The NAE Grand Challenge Scholars Program:
Response to the Grand Challenges from Higher Education

Tom Katsouleas
Provost and Robert C. Taylor Professor of Electrical Engineering
Co-chair NAE Grand Challenges Advisory Committee

NAE Annual Meeting
October 4, 2015
Born from the 1st NAE Grand Challenges Summit 2009
Goals of the Grand Challenge Scholars Program

• Create a generation/community of engineers with the skillset and mindset to solve Grand Challenges
  – “The 300” of ancient Sparta → today
• Attract diverse students to engineering
• Retain “
• Incent students to stretch
• Integrate co-curricular and curricular education into a whole greater than the sum of its parts
Looking Back to the 20th Century:

Welcome!
How many of the 20th century’s greatest engineering achievements will you use today? A car? Computer? Telephone?
Explore our list of the top 20 achievements and learn how engineering shaped a century and changed the world.

1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials
NAE Grand Challenges for 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 urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning
- Engineer the tools of scientific discovery
Implications of the Grand Challenges

• Don’t fit within any one discipline, or even within engineering

• Describe engineering in human-facing terms:
  – Sustainability, Health, Security, Joy

• Powerful tool for “Changing the Conversation”
Learning about NAE challenges enhances perceptions of importance and interest in engineering.

% saying engineering issues/problems are more interesting/important than those of medicine, business, and law

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<thead>
<tr>
<th>Category</th>
<th>Before hearing</th>
<th>After hearing</th>
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<tbody>
<tr>
<td>Men</td>
<td>21% much more</td>
<td>46%</td>
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<tr>
<td></td>
<td>29% much more</td>
<td>58%</td>
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<tr>
<td>Women</td>
<td>15%</td>
<td>33%</td>
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<td></td>
<td>26%</td>
<td>53%</td>
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<tr>
<td>High school or less</td>
<td>19%</td>
<td>41%</td>
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<tr>
<td></td>
<td>29%</td>
<td>59%</td>
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<tr>
<td>Some college</td>
<td>18%</td>
<td>37%</td>
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<td></td>
<td>31%</td>
<td>55%</td>
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<td>College graduates</td>
<td>15%</td>
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<td>22%</td>
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<tr>
<td>Postgrad education</td>
<td>16%</td>
<td>38%</td>
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<td>25%</td>
<td>51%</td>
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Solving Grand Challenges will require I-Shaped Engineers

- Solutions must be Feasible, Viable, Desirable
  - Feasible → Engineering fundamentals
  - Viable → Economics and business knowledge
  - Desirable → Context of culture and social policy

A couple of stories...
NAE Grand Challenge Scholars

- To prepare UG engineering students with the skillset and mindset to address GCs over the course of their careers

- Five critical components
  1. Project or research activity engaging a Grand Challenge
  2. Interdisciplinary curriculum – behavior, business, policy
  3. Entrepreneurship
  4. Global dimension
  5. Service learning

Simon GC Scholar Maggie Hoff working on potable water project in Peru

Courtesy Martha Absher
Project Example: Revenue-generating Public Toilets in Togo

Reinventing the pit latrine
Human waste digested to biogas, then used to heat sterilize effluent.

Duke Prof. Marc Deshusses, Gates Foundation  Grand Challenge Scholar: Conner Cotton
6 seat prototype in Togo

Biogas combustion to generate electric power and revenue
Project Example: Sustainable fishery in Kenya
Teaching wave mechanics to protect fragile shallow water reefs
Project Example: Exoskeleton controlled by Brain-Machine Interface

Courtesy M. Nicolelis, Duke
Project Example: Pratt Pouch

• HIV+ Women who give birth at home
  • 20-50% have HIV+ children [1]
  • Majority transmitted during delivery [1]
• 3TC, NVP and/or AZT can prevent transmission
  • Drugs expires quickly out of the bottle (<1mos)


Clinical Trials
Ecuador
Zambia
Tanzania
Namibia

Duke Pouch 12 mos NVP
Duke Pouch 12 mos AZT
Duke Pouch 12 mos 3TC

Courtesy: Bob Malkin
What students say about it

“...take advantage of the Grand Challenge Scholars Program if it's offered at your school.

It really does give you a great mindset to plan your future.

This list is about nothing other than the pursuit of something that will last beyond our lifetimes, and trickle down in the history lessons taught to future generations.

The 14 National Academy of Engineering Grand Challenges for Engineering aren't just a call to those already in the field. They're a call to anyone passionate about innovation and the grand impacts it can have on our lives.”

Kevin Mauro, Duke Engineering Grand Challenge Scholar 2015
Project: Brain to brain interfaces (Reverse engineer the brain)

Most say that the reflection on how their various education experiences fit and empower them is the most valuable.
TEACHING FOR THE FUTURE FIRST IN A SERIES

MORE ENGINEERING STUDENTS GET REAL-WORLD EXPERIENCE

Schools try to debunk it as a "field for geeks."

Dan Vergano
USA TODAY

DURHAM, N.C.

However, Duke University engineering student Kathryn Latham, 21, has changed her mind. "I think if more students pursued jobs that made a difference, the world would be a better place."

Latham's idealism took her to Bolivia this summer, leading a team of Duke engineering students building a 250-foot-long steel pedestrian bridge "by hand," she notes, to link two impoverished villages separated by a deep gorge.

Taking young engineers out of lecture halls to practice their profession represents the cutting edge of education in engineering, say educators and the field's leaders. Change is needed, however, because many educators, business leaders and students say the world's million-plus engineers expected to retire by mid-century.

"We have done a miserable job, by and large, of educating so that we change the world," says National Academy of Engineering chief Charles Vest. In a nutshell, he says, that helps explain why only about 4.6% of U.S. college graduates are engineers, while about 12% are in Europe and 28% in China and India.

"This is an idealistic generation, and it's a thought that everything is going to change the economy, and they want to help people," Vest says. "We have to get them out of the lecture hall and show them how engineers do just that."

On Oct. 1, the academy will host a Grand Forum event in Washington aimed at showing how the discipline can fix the problem. It will feature educators, industry leaders and the Gathering Storm, warned of eroding U.S. leadership in science and technology, and alarm bells have rung over the brightest students skipping engineering for finance, medicine or other fields in an era of declining U.S. manufacturing.

Much of the problem comes in the pipeline that carries kids from freshman chemistry to graduation, Vest and others say. Just 94% of women and 93% of men who started out as engineering majors in 2005 finished in five years. Only four years ago, many engineering professors in the past tried to chase out students in minuscule programs filled with calculus problems, lectures and little-life, but that culture has changed and is changing, Vest says.

Engineering students build things earlier in their college years. They leave the high school classrooms of math and science that their teachers have defined their education with the messy business of building things that do, or don't, work.

At Duke, students have to build something in weeks-long projects as freshmen and start a business that sells to real customers before they graduate. Our model is a music school with engineering as a performance art, and the studio time that students spend with each other is an enormous part of their education," Miller says.

At Duke, Latham is a "Grand Challenge" scholar in a national engineering academy program at a dozen schools. It asks students to tackle 14 big problems around the world, ranging from "preventing suicide" to "reverse-engineering the human brain." She's trying to grow algae in an epoxy "greenhouse" in a lab to help clean the water and use the growth in green diesel fuel projects.

Thomas Katonas sees success in the Grand Challenge program.

By person solely skilled in filling graph-paper pages with neatly answered math problems, the goal is to ground students in teamwork and entrepreneurship, as well. "We can't solve all our problems by technology alone," Katonas says. "They will require a deep understanding of human behavior."

"Khan Academy" online teacher Sal Khan, whose organization's short YouTube lectures on everything from calculus to civics have garnered more than 175 million viewers since 2006, when a National Academy of Sciences report, "Rising Above the Gathering Storm," warned of eroding U.S. leadership in science and technology, and alarm bells have rung over the brightest students skipping engineering for finance, medicine or other fields in an era of declining U.S. manufacturing.

America produces just as many great kids as ever. They just don't see engineering as attractive all too often. Instead, it's "a valet's field for geeks," says President Richard Miller of Ohio State University, who was a chemist before he switched to engineering.

"We need people who think differently, people who are creative, people who make things, people who can work in teams, not just alone on a computer," Miller says. Most radically at Ohio State, but increasingly at schools across the country, engineering students build things earlier in their college years. They leave the high school classrooms of math and science that their teachers have defined their education with the messy business of building things that do, or don't, work.

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Latham, a transfer into the discipline, says, "I've learned that engineering is really what you want it to be. You really can get out of the classroom and really solve problems."
NAE Grand Challenge Scholars Programs

6 years out

• 200+ GC Scholars graduated to-date (~50% women)
• 20 institutional GCSPs in the US + 2 international
• National Steering Committee:
  o Zhenya Zavstaker, Olin
  o Christina White, UT Austin
  o Louise Yates, USC
  o Linda Franzoni, Duke
  o Jenna Carpenter, Campbell (Chair)
• Partnership with EWB, EPICS, EpiCenter, AAES
• National GCSP Workshops (Olin College 2010, Austin 2011) and Panels (ASEE 2011, 2013, 2014)
## 22 Approved GCSP Programs

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<tr>
<td>Duke University</td>
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<td>Olin College</td>
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<td>Univ of Southern California</td>
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<td>Clemson University</td>
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<td>NC State University</td>
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<td>Lafayette College</td>
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<td>University of Tennessee</td>
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<td>The Ohio State University</td>
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<td>Taylor’s University, Malaysia</td>
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<td>University of Utah</td>
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<td>University of Texas at Austin</td>
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<td>Bucknell University</td>
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<td>Saint Louis University</td>
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<tr>
<td>Western New England College</td>
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<tr>
<td>SUNY College of Enviro Science</td>
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<td>Florida Gulf Coast University</td>
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<td>National Univ of Singapore</td>
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<td>Georgia Tech University</td>
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Vision of What Lies Ahead

• 20,000 ‘Grand Challenge engineers’ in the next decade
• A community of like-minded scholars within 5 years – lifelong network they may tap throughout careers
• A step toward transforming engineering higher ed for all students
• Halo effect on global engineering schools, K-12 and others
Announcing a Special Workshop

EDUCATING ENGINEERS TO MEET THE GRAND CHALLENGES

APRIL 30-MAY 1, 2014
National Academy of Engineering
in Washington, D.C.

Leaders of engineering service-learning organizations, associations, industry and academia will gather in the nation’s capitol next spring for a workshop focused on how the U.S. can best prepare future engineers to meet the NAE Grand Challenges for Engineering.

The goal of the workshop is to develop a consortium of 50 universities and organizations committed to incenting students to integrate specific curricular and co-curricular experiences that prepare them to address the Grand Challenges over the course of their careers. Attendance by invitation only.

Learn more at nae.edu/grandchallengesworkshop
US Engineering School Deans’ Response:

• “We the undersigned deans commit to educate a new generation of engineers expressly equipped to meet [grand] societal challenges…

• “We affirm the importance of such aims as a reflection of our core values, as a source of inspiration for drawing a generation to the call of improving the human condition, as a driver for our nation and world economies, and as essential to US and global security, sustainability, health, and joy of living …. 

• “Over the course of the next decade, we commit to graduating from each of our institutions **20 students a year** who are prepared with this unique combination of skills, motivation and leadership to address the Grand Challenges….

Signed by 122 deans across the country
We also commit to development and sharing of open educational resources that will inspire and empower more students to address Grand Challenges.

A measure of success will be the launching of hundreds of successful projects across the nation and globe, each benefiting a community while ultimately leading to solutions for the Grand Challenges themselves.

Over the course of the next decade, we commit to graduating from each of our institutions a minimum of 20 students per year who are prepared with this unique combination of skills, motivation, and leadership to address the Grand Challenges for Engineering of the 21st century. These 10,000 formally recognized “Grand Challenge Engineers” will produce a “bulwark of civic leadership” that benefits the education of all students, engineers and non-engineers alike, and ultimately all people. Like the 700 of ancient Sparta, whose special training and motivation saved a civilization, we envision the power of the 10,000 Grand Challenge Engineers to change the course of our civilization.

Finally, in order to facilitate an exponential expansion of this revolutionary movement in higher education, we are committed to sharing information with each other and the Administration about new and existing initiatives on our campuses in order to nurture development of Grand Challenge Engineers and ultimately address the 21st century’s Grand Challenges for Engineering.

Signed:

Richard A. Behr
Dean, U.A. Whitaker College of Engineering
FLORIDA SOUTHEAST UNIVERSITY

Garry S. May, Dean
Georgia Institute of Technology

Lorraine N. Fleming, Dean
College of Engineering, Architecture and Computer Sciences
HOWARD UNIVERSITY

Richard Plumb
Dean, College of Science and Engineering
LOTOLA MARYMOUNT UNIVERSITY

Richard A. Behr, Dean
Dartmouth School of Engineering
DARTMOUTH COLLEGE

Joseph Blake Hughes, Dean
College of Engineering
DREXEL UNIVERSITY

Thomas Katsoulas
VanK Dean of Engineering
Pratt School of Engineering
DUKE UNIVERSITY

Vincent P. Mann
Provost and Dean of Faculty
FRANKLIN W. OLIN COLLEGE OF ENGINEERING

Kenneth C. Hall, Dean
Voigt School of Engineering
GEORGE MASON UNIVERSITY

Natacha DePaula
Carol and Ed Kaplan Armour
Dean of Engineering
Armour College of Engineering
ILLINOIS INSTITUTE OF TECHNOLOGY

Dr. Robert Kohrolovic, Dean
College of Integrated Science and Engineering
JAMES MADISON UNIVERSITY

Hisham Hegab, Dean
College of Engineering & Science
LOUISIANA TECH UNIVERSITY
EDUCATING ENGINEERS TO MEET THE GRAND CHALLENGES

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College of Engineering
UNIVERSITY OF ARKANSAS

Enrique J. Laverna, Dean
College of Engineering
UNIVERSITY OF CALIFORNIA, DAVIS

Albert R. Jusko, Dean
Irwin and Joan Jacobs
School of Engineering
UNIVERSITY OF CALIFORNIA, SAN DIEGO

Michael Georgiopoulos, Dean
Engineering and Computer Science
UNIVERSITY OF CENTRAL FLORIDA

Rahul B. Varma, Dean
College of Engineering
UNIVERSITY OF DELAWARE

Gary A. Kunc, Dean
College of Engineering and Science
UNIVERSITY OF DETROIT MERCY

Larry Budner, Dean
College of Engineering
UNIVERSITY OF IDAHO

Andreas C. Cangellaris, Dean
College of Engineering
UNIVERSITY OF ILLINOIS AT URBAANA-CHAMPAIGN

Alex B. Scarron, Dean
College of Engineering
UNIVERSITY OF IOWA

Peter K. Kilpatrick
McCluskey Dean of Engineering
College of Engineering and Applied Science
UNIVERSITY OF NOTRE DAME

Peter K. Kilpatrick
UNIVERSITY OF NOTRE DAME

Sara Edwards
EDWARD MARSHALL

Sharon A. Jones, Dean
Shiley School of Engineering
UNIVERSITY OF PORTLAND

Tannis C. Vosko
Zoheib Kribiian Dean of Engineering
USC Viterbi School of Engineering
UNIVERSITY OF SOUTHERN CALIFORNIA

Wayne T. Davis
Wayne T. Davis Endowed
Dean’s Chair in Engineering
College of Engineering
UNIVERSITY OF TENNESSEE, KNOXVILLE

Wayne T. Davis
UNIVERSITY OF TENNESSEE, KNOXVILLE

Sharon L. Wood, Interim Dean
Cockrell School of Engineering
UNIVERSITY OF TEXAS AT AUSTIN

Cristina Amon, Dean
Faculty of Applied Science
UNIVERSITY OF TORONTO

Philippe M. Fauchet
Philippe M. Fauchet, Dean
School of Engineering
VANDERBILT UNIVERSITY

Candis Claiborn, Dean
Vanderbilt College of Engineering
WASHINGTON STATE UNIVERSITY

Ralph S. Quatramo, Dean
School of Engineering and Architecture
WASHINGTON UNIVERSITY IN ST. LOUIS

Zdeno H. Toth, Dean
Leonard C. Nelson College of Engineering and Sciences
WEST VIRGINIA UNIVERSITY

S. Hossein Cheraghi
S. Hossein Cheraghi, Dean
College of Engineering
WESTERN NEW ENGLAND UNIVERSITY

T. Kyle Vanderlick
T. Kyle Vanderlick, Dean
School of Engineering and Applied Science
YALE UNIVERSITY
White House receives commitment letter
March 23, 2015
Global GCSP Movement Beginning

- Global GCSP commitment letter drafted, 2015
- Program elements same as US but different perspectives and motivations
- Early supporters: Senegal, Cuba, Ghana, Nigeria, India, UK, Australia, NZ, UAE...
- Peter Kilpatrick, UND, to lead Global Engineering Deans Council signing campaign In Adelaide, Aus next month
Already ~1000 Engaged Indian Students

- 35% Women
- Rural & Urban
- Wide Range of Universities

**IUCCE-SPEED Workshops 2014:**

8-10 Sep; “21st Century Grand Challenges Faced in Engineering”; R.I.T. College of Engineering, Islampur; [BROCHURE](#)

8-10 Sep; “Engineering Beyond Boundaries”; B.M.S. College of Engineering, Bangalore; [BROCHURE](#)

15-17 Sep; “Engineering Education Without Borders”; Padmashree Dr. D.Y. Patil Institute of Engineering and Technology, Pimpri, Pune; [BROCHURE](#)

15-17 Sep; “21st Century Grand Challenges of Engineering”; Guru Nanak Institutions, Hyderabad; [BROCHURE](#)

15-17 Sep; “21st Century Grand Challenges of Engineering”; S.R. Engineering College, Warangal; [BROCHURE](#)

15-17 Sep; “21st Century Grand Challenges of Engineering”; Vidya Jyothi Institute of Technology, Hyderabad; [BROCHURE](#)

17-19 Sep; Dronacharya Group of Institutions, Greater Noida; [BROCHURE](#)

Courtesy Christina White, NUS/MIT
Tackling Global Challenges and Creating a Better Future

The 2nd Global Grand Challenges Summit

September 15-16, 2015 | 2015年9月15日-16日
Beijing, China | 中国·北京
120 deans coming together for an UG education initiative... **unprecedented**!

=> Something important is happening here
Let’s make it happen together!
Launched at the 2013 Global Grand Challenges Summit in London, the Charles M. Vest NAE Grand Challenges for Engineering™ International Scholarship Program provides a new opportunity for graduate students at selected international universities to pursue research addressing a global Grand Challenge at a leading United States university – with expenses paid for a year of travel and study.

Learn More  Apply  www.vestscholars.org

Scholarship Partners

Duke  California Institute of Technology  IIT Armour College of Engineering  MIT

University of Minnesota  NC State  Olin College of Engineering  USC Viterbi

University of Washington  West Virginia University
"As we think about the challenges ahead, it is important to remember that students are driven by passion, curiosity, engagement, and dreams. Although we cannot know exactly what they should be taught, we can focus on the environment in which they learn and the forces, ideas, inspirations, and empowering situations to which they are exposed."

Charles M. Vest
NAE President 2007-2013
Special Thanks

• Randy Atkins and Dan Mote, NAE
• Yannis Yortsos, USC
• Rick Miller, Olin
• Louis Martin-Vega, NCSU
• Kathy Banks, TAMU
• Joe Hughes, Drexel
• Tom Byers, Stanford
• Wayne Davis, UTenn
• Leah Jamieson and Bill Oakes, Purdue
• Cathy Leslie, EWB
• +Grand Challenge Scholars partner universities:
  – ASU, LaTech, Iowa, Lafayette, Bucknell, W. NE, St. Louis, UT, Utah, Ohio St...
• ASEE Bill Kelly, Jeff Goldberg, Paul Johnson
• AAES
The End Game: Not just education but solutions to Grand Challenges

• Some expected and some unexpected advances since 2007...
Provide Clean Water

Dean Kamen’s Slingshot and Stirling generator

>1,000 liters/day
<.001 cent per liter
Less electricity than a hairdryer
2010: Watson wins on Jeopardy

2013: IBM Watson as an AI Physician
2010: Make Solar Energy Economical

Algae?

May 20, 2010
First synthetic life form

- FUEL
- FOOD
- VACCINES

Algae: 10,000 gal/acre/year

250M Cars \(\Rightarrow\) \(~0.0048\) of US landmass
Carbon Sequestration

• Ca. 2012: Advent of fracking drives down natural gas costs, replaces coal in fixed power generating plants
• C emissions reduced 50% from US electricity
• Can we engineer the environmental risk out of fracking?
Personalized Learning

2011: First MOOC reaches > 100,000

2013

With Duolingo you learn a language for free while helping to translate the web

900,000 learners + Machine Learning → surpassing Rosetta Stone
Engr Tools of Scientific Discovery

Laser and beam-driven plasma wakefields can miniaturize a large particle accelerator:

- **RF structure accelerator**
  \[ \lambda \sim 30\text{cm} \]

- **Plasma wakefield**
  \[ \lambda \sim 100\mu\text{m} \]

0-42 GeV in 3km
42-85 GeV in 1m

Blumenfeld et al, Nature ‘07
Engineering Societies Committed to Educating Engineers to Meet the Grand Challenges
Providing Water in Ugandan Village
Single...
...To multi