Manufacturing Revolution May Mean Trouble for National Security

By Michael Lucibella

APS March Meeting 2015, San Antonio — Additive manufacturing, more popularly known as 3D printing, could be the future of industrial manufacturing while possibly undercutting national security, experts said at the APS March Meeting 2015. This technology was the central focus of several of the industrial physics sessions, highlighting both its commercial promise as well as its policy implications. “The early promise of the technology has been demonstrated,” said Prabhjot Singh, manager of General Electric’s Additive Manufacturing Lab. But the same aspects that make the technology enticing for industry — its flexibility, low cost, minimal waste, and small footprint — make it potentially dangerous for global security. The streamlined manufacturing processes that can print a car’s exhaust manifold can just as easily be used to surreptitiously manufacture weapons, researchers warn.

“This is an emergent, latent, and disruptive technology for issues related to national security,” said Bruce Goodwin, associate director at large for national security policy and research at Lawrence Livermore National Laboratory. “Additive manufacturing changes everything, including defense matters.”

Additive manufacturing is a general term for a range of technologies that stack thin layers to produce an object. Though there is a variety of methods, generally a nozzle scans a surface, following instructions in a 3D “build” file, and squirts out a micron-thick filament as it builds up the object. Plastics were some of the first materials available, but recent developments opened up the process to a range of metals and ceramics as well.

In contrast, traditional subtractive manufacturing uses computer-controlled machines to carve out a part of raw material. By working from the ground up, additive manufacturing can build solid shapes that were impossible with older manufacturing methods, while almost totally eliminating waste.

Though originally promoted as a means for rapidly prototyping products, 3D-printers are now producing the products themselves. Enterprises both large and small are now directly marketing 3D-printed products to consumers.

One of the fastest growing markets is fulfilling orders for obscure parts that have been uncommercial to mass-produce using traditional machining. “[The] worldwide prototyping market is limited, but the important thing is manufacturing,” said Michael Cima of MIT. “The entire system was commercialized because there was a quick way to make a few key parts.”

With some improvement, the largely-automated technology promises to shrink the footprint of manufacturing. Entire machine shops staffed by a multitude of specialists could be reduced to a couple of machines overseen by a few technicians.

Breeding a Better Robot

By Shannon Palus

APS March Meeting 2015 — Today, true artificial intelligence proliferates only in fiction. At the APS March Meeting 2015, robotics researchers debated how we’ll achieve smart robots in real life — and what we’ll do with them when we get them.

There are robots that can vacuum floors, robots that beat world-class talent at chess and Go, and even robots that are capable of driving a car. These are examples of what Michigan State University computational biologist Chris Adami calls “special-purpose intelligence”: robots that do just one complicated thing well, but not much more. Case in point: You wouldn’t want a Roomba behind the wheel.

Currently, computers have trouble recognizing faces and learning spoken languages, both skills that infant humans quickly acquire. Babies learn by exploring their world: as they wave their arms and legs around, they receive feedback as they find some movements more pleasurable than others. They take in that sensory information through a wide variety of senses that link it via synapses with different neurons that control motor actions.

Artificial neural networks that work in a similar way have been around for decades, with varying results. But a new piece of hardware, presented by Seyoung Kim of the IBM T. J. Watson Research Center, would make artificial neural networks smaller and more efficient than past versions, which have required multiple digital gates and control circuits to mimic synapses.

The IBM device is a semi-conductor with two electrodes sandwiching a metal oxide. Put

New Director of ARPA-E on Transformative Technology

On December 8, 2014, Ellen Williams was confirmed as the director of the U.S. Department of Energy’s Advanced Research Projects Agency—Energy (ARPA-E). She received her Ph.D. in chemistry from the California Institute of Technology, and previously served as the senior advisor to the director of energy and as the chief scientist for BP. She is currently on a leave of absence from the University of Maryland, where she is a distinguished university professor in the Department of Physics. Alaina G. Levine interviewed Ellen Williams for APS News to discuss goals for her new job and what lies ahead. The full version of this edited interview is online.

AGL: I’d like to ask you about your physics background and why you chose physics in the first place. How has physics helped you in your career?

EW: To a certain extent, I would say that I didn’t actually choose physics. I think physics chose me. I don’t have a degree in physics. My undergraduate and graduate degrees are in chemistry. When I was in graduate school, I was very interested in some problems in physics, so when I graduated, I took a position in a physics department. The physical chemistry discipline and the physics discipline aren’t so different that that’s impossible to do, but it’s not that easy either. But physics is a great background. The rigor and the discipline of physics and the skepticism that you have to bring to your discipline have been incredibly important to me all throughout my career.

AGL: It’s interesting that your background is chemistry but you identify yourself as a physicist. So far in your career, the physics you’ve been most excited about?

EW: A big accomplishment for me was pulling together an interdisciplinary team to form the Materials Research Center at the University of Maryland. That was both an accomplishment, and very much represents a way of doing science and a way of thinking about research that I think is crucial for
director continued on page 6

Ellen Williams

The world’s first 3D-printed car is an example of the dramatic changes in manufacturing.

At the APS March Meeting 2015 researchers showed how origami can inspire new devices. A group at Leiden University reported that 2D panels joined along fold lines (top) can pop in and out of stable 3D configurations. A similar toggle effect was seen with joined tiles (middle). A team at the Wyss Institute (Harvard University) used a square-twist pattern to create structural toggle switches in paper (bottom) and in microscopic gel sheets that are actuated by temperature changes.
This Month in Physics History

April 28, 1926: Schroedinger Describes “Wave Mechanics” in Letter to Einstein

S
EIN ISAAC NEWTON ushered in a new era in physics when he devised his universal law of gravity and equations of motion. Three hundred years after Newton’s death, Erwin Schroedinger made a similar contribution with an equation that is the quantum equivalent to the classical laws of motion and conservation of energy in classical physics.

Schroedinger was the only child of Rudolf Schmidt and Helene, a prosperous oilcloth factory, whose financial independence enabled him to pursue scientific interests in chemistry and botany. Other than a part-time tutor, young Erwin received most of his early education from his father, before matriculating at an academic gymnasium in Vienna (the equivalent of a prep school in the U.S.). He loved math and physics but also appreciated German poetry and the theater, although literary criticism and romemorization of historical facts bored him. He continued his studies at the University of Vienna, where he first attended lectures in theoretical physics by Friedrich Hasenbohm, who became his thesis advisor.

In learning his doctorate in 1910, Schroedinger worked in a laboratory for Franz Exner in Vienna, supervising the large lab corforce and considered to be invaluable experimental skills in the process. He served in World War I, keeping up with physics in the remote areas where he was stationed on the Italian front. He moved around a great deal for much of his early career, partly because of the political turmoil. By 1921, he was at the University of Zurich until he replaced Max Planck as a professor at the Friedrich Wilhelm University in Berlin six years later.

Quantum mechanics was still in its infancy, but developing rapidly. In November 1924, Louis de Broglie defended his doctoral dissertation, postulating that not just light, but matter, evinced particle-wave duality. Schroedinger heard of the breakthrough while reading one of Einstein’s papers (Einstein learned of it from Paul Langevin), and was intrigued by the concept of these so-called de Broglie waves.

Schroedinger had never much cared for Bohr’s model of the atom, and a footnote in Einstein’s paper inspired him to model the motion of an electron around a nucleus as a wave rather than an orbiting particle. In 1925, Schroedinger was stymied in his attempt, and decided to spend some time in seclusion at a mountain cabin in Arosa, Switzerland, accompanied by one of his mistresses. Romantic seclusion did the trick: He cracked the enigmatic equation in January 1926, and then he published his wave equation for a hydrogen-like atom and also a series in Einstein on April 28, 1926: “This whole conception falls entirely within the framework of “wave mechanics”; it is simply the motion of electrons in space, that of the gas instead of the atom or the oscillator.” Einstein responded with much enthusiasm. He was not alone: Schroedinger’s wave equation is considered one of the most important equations of the 20th century, complementing rather than contradicting the matrix model developed by Werner Heisenberg around the same time. (Bohr’s approach was easier to adopt, in fact, because it was familiar to most physicists.)

That said, he never fully reconciled his work on quantum mechanics with its philosophical implications, which he found deeply unsatisfying. The Schroedinger equation expresses the wave function of a quantum system and how it changes dynamically over time, but it doesn’t define what a wave function actually is. The equation is not strictly deterministic; it predicts a probabilistic distribution of likely outcomes. “I am amazed at the movement around a nucleus as a wave rather than an orbiting particle,” Schroedinger said in his Nobel Lecture. “The Nazis rose to power in Germany in 1933, and like many scholars of that era, Schroedinger was deeply disturbed by the purging of Jewish intellectuals from the universities. He opted to leave Germany for Oxford University in England. Within a week of his arrival, he learned he had won the 1933 Nobel Prize in physics, along with Paul Dirac, who devised his own equation to incorporate electron spin, a largely new concept at the time. He should have heralded a long- overdue period of professional stature, but rumors soon spread about Schroedinger’s unconventional domestic situation: an open marriage with wife, Anny, and a son by his mistress, the wife of another colleague which Schroedinger declined, perhaps because there were similar reservations about his desire to bring both wife and mistress to the U.S. Fortunately, his physics research continued to be of the highest caliber despite his professional upheaval: He came up with his famous paradoxical thought experiment, Schroedinger’s cat, during this period.

In 1938, the Nazis annexed Austria within two years, and he found SCHROEDINGER continued on page 3

Erwin Schroedinger

Advisors from other societies (non-voting)
H. Edward Dollar, APS-MIT Undergraduate Physics Mentorship Program

International Advisors (non-voting)
Albert J. Sutcliffe, AIP Committee on Associate Physicians

Self-Representation
Tracy Morgan, Division, Forum on International Physics (Forum on International Physics)

Internal Officers
Barbara Bennett, Co-Chair, Division, Forum and Section Councilors

Compliance
Michael Stephens, Director, Journal Operations

Conflict of Interest
Lori E. Lipke, Director, Journal Operations

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Erwin Schrödinger (1887-1961) was an Austrian physicist who made groundbreaking contributions to quantum mechanics, molecular biology, cosmology, and philosophy. His most famous work is the wave function, which he used to describe the behavior of particles at the quantum level. He also contributed to the development of quantum electrodynamics and the theory of solitons. Schrödinger's work has had a profound impact on modern physics and the development of quantum mechanics.
Register by May 5 for the 2015 Physics Department Chairs Conference

APS and the American Association of Physics Teachers are pleased to announce the 2015 Physics Department Chairs Conference will be held June 5-7, 2015, at the American Center for Physics in College Park, MD. Registration opens in February. For more, see www.aps.org/programs/education/conferences/chairs/

SCHROEDINGER continued from page 2

Planning Africa’s First Synchrotron

By Michael Lucibella

APS March Meeting 2015

San Antonio — Africa may get its first synchrotron sometime in the next ten to fifteen years, joining other nations that seek to bolster their scientific and technological development. At this year’s March Meeting, experts highlighted how scientists from across Africa and around the world are working to build the first such source on the African continent.

The project is still in its early phases, but scientists from South Africa, Nigeria, and other nations have signed on. After convening an interim steering committee in August of last year, they announced that a major planning workshop will be held in November at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France.

The organization for the proposed African Light Source is patterned after the international collaboration building a third-generation synchrotron in Jordan: The Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME). A collaboration among nine member states to build a third-generation accelerator facility under the auspices of UNESCO.

A February 2015 article for [The African Light Source?] is really the SESAME project, which itself is modeled on CERN,” said Her- man Winick, professor emeritus at the SLAC National Accelerator Laboratory.

Winick was instrumental in getting SESAME off the ground, and he is now working with the newly-formed steering committee to do the same in Africa. He added that the demand for a user facility is there. South Africa recently signed on to ESRF as a member state, to build a third-generation accelerator facility under the auspices of UNESCO.

The local light source has been a big boost to the scientific infrastructure in Brazil, helping to make the state of Sao Paulo the scientific powerhouse of the continent. Three other labs, devoted to nanotechnology, microbiology and bioethanol research, have been built on the same campus as the synchrotron.

“Our major effort throughout these few years is to attract more use of such facilities, so dedicated, motivated African scientists can work on biomedi- cal [and] environmental problems that are of particular interest to that region.”

He added also that the team was hoping to construct the finished accelerator within ten to fifteen years.

Synchrotron facilities are both a hallmark of national develop- ment and a catalyst for it. Around the world, many countries are ramping up their science programs build such machines to boost sci- ence and industry at home and keep their best-trained researchers from emigrating.

“Even a smaller level of investment in research assistants, misleading research assistants, mislead- ing financial exiles once again, despite a desperate attempt to appease the Nazi regime by recant- ing former opposition — an act that earned the rancor of many of his colleagues, including Einstein. Schroedinger later apologized for his colleagues, including Einstein.

“Einstein... generously in every respect,” he later recalled, “and thus my aca- demic career ended happily at the same Physics Institute where it had begun.” He died on January 4, 1961, of the tuberculosis that had plagued him for much of his life.

Further Reading


South Korea also were losing many talented young scientists to institu- tions abroad.

“Taiwan, Korea [and] Brazil started their discussions about national light sources in the 1980s,” Winick said, referring to facilities that became operational in the 1990s. “In the time since then ... they’ve trained hundreds of Ph.D.s locally without losing them. They’ve attracted dozens of mid-career people to return.”

Irish and Turkey are currently designing and building their own national light sources. Even though both nations are members of the SESAME collaboration, the capabilities of the respective light sources were not in the same league as the capabilities of the Brazilian-based machines.

Since its announcement in 2010, engineers working on the Iranian Light Source Facility completed a detailed plan and built a number of prototypes for nearly every major component of the injector and stor- age rings. The synchrotron will be located at the Imam Khomeini Science and Technology Park in Qazvin province. The original plan was to have the facility online by 2018, but the schedule has since slipped.

The Turkish Accelerator Center announced in 2009 that it is cur- rently working on building the first of its three planned projects. The DARLA electron laser is slated for completion in 2016, while the second phase of the project, the planned ion-laser-based synchrotron, is still in the design phase.

“The community of users that need these machines is growing more rapidly than the available facilities and beamlines, so we need SESAME.” Winick said. “We need an African Light Source and we need more national light sources.”

Self-organized explanation of French physicist Paul Langevin, who suggested the idea of a synchrotron in 1927, and Einstein’s famous paper of 1905 on the photoelectric effect were among the first to describe how the new device could work.

In the late 1920s, researchers in Europe and the United States started designs for large-scale devices. The world’s first successful synchrotron was built in 1942 in the United States by V. L. Weisskopf and Robert Serber. It was designed to study the interaction of protons and neutrons and was used to produce the first artificial radioactive nucleus.

By Michael Lucibella

A committee of the National Academies is preparing a report that will take a tougher stance on research misconduct. The committee will focus on attacking the institutional environment that often leads to it. The report, a draft of which was broadly adopted by the federal government in 2000. It also highlighted other “questionable research practices” that didn’t amount to outright fraud but skirted the line of propriety. These include authorship abuses, exploit- ing research assistants, misleadingly statistical analyses, and withholding data, all of which fall short of falsification and fabrication.

“We suggest they be renamed ‘detrimental research practices,’ that we don’t equivocate on that issue, and don’t suggest that by ‘questionable’ they might be ok,” said Paul Wolpe of Emory Univer- sity. “We want to take a stand and say no, let’s call them ‘detrimental research practices’ because we don’t want there to be any question about how we consider them and the damage that they do to science as an enterprise.”

Committee members are hoping

National Academies Studies Institutional Influences on Ethics

Education Corner

AP NEWS online: www.aps.org/publications/apsnews
Physicists Look at Animal Behavior

By Shannon Palus

APS March Meeting 2015 — How do you get physicists at a cocktail party? What do they wear to work, and what do they do when they are stuck in a state of maleness? A previous study showed that the presence of other people — an equivalent of what Potvin calls “recognition beliefs” — was the number one predictor to whether or not a student, of any gender, would feel that she could succeed. If others can come from teachers or peers, it can be as simple as an acknowledgment of a strong performance in a lab or an exam. That praise needs to accumulate to translate to a strong sense of confidence. Based on the March Meeting survey, University physics education researcher Vashti Sawtelle remarked, "It is insufficient to have one positive experience. Sawtelle offered the session’s refrain: “The data that I have is sad.”

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**Policy Update**

**President’s Budget Request**

The President released his Fiscal Year 2016 (FY16) budget request (PBR) on February 2nd, 2015. In some members of Congress were already criticizing the request before it was officially released. As a start to negotiations, however, the President’s budget request (PBR) made clear that the Administration prioritizes biomedicine, energy efficiency, climate change, advanced manufacturing, and science, technology, engineering, and mathematics (STEM) education.

For instance, the PBR proposes funding the Department of Energy Office of Science (DOE) at $5.34B (+3.1%), which, Energy Sciences would receive a 10.1% cut, whereas Advanced Scientific Computing Research would receive a 14.7% increase (part of which would be devoted to brain-computer interface research). Energy Efficiency and Renewables a 41.7% increase, and the Advanced Research Projects Agency-Energy a 16.1% increase.

The PBR for the National Science Foundation (NSF) reflects the same priorities. Proposed NSF funding is $7.7B (+5.1%). The Education and Human Resources directorate would receive the largest increase at 11.1%, whereas the Mathematics and Physical Sciences (MPS) directorate would see an increase of 2.2%. Within MPS, Physics would receive a boost of 10.0%, while Astronomy would rise by 1.0%, and Materials Research would rise by 3.0%.

The Department of Defense Basic Research (D.1) account would be cut 7.9% in the PBR, whereas the Applied Research (D.2) account would receive a 2.1% increase. The National Science Institutes and Centers (NIC) would receive $1.12B (+29.6%), with the Science and Technical Research Services account increasing by 11.7%. NASA Science would receive $5.29B (+9.9%) and the James Webb Space Telescope would receive $694M (+35%). The National Institutes of Health would be funded at $31.3B (+3.3%), with much of the increase going toward the President’s precision medicine initiative.

Congressional budgets are expected to adhere to the strict caps set forth by the Budget Control Act of 2011. These caps are $71B below the PBR, split evenly between defense and non-defense.

**Chairman Smith and the National Science Foundation**

Since taking up the gavel as chair of the House Committee on Science, Space, and Technology, Rep. Lamar Smith (R-Tex.) has consistently attacked what he sees as wasteful spending at NSF. Chairman Smith has on multiple occasions tried to advance legislation opposed by the scientific community, such as the High Quality Research Act and the Frontiers in Innovation, Research, Science, and Technology (FIRST) Act.

While no legislation has passed, the NSF has reacted to Mr. Smith with a series of reforms including the most recent: requiring each grant funded by the NSF to be verified to be in the national interest. APS remains concerned that such a provision might at best be a meaningless waste of time as a checked box and, at worst, limit flexibility to pursue the most interesting scientific leads during a research project. Such flexibility has been a hallmark of NSF and a distinguishing feature of grants as opposed to contracts.

**Upcoming Legislation**

Work on the Elementary and Secondary Education Act (ESEA) continues, with both parties support the bill is finished. Sen. Alexander’s (R-Tenn.) office released a draft version of ESEA for a public comment period, which has since closed. The draft version of the bill places excessive responsibility for achievement from federal to state government. After the public comment period closed, staff from both the majority and minority have been working to refine the draft and meet stakeholder input. Expectations for passage this year remain high.

**Washington Office Activities**

**Media Update**

Science Magazine and Chemistry World recently published stories about two prominent physicists on faculty at Siena College for- mally joining APS. APS Director of Public Affairs Michael S. Lubell and Tom Culligan, vice president of the Tri-Biomey Group, developed the idea. The stories can be read at the following URLs: http://bit. ly/1MoAudc and http://sci.18D0KX7/.

**Panel on Public Affairs**

The draft statement on Earth’s Changing Climate, described in the insert of this issue of APS News, is open to the APS membership for comment. Please check your email for a link to the statement and the comment site.

**Dispatch continued on page 7**

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**Solo Physicist in Congress Prepares to Defend Science**

By Michael Lucibella

A new policy of the National Science Foundation (NSF) might settle the ongoing feud between the funding agency and the House of Representatives Science Committee over Congressional oversight of its grant-award process. In December 2014, the National Science Foundation declined to comment for this article.

Tensions between the committee and NSF have been simmering since March 2013, when the Republican-led committee started requesting NSF documents about its grant review process. 

Chairman Smith called a number of the awards “questionable,” and his requests focused primarily on grants from the Directorate for Social, Behavioral, and Economic Sciences, as well as grants related to climate change.

More recently, the committee seemed to have expanded the scope of its inquiries. The committee’s latest request for information targets more physical science, math, and engineering grants than before.

In mid-February, the committee requested information about the grant review process for 13 grants from across the foundation’s program directorates.

In addition to grants about climate change, the most recent group of targeted grants includes research about the impact of protecting the military against cyber attacks, detecting malware, and mitigating the effect of space weather on the global power grid.

According to a committee aide who asked not to be identified, the grants shouldn’t necessarily be considered “questionable” just because the committee requested more information on it. He said the committee was simply exploring the use of information requested in order to get a better handle on the more technical grants.

Because composition of an understandable, non-technical description may be more difficult for complex projects and perhaps particularly difficult for some projects in the physical sciences, the committee wanted to look at complex projects from each NSF research directorate, the aide said in an email.

Allan Weatherwax, a plasma physicist at Siena College in New York, finds this explanation plausible. He said that if he were to put together a cross-section of NSF grants in each directorate that is different from what the committee selected, “It’s an eclectic list,” Weatherwax said. “I looked at them and I saw no common theme in the proposals.”

This is one of the proposals that the committee is currently reviewing. He researches Earth’s magnetic fields around the poles and how the aurora can sometimes disrupt GPS systems. Despite the surprise to hear that his grant was being reviewed, he’s not concerned about the inquiry or any potential effects on his reputation. “I’m using taxpayers’ dollars, and I think our work is outstanding,” Weatherwax said. “It’s [Congress’s] prerogative to review our work.”

Accused of political attacks on the science community, Weatherwax said. “It’s [Congress’s] prerogative to review our work.”

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**NSF and Congress Seek Rapprochement**

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**Ukraine continued from page 4**

CRDF Global is consolidating funding from several U.S. and European foundations for support scientists in Ukraine. Among their many efforts, they are working to identify an unknown object at the bottom of the sea. They also offer moral assistance by reaching out and making contact with Ukrainian colleagues. You can do this by sending a message to the UPS office (ukr@crdfglobal.org) or individually if you have friends there. The UPS has organized a task force to provide assistance to the displaced physicists. Additionally, many Ukrainian scientists have recently immigrated to the U.S., including you, if you're underground. Some Ukrainian scientists have been granted asylum and are currently in the U.S.

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**Bill Foster**

Bill Foster is an experimental physicist at Fermilab and has been the lab’s director for more than twenty years. He helped design particle accelerators and was a part of the team that discovered the top quark in 1995.
REVOLUTION continued from page 1

tric is aggressively pushing the technology into its manufacturing lines. We are seeing the leap into industrial additive manufacturing," Singh said. "We are starting three new facilities in the industrial use of these technologies."

Medical applications are also just starting to appear. Creating custom implants and prosthetics for patients could potentially revolu-
tionize medical treatments. Such 3D-printed body parts are subject to the same U.S. Food and Drug Administration (FDA) regulations as devices manufactured through traditional means. Since more than 70 applications have been approved, including skull plates, spinaltrusses and even whole jaw
bone replacements.

The portability of smaller 3D printers, some not much bigger than a microwave oven, could help bring advanced treatments to areas un-
served by the healthcare system. "Think of what that might mean for mobile hospitals, for example," said Katherine Vorvolakos, a chemical
engineer at the FDA. "Production can happen anywhere."

However, she emphasized that shrinking the footprint of manufac-
turing has a dark side, one with potentially global ramifications. "I would say that at the moment it is that it could dramatically increase [nuclear] proliferation and make it harder to track those who have it."

Nonproliferation monitors have long used the large scale of the nuclear weapons industry to track proliferation — but now they might not only do the nuclear facilities themselves take up large areas and resources, but the manufacturing efforts to build bomb parts do as well. "Waste stream elimination eliminates one of the major indica-
tors and warnings of proliferation," Goodwin said.

Advances in metal printing techniques like direct-metal-laser sintering could be used to fabri-
cate a variety of weapons. Goodwin highlighted an instance where he downloaded from the Web the build file for an unnamed part to a nuclear reactor and printed it out. Using
traditional fabrication methods, the part would have required 168 weds alone to build it. Using a 3D printer, the part could be built in less than four hours, Goodwin said. "In 15 years, this will be a nightmare."

This has significant implica-
tions for the control of conventional nuclear materials. "I have heard tales of hand-
guns made headlines already, but Goodwin said that the problem could be bigger. General Electric routinely prints space-grade components for jet engines, a technology that could potentially be adopted to produce the parts to build whole jet fighter planes."

He added that digital build files, the essential data telling printers how to construct an object, shifts the problem of import control into the cyber realm, an altogether more

EW: The results were that when you're trying to [solve] something — say a nuclear [explosion] — you can detect tests at different levels with different lev-
els of confidence. So if someone is doing a test at the large scale, which might be necessary to create a highly advanced type of nuclear weapon, we believe that would be detectible. But it's not very crude development, it's a very simple nuclear weapon, that might not detectible. It's much more important that the understanding of what we're looking for and what the risks are in the near term, the meaning of detection was.

AGL: What are you excited about in ARPA-E? What are the important projects that you and your team are working on?

EW: I'm excited about ARPA-E because of the sort of innovation that it allows and the challenge of the problems that we're trying to solve. The whole energy challenge is so important to society.

AGL: Is there a particular model for ARPA-E, because of the real poten-
tial for impact. The unique thing about ARPA-E is that we combine technical innovation with really a cold eye, razor-sharp focus on making sure that the technolo-
gies work in the real world, really the path to being competitive in the marketplace. And that's what makes ARPA-E different and it's going to allow us to be continuously expanding impact.

AGL: What are the transfor-
mative breakthroughs that are at play in energy research at the moment that will have or could have the biggest impact, and how is ARPA-
E helping with that role?

EW: I think heat capture is huge. We waste so much of our energy having it go off as heat. Energy storage — that one is again, a huge issue for stabilizing the grid, allowing distributive generation, allowing more integration of renewable energy resources. It's interesting that when people tend to think of energy storage, they think about batteries, but we believe that a lot in batteries, but batteries is not the only approach. In the end, we're not going to be the ones who will discover the answer to the implementation in the world, what we're going to do is put the techni-
cal solutions to the people who then will then be available to see what the best fit is for the needs and politics of the future.

EW: How is your energy research changing, and how is ARPA-E helping to facilitate that?

EW: I would say that at the mountain view, energy research is changing by [having] a much greater focus on the all different aspects of the energy system. How [everything] works together is the great challenge. Another is the path to being competitive, the path to being detectable. If someone was doing

A-G: What were the results?

EW: The downside of this is that it could essentially eliminate the use of trade sanctions for foreign policy," Goodwin said.

So far, no one has demonstrated a way to 3D-print fissile materials. "I think there are far fewer people involved than you might think," Goodwin said. "[But], I think you have to assume that any system of control is going to break down."
to perform a cleansing ceremony that identity came in her interaction with the group. One leader told her: “People don’t have a good physicist entails performing a revision of the APS Statement on Civic Engagement and teachers in the classroom, women-scientist guest speakers, role models, and discussions of the problem. Discussing — which clumps together — is more difficult. Georgia Institute of Technology physicist Daniel Goldman — which clumps together — is more difficult. Georgia Institute of Technology physicist Daniel Goldman defined it themselves at some point during their career. “That is implying a much higher rate of scientific misconduct than we normally appreciate,” Wolpe said. In addition, the number and rate of retractions has been rising over the last two decades as well. “It might be heartening because what it might mean is not more misconduct, but more vigilance, and lets hope that is in fact what we are seeing,” Wolpe said. The committee is in part drawing on current social psychology research that looks at the motivations for improper behavior. Their approach puts a new emphasis on the influence that an institutional environment can have on a person’s actions. “As we learn more, all the time, about the cognitive biases, the fallacies, the pressures, the incentives, and in particular the environments in which we operate, it means that we have to think a little differently about how we protect ourselves against the errors to which we are all prone,” said Kristina Gunalas of the National Center for Professional and Research Ethics. She added that individuals tend to give into temptation when they and their peer groups are overly ambitious, promote a sense of entitlement, or work in obtuse systems with inefficient rules. “The amount of cheating which humans are willing to engage in depends on the structure of our daily environment,” Gunalas said. “It is always possible to rationalize some- thing scummy you want to do.” The committee hopes that by highlighting these root causes and laying the groundwork for an effort at research institutions to identify and address problems in their working atmosphere. “Either the scientific community [and the research community] address these problems, or the government will,” Nerem said. “Government intervention in my opinion would not be desirable, and I suspect that’s true of everybody in this room.”
In August 2014, I attended the 5th IUPAP International Conference on Women in Physics (ICWIP 2014) in Waterloo, Canada as part of the U.S. delegation. This conference was attended by approximately 215 female physicists and a few male physicists, all from 49 different countries. There were research talks, panels, workshops, breakout sessions and posters on issues related to gender diversity in physics. A major focus of the conference was to address the many barriers that uniquely affect the advancement of women in physics worldwide. Barriers that were listed in the country reports included societal biases affecting women and accumulating over time from as early as gender, unconscious gender bias, and the effects of stereotypes. Also contributing are family responsibilities, unfriendly and unsupportive environments in physics departments, lack of mentoring, lack of a critical mass of women in physics, and some women are impacted so much that they even start questioning their own ability to ever be equal to or better than men in STEM fields.

In some countries such as the US, when women did not number in women's places and roles, people often attribute it to their poor abilities; but when men do not succeed, people often attribute it to their lack of effort or poor teaching, but not to their lack of ability.

Societal biases related to women not being smart enough to pursue careers in male-dominated STEM fields can impact women’s beliefs about their own capability and negatively influence whether women pursue STEM majors and how they perform in STEM courses. In some countries like the U.S. many tend to step away, often because they unwittingly conform to societal gender stereotypes. Women in some countries like the U.S. are often victims of gender stereotypes from very early on, and some women are impacted so much that they even start questioning their own ability to ever be equal to or better than men in STEM fields.

Regardless of the country, the common theme at the conference was that women are highly underrepresented in leadership positions and decision-making roles.

Regardless of the country, the common theme at the conference was that women are highly underrepresented in leadership positions and decision-making roles. The overall proportion of female researchers in Estonia is over 40% and exceeds the European average, but the gender imbalance in the researcher population increases with age. Women physicists from some Asian countries, e.g., China, noted that everything was fine up to graduate school, and there was no significant barrier for women in physics until they obtained their Ph.D. After the Ph.D., there is a perception that women do not have the ability to be good physics professors, researchers, or scientific leaders, or that they should focus on their family rather than pursuing a high-profile career as a physicist. The glass ceiling was cited as a major factor why women fail to reach the top in physics across the world.

In 2012 the American Institute of Physics released the results of the Global Survey of Physicists, which was completed by 15,000 female and male physicists in 2009-2010, analyzed by regions, and restricted to 12 countries with sufficient data. Staff member Casey Tesfaye described how in nine of the analyzed countries, women had fewer opportunities than men, and in a different nine-country subset they had fewer resources than men. Regarding career progression, women physicists performed more slowly than men in eight of the analyzed countries.

Women physicists, especially from some African countries, noted that taking an interest in physics is also perceived to diminish their feminine attributes. In fact, even in the U.S., the stereotyped portrayal of female scientists by popular media (e.g., the TV show “The Big Bang Theory”) which make them look unattractive, does not help in encouraging more young girls to pursue physics. Eileen Pollack, who wrote an opinion piece in The New York Times (October 13, 2013) about why there are so few women in science, attended this ICWIP 2014 conference as a panelist and raised the point that the paucity of women going into physics is exacerbated by the stereotyped portrayal of female scientists.

Women physicists from Iran noted that more than 60% of B.S. and M.S. students, 47% of Ph.D. students, but only 18% of faculty members in physics departments are currently women. These high percentages of female physics students are partly because men in Iran are often more interested in engineering, because the career prospects are better. Women from Egypt noted that the reason many women do not take comparable jobs to men, even after obtaining their Ph.D., is that they want to be closer to home in order to take care of their families, so they have lower aspirations professionally in order to balance work and family.

What was clear is that in many of these non-Western countries, the women physicists have greater difficulty balancing family and work. Not only are they responsible for everything at home, but in addition, childcare and flexible work hour options are much less common in these countries. Some of these women physicists seemed resigned to the fact that they are unlikely to get an opportunity to pursue a career in physics; rewarding as the one afforded to their male counterparts because they have to find a job closer to home in order to balance work and life. In some of these countries, efforts to provide opportunities to balance work and family and counter-biases that exacerbate the difficulties, are impossible to even dream of at this time.

Even in western countries female physicists face challenges. The German contingent discussed data suggesting that female physicists are less likely to pursue high-profile careers as rewarding as the one afforded to their male counterparts because they have to find a job closer to home in order to balance work and life. In some of these countries, efforts to provide opportunities to balance work and family and counter-biases that exacerbate the difficulties, are impossible to even dream of at this time.

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