Physicists Use Scientific Skills to Improve World Through Jefferson Science Fellowships

By Tawanda W. Johnson

Three physicists are using their scientific skills to improve the world through projects that will benefit energy development in Africa; help educate faith communities about climate change; and boost economic development in Eastern Europe.

Professors Steven Greenbaum, of Hunter College; Alice Bean, of the University of Kansas; and Martin Richardson, of the University of Central Florida – all serve as science and engineering advisors through the Jefferson Science Fellows program run by the National Academy of Sciences and sponsored by the U.S. Department of State, the U.S. Agency for International Development (US-AID) and the physicists’ respective academic institutions.

The program provides 13 science and engineering advisors to the State Department and US-AID for one year. Fellowships are awarded to tenured professors from a broad range of science and engineering disciplines. The fellows’ home institutions pay their salaries as part of the sabbaticals they take from their careers.

Greenbaum works in the State Department’s Global Entrepreneurship Program, coordinates entrepreneurship courses for U.S. foreign service officers: builds networks of U.S. mentors to help developing countries; and helps staff technical working groups for the Poland-U.S. Innovation Program, a bilateral framework for investment in defense, health and energy. “I’m searching for mentors who will work with innovators on renewable energy projects in Africa,” said Greenbaum, whose scientific research involves work with CoSTAR, a robot designed to perform manual tasks.

Richardson, who is the head of the Computational Interaction and Robotics Laboratory at Johns Hopkins University, is using his skills to help foreign service officers in Eastern Europe.

“I’m searching for mentors who will work with innovators on renewable energy projects in Africa,” said Greenbaum, whose scientific research involves work with CoSTAR, a robot designed to perform manual tasks. (Photo by Tawanda W. Johnson/APS)

Scientists Showcase Discoveries During 21st Annual CNSF Exhibit

Nearly 40 universities and scientific associations showcased their research during the 21st Annual Coalition for National Science Funding (CNSF) Exhibition and Reception held on Capitol Hill on April 29. The presentations by universities and scientific institutions reveal discoveries in an array of fields, from a potentially revolutionary way to gauge voter sentiment to algorithms for predicting space weather and the physics of how cells move. The CNSF exhibition and reception annually draws more than 300 attendees, including members of Congress and their staff, congressional committee staff, the leadership of NSF, and representatives from the White House and other policymaking and research agencies.

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APS President Responds to Recently Introduced America COMPETES Bill

The following letter, written by APS President Samuel H. Aronson, was recently sent to House Science Chairman Lamar Smith (R-21st) and Eddie Bernice Johnson, Ranking Member, House Science Committee (D-30th):

Dear Chairman Smith and Ranking Member Johnson,

As president of the American Physical Society (APS) and its more than 50,000 members, I want to express my gratitude for your service as leaders of the House Committee on Science, Space, and Technology. I appreciate your ongoing efforts to raise the visibility of science, to promote the importance of STEM education, and to maintain the United States as a leader in science, technology, and innovation.

While APS thanks the committee for its general support of scientific research – and physics in particular – in the recently proposed America COMPETES Reauthorization Act of 2015, the bill contains numerous elements, both budget-and-policy-related, that raise serious concerns for our organization and its members. These include, but are not limited to:

• Flat funding for NSF’s Education and Human Resources (EHR) accounts, which are responsible for in STEM programs.
• Burdensome regulations for NSF’s large-scale facility management that will lead to higher costs and inefficiencies.
• Steep budget cuts for NSF’s Social, Behavioral, and Economics (SBE) Directorate, DOE’s Energy Efficiency and Renewable Energy (EERE) programs.

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CoSTAR robot performs manual task. Congresswoman Eddie Bernice Johnson (far left) learns about projects in undergraduate math. (Photos courtesy of CNSF)

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What’s New in Innovation?

Getting More Electricity out of Solar Cells

By Nancy W. Staufer

When sunlight shines on today’s solar cells, much of the incoming energy is given off as waste heat rather than electrical current. In a few materials, however, extra energy produces extra electrons—behavior that could significantly increase solar-cell efficiency. A team at a Department of Energy (DOE) Energy Frontier Research Center led by MIT has now identified the mechanism by which that phenomenon happens, yielding new design guidelines for using those special materials to make high-efficiency solar cells. The results are reported in the journal Nature Chemistry by MIT alumni Shane R. Yost and Jie Lu, and dozens of other co-authors, all led by MIT’s Troy Van Vooths, professor of chemistry, and Marc Baldo, professor of electrical engineering.

In traditional solar cells, a photon (a packet of sunlight) delivers energy toward one electron—plus waste heat. A few organic molecules don’t follow that rule. Instead, they generate more than one electron per high-energy photon. That phenomenon—known as singlet exciton fission—was first identified in the 1960s. However, achieving it in a functioning solar cell has proved difficult, and the exact mechanism involved has become the subject of intense controversy in the field.

For the past four years, Van Vooths and Baldo have been pooling their theoretical and experimental expertise to investigate this problem. In 2013, they reported making the first solar cell that gives off extra electrons from high-energy visible light, which makes up almost half the sun’s electromagnetic radiation at the Earth’s surface. According to their estimates, applying their technology as an inexpensive coating on silicon solar cells could increase efficiency by as much as 25 percent.

While that’s encouraging, understanding the mechanism at work would enable them and others to do even better. Exciton fission has now been observed in a variety of materials, all discovered—like the original ones—by chance. “We can’t rationally design materials and devices that take advantage of exciton fission until we understand the fundamental mechanism at work—until we know what the electrons are actually doing,” Van Vooths says. To support his theoretical study of electron behavior within PVs, Van Vooths used experimental data gathered in samples supported by By the U.S. DOE Office of Science. Experimental equipment at the Department of Energy’s Brookhaven National Laboratory and the Cavendish Laboratory at Cambridge University, under the direction of Richard Friend.

“The simple theory proposed decades ago turns out to explain the behavior. The controversy, or ‘exotic,’ mechanisms proposed more recently aren’t required to explain what’s been observed here.”

says Troy Van Vooths.

Van Vooths’ new first-principles formula successfully predicts the fission rate in materials with vastly different structures. In addition, it confirms one and for all that the mechanism is the “classical” one proposed in 1960s: When excess energy is available in materials, an electron at an excited molecule swaps places with an electron in an unexcited molecule nearby. The excited electron brings some energy along and leaves some behind, so that both molecules give off electrons. The result: one photon in, two electrons out. “The simple theory proposed decades ago turns out to explain the behavior,” Van Vooths says. “The controversial, or ‘exotic,’ mechanisms proposed more recently aren’t required to explain what’s been observed here.”

This work was performed in the Center for Excitonics, an Energy Frontier Research Center funded by the U.S. DOE Office of Science. Experimental equipment at the Department of Energy and Physical Sciences Research Council, and work at the Center for Functional Nanomaterials at Brookhaven National Laboratory was also supported by the DOE Office of Science.

—Nancy W. Staufer, MIT Energy Initiative, staufer@MIT.EDU

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APS Members in the Media

The New York Times

“It’s beyond our imagination right now. ’ ’
Xiang Zhang (CA-13th), Uni-

The New York Times

“The hope to see many, many more Higgs we can study in de-
tails.”
Ulrich Heintz; (RI-1st), Brown Un-

The New York Times

“The fact is that Spock was a cool geek... Scientists are not always portrayed as being very strong. Usually, they’re the guy with the tape on their glasses and their pants too high. He was clearly a person who had desirable components beyond just being smart.”
Don Lincoln (IL-14th), Fer-
milah, on the passing of Leonard Nimoy, who played the character Mr. Spock on Star Trek, The New York Times, February 27, 2015.

The Chicago Tribune

You’d need the best equipment, and you’d need everyday to go right, like landing in the ex-
act right spot, but there’s no reason a car couldn’t parachute down and keep right on driving.”
Matthew Kleban (NY-12th), New York University, on the driving physics in the film “Furious 7,” The Chicago Tribune, April 4, 2015.

The New York Times

“This is not built upon trust... This is built upon hard-nosed requirements in terms of limitsa-
tions on what they do, at various timescales, and on the access and transparency.”
Ernest Moniz; (MA-7th), U.S. Department of Energy, speaking to Congress about inspection re-
quirements for Iran in the recent-
ly agreed-upon nuclear frame-

The New York Times

“What I find interesting about this is you’re suddenly talking about your work in a way you’ve never talked about it before.”
Alan Alda (NY-12th), Stony Brook University, on scientists using improv comedy classes to learn how to better communicate their research, The New York Times, March 2, 2015.
By Shannon Palus

Every day, some 60,000 shipborne cargo containers pull into United States ports, and each metallic box is about 2.4 meters by 2.4 meters by 12 meters, which is plenty of space to hide a nuclear bomb, says Aram Danagoulian, a nuclear scientist at MIT. In fact, there are bombs that could blow up several city blocks, and could fit in a back- pack. Danagoulian asks, “How do we detect something so small?”

During the APS April Meeting in Baltimore, MD, Danagoulian presented data from a proof-of-concept demonstration that peers into cargo with beams of gamma rays. Within the decade, he hopes, the method will be used at ports to accurately scan cargo at a rate of about 2 minutes per container. His is just one of the technologies that physicists are developing to prevent the proliferation of nuclear materials, whether through terrorism or war.

It’s been decades since school children were advised to “duck and cover.” Today, we receive alerts from Cold War atomic bombs. According to the National Academy of Engineering (NAE), preventing nuclear terrorism is still an important goal, and the NAE put it on the list of 14 Grand Challenges of Engineering to be solved in this century:

“Peaceful energy programs could mutate into weapons programs,” says Danagoulian. “You could use a reactor for synthesizing plutonium, and [make] a weapon out of that.” Also, weapons can be stolen from existing stockpiles: there are 17,000 people in the arsenals of Russia and the U.S.

Today, port inspectors use passive methods to detect nuclear contraband, like looking for radiation coming from a container. That is easy to block with lead if the smuggler has any competence, says Danagoulian. Inspectors also use broadband X-ray beams, ranging in photon energy from 1-6 MeV (million electron volts), to gauge the density of the material inside the container. But when used to discern the atomic number, the method is inefficient, and requires a higher dose to work.

In Danagoulian’s cargo interrogation method — 10 times as efficient as the broadband method — two monochromatic gamma-ray beams, one at 4.4 MeV and at 15.1 MeV, pass through a container to a detector on the other side. The flux of the 4.4 MeV beam through the container reveals the density of the material; combined with the 15.1 MeV flux, the method also yields information on the atomic number, Z, expressive of the number of protons in an atomic nucleus.

Danagoulian has completed a proof-of-concept test of the technique with several materials, from almonds to iron to cobalt; he says, “But, lead is not plutonium, which is hard to get, even for a scientist studying how to stop it from spreading. The data clearly show that as Z increases, the number of photons that go through the container decreases.

But his system alone isn’t enough to conclusively determine what’s inside the container. “If you start mixing materials, you are going to measure the effective Z,” says Danagoulian. Adding low-Z materials to a container with plutonium could throw off the system.

When it comes to capturing a warhead, or the material for one, “There is no silver bullet,” says Danagoulian. Ultimately, he envisions a combination of methods employed at ports, the data from each utilized in a decision-making algorithm. And the methods work for catching more ballistic contraband, too. Coffee importers smuggling beans to avoid import taxes may not be as threatening of a scenario, but it’s one customs agents are more likely to see on a regular basis.

This story was previously published in APS News.
Since our founding fathers broke away from the crown and forged a new nation over 200 years ago, the world has always looked to the United States as a guiding light. They have looked, not just to our democratic ideals, but to our role as innovators in science and technology. But in the increasingly competitive global economy, our light is starting to dim.

The greatest long-term threat our country faces – on both the military and economic fronts – is the threat of losing our role as world leaders in innovation in science and technology.

Without appropriate support for basic science research, it is very likely that the next big innovations, and the jobs they create, will occur overseas.

For the last century, the majority of major technological breakthroughs – including the Internet, GPS, passenger jet planes, and medical imaging technology – were driven by federally supported research. Our nation’s ability to innovate was a cornerstone of our status as a world economic superpower. In fact, since World War II, over half of U.S. economic growth has been driven by science and technology.

Despite the invaluable return we have seen in the past, federal investments in research and development are at a historic low, comprising merely 3.8 percent of the federal budget and 0.8 percent of GDP.

According to estimates by the American Association for the Advancement of Science, from 2010 to 2013, federal research and development was cut by 16.3 percent, the fastest decline in a three-year period since the Space Race ended. Sequestration alone will lead to an average annual cut of $11.5 billion in federal funding, bringing it to the lowest levels in over a decade.

These cuts have an immediate impact on current research, and they discourage the best and the brightest from entering careers in research and development. Those effects may not be felt yet, but the impact on our long-term competitiveness will be devastating.

Study after study has shown that federal funding of research has a high return on investment. By underfunding basic science research, the U.S. is slowly chipping away at our global competitiveness.

From 2001-2011, the National Science Board indicates that the percentage of global R&D invested by the U.S. shrunk from 37 percent to under 30 percent, while Asia inched forward, now accounting for the top quark, the heaviest known form of matter. He also led the teams that designed and built several scientific facilities and detectors still in use today, including the Recycler Ring, the latest of Fermilab’s giant particle accelerators.

Foster lives in Naperville with his wife Aesook Byon, who is also a physicist. His father was a civil rights lawyer and his younger brother co-founded Electronic Theatre Controls, Inc., a company that now manufactures over half of the theater lighting equipment in the United States.

We cannot retreat and stop investing in American innovation. We need to maintain a competitive advantage now more than ever. As Congress crafts future budgets, it is critical to remember what is at stake.

While investing in research and development is critical, the rhetoric coming from our leaders also plays an important role in maintaining America’s global scientific leadership. As leaders, it is our duty to inform the public of the truth. For those of us with scientific and medical backgrounds, this duty falls even more seriously.

We recently saw the real and dangerous consequences of false rhetoric. By 2000, the United States had effectively eliminated endemic measles, an effort 40 years in the making. But all of that progress is quickly coming undone, not by an act of nature, but by willful ignorance.

Last year, there were 644 cases of measles in the United States – the highest number in 20 years – and already this year, there have been 159 cases in 18 states, including my home state of Illinois.

Congressman Bill Foster is a scientist and businessman representing the 11th Congressional District of Illinois. Foster is the only physicist in Congress. He is also a member of the Committee on Science, Space, and Technology. Foster participated in the creation of several important reforms in the financial services and housing sectors, most notably the Dodd-Frank Wall Street Reform and Consumer Protection Act.

Foster’s business career began at age 19 when he and his younger brother co-founded Electronic Theatre Controls, Inc., a company that now manufactures over half of the theater lighting equipment in the United States.

His scientific career was as a high-energy physicist and particle accelerator designer at Fermi National Accelerator Laboratory. Foster was a member of the team that discovered the top quark, the heaviest known form of matter. He also led the teams that designed and built several scientific facilities and detectors still in use today, including the Recycler Ring, the latest of Fermilab’s giant particle accelerators.

Foster lives in Naperville with his wife Aesook Byon, who is also a physicist. His father was a civil rights lawyer who wrote much of the enforcement language behind the Civil Rights Act of 1964.