Testimony to
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Committee on Science and Technology:
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by

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SCHOOL OF ENGINEERING

Good morning to Chairman Lipinski, ranking member Ehlers, and other members of the subcommittee; to fellow witnesses; and to all who share an interest in and concern for the future of engineering. Thank you for inviting me to testify on the specific subject of “Engineering in K-12 Education.” My name is Darryll Pines and I am the Nariman Farvardin Professor and Dean of the A. James Clark School of Engineering at the University of Maryland, College Park.

The Clark School is fortunate to attract a large number of outstanding young people from the highly regarded Maryland school system and Maryland private schools, as well as from excellent schools across the country and around the world. We have developed a strong sense of the skills and attributes students need to complete our rigorous curriculum and developed programs that are proving effective in retaining and graduating more of those students. We have also developed an array of programs to interest younger students in the field of engineering and a few insights concerning the inclusion of engineering concepts and approaches in pre-college education. Chief among these is the following very simple, but sometimes forgotten, idea:

In K-12 engineering education, the proper pacing is critical. By engaging students at the proper level at the proper time, schools can ensure that students are neither intimidated by the difficulties of engineering, nor deluded that engineering is essentially dreaming up ideas without the foundation of creating, analyzing, testing, and refining a solution using math and science.

If we can achieve proper pacing, we can show students engineering’s potential for positive impact in the world, the great satisfactions engineers experience in creating that impact, and the rewards and challenges of doing so, while beginning to train them in the skills they will need to take on those challenges and succeed in the university setting.

For proper pacing to occur, those of us in the Clark School and other university programs must do a better job of educating high school and middle school teachers about the field of engineering, the academic capabilities their students must develop to enter the field, and the right level of engineering concepts teachers can include in their lessons. By providing such support, we can show students, parents, teachers, counselors, and administrators that introducing engineering in K through 12 education is both feasible and of great benefit to the students themselves and to progress in our nation and our world.

In my testimony I will report on current Clark School activities and propose a number of new ideas that may be of value.

Let us begin at the end of the educational process for most engineers: obtaining the bachelor of science degree. The successful undergraduate engineering student should leave the university with the following knowledge, skills, characteristics, and experiences:

1 A high awareness of the areas of opportunity and challenge in which engineering can make a positive difference in our quality of life.

2 Time spent in direct work in one or more of those areas, whether through participation in related research, internships, or volunteer and service programs.

3 The entrepreneurial drive, skills, and confidence to organize and launch an initiative—even a company—in one of those areas, where none existed before.

4 Demonstrated ability to solve open-ended problems in those areas by applying engineering methods, mathematics, and current knowledge of physics, chemistry, and/or biology.

5 Demonstrated ability to focus on a situation or problem and imagine one or more ways to improve it or solve it.

6 Evidence of a strong work ethic in pursuing assignments and activities, and an ability to learn autonomously.

7 The ability to communicate with professionals and lay people, both to express ideas and listen to and appreciate feedback.

8 The ability to work alone or in teams, and to lead teams when required.

To make it more likely that students will possess these skills and attributes on graduating from college, and indeed to increase the number of students who achieve that goal, we must ensure that students come to us from high school possessing all of the skills in some degree, and the last five in a high degree.

Thus, if the process works correctly, freshmen come to us with the ability to:

- Solve problems using mathematics and science
- Focus on an opportunity or challenge and imagine solutions
- Apply themselves at a high level, consistently over time, and not be deterred by difficulties and failures
- Communicate ideas and information through speech and writing
- Work alone or in teams, and lead when required.

If students also know about some of the areas in which engineering can make a positive difference, and have engaged in low-level aspects of engineering thinking, they are more likely to consider engineering as a path, and succeed in that path in college.

An example would be making a truss bridge, a project that many high school students do in a science or engineering class. They will build a truss bridge according to how they think it should look, how they think they can make it stronger, relying largely on experience and intuition. This is appropriate for high school.

In their mechanics class in college, students will learn the concepts of stress and strain, axial loading, material properties, and other concepts that allow them actually to design the truss, then build it, rather than simply put something together and see how it stands up to a load. This is appropriate for college.

Pre-college engineering education can make the student aware of and excited by the potential impact of engineering to improve our world, and prepare him or her for the challenges of the university engineering program.

The first step is to identify students who are proficient in mathematics and science, because without these strengths, it will not be possible for students to succeed in the field.

Next, introduce students to the many real-world opportunities to apply that proficiency--from healthcare to transportation to homeland security to space flight to communications. This introduction can provide the spark of excitement so that students know, at least in an elementary way, what engineering is all about. Challenging students to apply their proficiency also allows them to be *creative*, an important and highly satisfying aspect of engineering, which they might not have the opportunity to do except in these classes.

Throughout, *pacing* must be part of the process. Young students must have a firm grasp of fundamentals, especially mathematics, before they are introduced to substantial engineering concepts. Middle school is probably the right time to weave in some of the basic applications of engineering, but too early to do any rigorous engineering-type classes. The four years of high school are the right time for this. The typical high school curriculum is fairly packed, but having engineering electives available in each of the four years could be appropriate. These should be coordinated with what the students are learning in math and science.

Students must not be overwhelmed. They must have the firm grasp of the basics. If they do not, they end up not really understanding what they are doing beyond a superficial level.

The Clark School delivers an extensive variety of K through 12 programs and initiatives.

Our summer programs target students from elementary school to rising high school seniors. They include residential and non-residential offerings, and typically are one week in length. Each program allows students to explore engineering in a variety of different ways, including hands-on projects, design problems, lab tours, and presentations by faculty members. We also offer our *Introduction to Engineering Design* course to high school students (typically rising seniors). They obtain college credit for the course and a more in-depth engineering hands-on experience.

We deliver a number of programs throughout the academic year as well. Our Center for Minorities in Science and Engineering offers two:

- The ESTEEM Program brings students to campus in the summer, and arranges for them to begin a research project with a faculty mentor. Students will continue to work on the project with the mentor during the school year.

- The Maryland MESA program, meaning Mathematics, Engineering and Science Achievement, engages students from a large number of Prince George's County Public Schools in Saturday Academies, summer programs, and in-service and after school enrichment programs to prepare them for university science and math. Our Center for Minorities is a regional MESA center.

Another academic year K-12 offering is the Lead Academies offered through our Women In Engineering program. The academies introduce students to one of the Clark School's academic programs, such as aerospace engineering or bioengineering, again using demonstrations, hands-on projects, and so forth.

Evaluation of these programs' effectiveness can be a challenge, especially for the younger students. We have case by case evidence that students who participate, and their parents, become more positive about engineering and the students go on to apply to the Clark School.

Regarding formal partnerships, we have identified the twenty-five Maryland high schools that send us the greatest number of students, and sent them letters proposing closer relationships involving information exchange, opportunities for students to engage in engineering activities at the Clark School, training for teachers, and the availability of merit scholarships. We hope that this is the beginning of strong partnerships that increase awareness and involvement in engineering, and bring still more great students to the Clark School. Historically, we have worked closely with a small number of local high schools. The Top 25 program should expand this process to a much wider field.

We have produced a number of different summer programs for high school STEM teachers. They have received presentations from faculty, done hands-on projects, toured our facilities, spoken with faculty, all to enhance their understanding of engineering, and encourage them to take their new knowledge back into their classrooms. We have submitted NSF proposals (which weren't funded) for a summer educational program which, as a key element, includes high school teachers who would work closely with STEM faculty (math and engineering) and incoming at-risk university freshmen. We also work individually with teachers on request.

We do not at present incorporate engineering into College of Education programs, although these discussions have been initiated. We have arranged a meeting with the Maryland State Department of Education's STEM coordinator to explore ways to establish closer cooperation between our two organizations. We hope through this process to make a presentation about engineering education to Maryland high school math and science chairs in the summer of 2010. Through a discussion of their interests and needs, we hope to create a more extensive program that will not only assist current teachers but become the basis for including engineering in our College of Education degree and pre-service certification programs.

I would like to add a few ideas on future programs that would be pertinent to this discussion—ideas that could have a highly positive impact on our current Clark School students and current high school students.

First: "Students Without Borders."   The idea is to establish a program for Clark School students of mandatory community service (40 hours per academic year) to earn credit through mentoring, tutoring, judging science competitions, and other activities with middle and high school students. We find that today's Gen Y student is excited to do something useful to help society and add social value experiences to his or her education.

Second: Online STEM Education System. Here we would use existing TV communications systems and the Internet to bring the best high school and middle school STEM teachers into the areas where they are in short supply, whether in the form of complete courses or highlight sessions that add excitement to local courses.

Third: University-Based STEM Governor's Schools. Modeling our existing and highly successful living/learning programs, create STEM living/learning programs on university campuses for academically talented and mature students who have completed 11^{th} or even 10^{th} grade. This would enable them to complete their university degrees early and obtain early access to internship and employment opportunities with partnering corporations and government agencies.

Fourth: Nationwide Keystone Professors Program. Modeling the Clark School's highly successful Keystone Professors Program, create an expanded, nationwide university-based program that brings the best teachers into the most elementary university STEM courses and thus improves retention of students over four years. Keystone provides funds to increase the base salaries of participating professors and to support technicians and equipment used in the courses.

Fifth: Articulated Agreements with Community Colleges. Develop agreements with community colleges to ensure that their courses align with university requirements. This will enable students automatically to transfer all credits after two years rather than require evaluation of each course for transfer.

My thanks to the subcommittee for the opportunity to report on the Clark School's experience with K-12 engineering education and suggest a few ideas for expanded use. I will be happy to answer any additional questions, and to make myself available to work out these ideas as deemed appropriate.

BIO FOR DEAN DARRYLL PINES

Dr. Darryll Pines became dean of the Clark School on January 5, 2009. He came to the University of Maryland in 1995 as an assistant professor in the Clark School and has served as chair of the Department of Aerospace Engineering since 2006.

Under his leadership, the department was ranked 8th overall among U.S. universities, and 5th among public schools in the *U.S. News and World Report* graduate school rankings. In addition, during his tenure as chair, the department has ranked in the top five in *Aviation Week and Space Technology's* workforce undergraduate and graduate student placement study. The undergraduate program was ranked 9th during that time. Pines has been Director of the Sloan Scholars Program since 1996 and Director of the GEM Program since 1999, and he also served as Chair of the Engineering Council, Director of the NASA CUIP Program, and Director of the SAMPEX flight experiment. Last year, he served on the university's Strategic Planning Steering Committee.

During a leave of absence from the University (2003-2006), Pines served as Program Manager for the Tactical Technology Office and Defense Sciences Office of DARPA (Defense Advanced Research Projects Agency). While at DARPA, Pines initiated five new programs primarily related to the development of aerospace technologies for which he received a Distinguished Service Medal. He also held positions at the Lawrence Livermore National Laboratory (LLNL), Chevron Corporation, and Space Tethers Inc. At LLNL, Pines worked on the Clementine Spacecraft program, which discovered water near the south pole of the moon. A replica of the spacecraft now sits in the National Air and Space Museum.

Pines' current research focuses on structural dynamics, including structural health monitoring and prognosis, smart sensors, and adaptive, morphing and biologically-inspired structures as well as the guidance, navigation, and control of aerospace vehicles. He is a Fellow of the Institute of Physics and an Associate Fellow of AIAA, and he has received an NSF Career Award.

Pines received a B.S. in mechanical engineering from the University of California, Berkeley. He earned M.S. and Ph.D. degrees in mechanical engineering from the Massachusetts Institute of Technology.