contagious. Jessica White is the science department chair and a seventh-grade teacher for King George County Public Schools in Virginia, where students regularly interact with engineers from the Dahlgren Navy base. For the first time the English department is getting into the act and will match its curriculum for three weeks to the theme of coral reefs. White says the civics department is thinking about joining next year. To encourage teachers to train over the summer and scientists and engineers to make time to participate, the program covers a portion of their salary. It also helps fund materials and learning kits for the classrooms. Teachers and scientists who have participated report they are developing professional relationships that often go beyond the 10-week classroom sessions.

Dianne Clowes, a science teacher at Ni River Middle School in Spotsylvania County, Va., says the relationships developed during the training sessions, and with the engineers and scientists who work in the classrooms, has a payoff beyond the official work. “I started a rocketry club last year and was having difficulty with some of the motors,” Clowes says. “I contacted the engineers and they were really great about telling me the answer or helping me work it out. You build relationships in the community through this program.” The expectation is that the exposure may one day encourage a student to pursue a career as a defense lab researcher or as a teacher to steer an aptly skilled student in that direction.

“This is a tremendously challenging initiative that has enormous potential in its ability to positively influence the students’ impression of science and mathematics at a crucial point in their academic career,” says McGahern. “We rely heavily on our defense scientists and engineer coordinators to build the necessary bridges to other local community school systems. As we vigorously expand this initiative to different states, I have asked our coordinators to remain focused on execution – partnering our defense scientists and engineers with the local school teachers to deliver exciting programs in the classroom.”

### Bringing in the Role Models

Participation by defense lab personnel is the key to NDEP’s success. Kirt Moser, the technical director of the space and missile division for the Air Force Research Laboratories at Wright-

Patterson Air Force Base in Dayton, Ohio, has supported educational outreach programs at several Air Force bases, including helping start the Space Scholars Program at Kirtland Air Force Base in New Mexico. “We really need to be involved to entice young people into science and engineering,” Moser says. “If we don’t get some of our best young men and women to go into math and sciences at some time we might find ourselves playing second fiddle to another country in terms of innovation.” Moser is a strong supporter of the goals behind the National Defense Education Program.

“I am excited about NDEP and LABTV reaching kids at an age when they really haven’t decided what they want to do,” says Moser. “These programs give them a sense of understanding about the work we do at the labs and put them in virtual contact with some of our scientists. It shows them the excitement of the young engineers in the workforce. Excitement is infectious.” Carol Gick, an eighth-grade teacher at Battlefield Middle School in Spotsylvania County, Va., says the scientists and engineers who help her students build and program robots to retrieve fake land mines are great role models. “Working with a person who is out there in the field is the key to the entire program,” Gick says. “They show the kids what they are doing out there in their jobs and how these little Lego robots can demonstrate how real problems are solved. If it was just me doing this program, it would not be the same.”

Dr. Jim Rohr, a researcher with the office of science and technology at Space and Naval Warfare Systems Center Pacific (SSC-Pacific) in San Diego, is the site coordinator for NDEP charged with building relationships between the Navy laboratory and local schools. A teacher since his days in graduate school, Rohr first got interested in taking the sciences to the middle schools when his own son was a student and his wife challenged him to help the class. Rohr wrote a successful grant for \$15,000 and hasn’t stopped since. “At that time, although a lot of people in the lab were doing things in the community, we were mostly working individually,” Rohr says. “Today, thanks to NDEP we have more collaboration and support from management.”

The engineers enjoy the classroom experience. “When you actually go into the classroom, you see the enthusiasm of the kids,” Aaron Kota says. Kota is the NDEP site coordinator at the Naval Surface Warfare Center Dahlgren Division in Virginia. “They are excited to have us there -- there is excitement for what we are working on.” When students run into difficulties, the engineers are there to help. “We ask guided questions, we don’t give answers,” says Kota. “Letting them discover on their own is the critical part.” Kremar agrees. “After the kids build and program a robot, they have to see if it does what they want it to do,” says Jason Kremar, a former engineer at Dahlgren and now a full-time science education specialist at the College of William and Mary. “It is all the things we do: test, engineer, design, and redesign. You hardly ever get it right the first time.”

Kremar has been impressed by the seventh- and eighth-grade students he has taught. “They are underestimated a lot,” Kremar says. “Giving a good challenge, and challenging the kid, is important. We, in society, are too quick to judge what a kid can and cannot do. I have been impressed so many times with which students are the best performers. It is not always the best student doing the best engineering work. It is the one who is patient, who is willing to try something over and over. The students who typically get the answer right the first time, find out they don’t get it right with this program, and that is a great lesson.

But the student who doesn't get it right finds out how to get it right. The more the students struggle with the engineering part of it, the more excited and motivated they get when they solve it." The classroom experience can be critical in influencing a student's choice of career. A paper by the American Institute of Aeronautics and Astronautics concludes, "While a foundation in math and science is important, preparing (quality education materials) in these areas alone will not address critical STEM workforce requirements. Students who have no exposure or experience with engineering have a very low probability of choosing engineering as a career or taking the courses needed to pursue a career in engineering."

### Setting an Example

As its programs mature, NDEP expects partnerships between classroom teachers and DoD professionals to serve as an example for other organizations interested in partnering with schools to bring their STEM expertise into local classrooms. Those organizations can take advantage of NDEP's K-12 Program (PEP). One of the thrusts of NDEP's K-12 effort is to scout out and make available education programs and materials being developed independently by the nation's defense labs, or even outside private or nonprofit STEM ventures. "Our partnership arrangements get us access to certain things," says McGahern. "Let's say if SSC Pacific wants to try something out with San Diego schools and it works. Then we can include their experiences and make it available to all of our schools and labs."

Its focus on local and national partnerships helps set NDEP apart from other government-sponsored STEM initiatives. "NDEP's focus on creating a culture of partnerships, even on the limited basis of the labs and nearby schools, is powerful," says John Yochelson, president of Building Engineering & Science Talent. "The enduring part is the relationships with the labs that make the teachers better and connects the dots with the kids between what they are learning and how some people help the country. Anything that lights that spark is a plus." These NDEP programs are expanding to offer more to those in K-12 grades outside of the middle-school focus area. Rohr advises not underestimating the interest of younger students. When, by accident, he ended up before a fifth-grade classroom, the reaction was very positive. "At the end of this class we asked, 'Who would want to be an engineer and scientist?' All the hands went up. When we ask that question in middle and high school, much less students raise their hands."

### A Mentor's Helping Hand

Mentors can play a key role in keeping a student on track in the sciences, and helping develop them is another key focus of NDEP. The role of mentors is considered particularly important in the underrepresented communities. African-American and Hispanic students combined make up 25 percent of the U.S. population but account for only 11 percent of engineering bachelor's degrees awarded to U.S. students. "You do not find many Hispanics or African-Americans in the fields of physics or engineering," says Ayax Ramirez, an engineer with SSC Pacific, in San Diego. "Science is a difficult subject. That's why we have to make sure students develop an interest in it and the necessary skills early in their academic life. I am currently teaching physics at Southwestern Community College, a school with a large Hispanic population, and I ask myself, 'How many students are going to be getting a degree in physics, math, or engineering, and what can I do to increase those numbers?'"

Ramirez has mentored 26 students from Southwestern, a large number of them of Hispanic origin. The students in his program work at SSC Pacific and are paired with a professional for 10 weeks working in different physics and engineering projects such as laser annealing, antenna design and modeling, and communications. Several have gone on to prestigious universities and have reported back on the valuable experiences they had at SPAWAR. “We are making a difference and we are changing lives,” Ramirez says. “We are telling these kids it is possible to get a job in physics and engineering.”

A challenge at the junior-college level, Ramirez says, is overcoming the tendency to believe the students could not get into a four-year college and that it will be hard for them to succeed in the sciences. The fallacy is that often it is economic reasons that kept these students out of four-year schools. “A lot of smart and educated kids are attending junior colleges,” Ramirez says. “We want to tap into that talent, to tell them about the good work we are doing for the Navy here at SSC Pacific and how they can be a part of that effort. And you have to do it consistently and you have to do it with passion.”

McGahern sees much of NDEP as a large mentorship, from middle-school students in eighth grade being mentored by engineers or specially trained teachers, such as when San Diego’s Jim Rohr recently hosted a capacity crowd for a “Girls Day Out” event for middle-school girls interested in the sciences, or SMART students doing internships and jobs in labs, or NSSEFF recipients using their funding to bring other researchers into the fold on efforts that later may be a key to national security.

#### A Role to Play

NDEP and similar efforts of other government agencies, like NASA, the Department of Energy, National Science Foundation, and Department of Education, are the keys to ensuring the nation has a strong supply of science, math and engineering students. The good news is that since 1999, the number of engineering bachelor’s degrees has gradually been rising. The sobering news is that today’s numbers are still below the high of 77,572 issued in 1985.

So there is room for growth and for opportunity within the Department of Defense. The academic disciplines identified as DoD needs are diverse. They include: aeronautical and astronautical engineering; biosciences; chemical engineering; chemistry; civil engineering; cognitive, neural, and behavioral sciences; computer and computational sciences; electrical engineering; geosciences; materials science and engineering; mathematics; mechanical engineering; naval architecture and ocean engineering; oceanography; and physics. The key is getting that message out. “The Department of Defense has very interesting challenges at its labs,” Adolfe says. “The idea here is to match the individuals to those challenges.”