Perspective: Science and technology policy – What is at stake and why should scientists participate?

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US legislators prepare and make decisions on bills that involve science and technology (S&T) policy components, but they or their staff may not have sufficient expertise to do this. Therefore, it becomes critical that scientists and engineers from academia and industry spend time in Washington, DC to constructively engage in policy decisions. R&D investment helps drive economic growth. However, US R&D investment has been on the decline, whereas investment continues to increase in some emerging and developed economies. Scientists and engineers need to be champions for R&D investment to keep the USA competitive in the global market. This perspective paper discusses: what is S&T policy, who makes laws, the federal R&D budget and the importance of sustained R&D funding, how the USA compares with the rest of the world in R&D investment and numbers of science graduates. Finally, the author discusses his experiences as an S&T fellow in Washington, DC.

Keywords: science and technology policy; R&D; employment; US Congress; engineers; scientists.

1. Introduction

Legislators prepare and make decisions on bills which involve science and technology (S&T) policy components, but they or their staff may not have sufficient expertise to do this. Given the variety of bills and issues handled, it is hard to have sufficient breadth regardless of staff backgrounds. Scientists and engineers from academia and industry in the USA should spend time in Washington, DC to constructively engage in policy and funding decisions. In order to be constructive, they need to understand the legislative process.

Since R&D investment helps drive economic growth, scientists and engineers should promote R&D investments. The USA has been a global leader in these investments, but its dominance is slipping as other developed and emerging economies are rapidly increasing their R&D investments. Traditionally, the USA has invested in basic research and relied on industry to transfer that research to viable products for the market. However, industry has increasingly been unwilling to take the risks involved in technology transfer, resulting in lowered returns on investment for the significant funding that the USA provides for basic research. Increased federal investments and public–private partnerships are needed for technology transfer to make the products of research attractive to venture capitalists and industry, which will once again return the USA to global technological leadership.

Furthermore, industry needs science, technology, engineering and mathematics (STEM) graduates in the workforce to perform science and engineering (S&E) tasks. The USA needs to maintain a steady supply of graduates to satisfy this demand. Thus, increased investment in STEM pathways, increased emphasis on STEM opportunities at the high school level, and recruitment of underrepresented groups, including minorities and women, will ensure a continuing supply of STEM graduates.

In this paper, S&T policy is broadly defined, followed by an overview of the law-making process, and reasons for
our participation in the process. The federal R&D budget is presented in a historical context, as well as in the current global context, to show how US investments are declining, thus jeopardizing economic growth. Next, the importance of STEM graduates and their number in a global context are discussed to highlight deficiencies and potential untapped resources. Then, I share my experiences as an S&T fellow to show the education I derived from the opportunity, as well as the prospect for major impacts that can be made on current policies. Finally, a summary and outlook are presented to encourage others to participate.

2. What is S&T policy?

2.1 S&T

The word science is derived from the Latin scientia, meaning knowledge (Neal et al. 2011). Science is about both the search for truth and new knowledge. Scientific pursuit is referred to as basic research. Technology relates to the application of scientific and engineering knowledge derived from basic research to develop an object of practical importance. The term R&D comprises investigations in science (basic research) and technology (applied R&D).

2.2 S&T policy

National S&T policy refers to the federal rules and regulations pursuant to which S&T research is conducted (Neal et al. 2011). It is important for scientists to understand the process of federal R&D policy-making. First, Congress prepares legislation that mandates how federal R&D funds will be spent. The President then signs that legislation into law. However, separately, the Appropriations Committee negotiates and passes a budget that allocates those funds. The executive branch then spends the funds. Thus, Congress could pass a law that has no appropriated funds for the executive branch to carry it out. Legislation is written on the basis of facts, shaped by lobbyists and stakeholders, and becomes tainted by the political process. The legislative and executive branches of government are political institutions, and a member of either is a politician and policy-maker. He or she has his or her constituents to please, as well as trying to conform to the party platform. Therefore, policy and politics are intimately related, and navigating the intricate relationships is paramount to developing future S&T policy.

3. Who makes laws?

3.1 The legislative body: Congress

The US Congress is comprised of 435 House representatives, 100 senators, and five non-voting delegates (one of which is Puerto Rico’s ‘resident commissioner’): a total of 540 legislators. Fewer than 5% of the members of Congress are scientists, engineers, or health professionals. For example, in the 113th Congress, only 12 of those 540 legislators had an engineering degree. On the other hand, about 40% are lawyers, ensuring a maximum of argument and a minimum of agreement.

Congress employs about 14,000 staff members who prepare legislation and provide scripts for all legislative actions. The staff tends to be rather young, political science or public policy graduates. There is a high turnover of staff, who are typically 22–35 years old and may be in post for as little as two years. In 2014, only about 18% were women, and the number of staffers with a college degree in physical S&E was about 5%. Most lack work experience in either academia or industry. Given the variety of bills and issues they handle, it is difficult to employ sufficient breadth regardless of staff backgrounds.

It is helpful to think of staff as ‘unelected’ officials with partisan agendas. They organize hearings and write legislation, news articles, and public speeches. Moreover, their work is heavily influenced by lobbyists (having started with residences at K St. and now all over town) and stakeholders. Lobbyists and stakeholders make a point of creating direct relationships with these staffers, as a way to impact the policies and legislation they draft. In contrast, staffers do not organize town hall meetings or have access to nonpartisan experts in fields affected by that legislation and policies. Despite the lack of a background in physical science or engineering, as well as a lack of experience, staffers do a good job in putting bills together. However, ultimately legislators do not have the resources within their offices to be well informed about the relevant S&T. It is necessary for S&T professionals to provide them with expert guidance.

3.2 The legislative process

A bill takes a complex path in Congress (see Fig. 1) (White and Carrey 2011). This path includes hearings and mark-ups by the relevant committee, followed by a vote in the House and Senate. Each chamber must pass the bills, which are then converted into a bill with identical language by a conference committee, and then signed by the President to become law. Most bills do not complete the process. For example, the 110th Congress handled nearly 14,000 pieces of legislation, but only about 3% were signed into law.

Each bill, upon introduction, is known as a resolution. The resolution is assigned a number, along with the number of the Congress, the session, and chamber identifiers (e.g. in 2014 it was the 113th Congress, 2nd session, followed by H.R. for in the House of Representatives and S. for in the Senate). Bills are introduced either by a legislator or an informal group of legislators or by a formal committee that has jurisdiction over the issue. If introduced by a legislator or informal group, a resolution must go through an additional step of referral to a formal
committee before proceeding. There are roughly 24 committees in each chamber, although this number fluctuates. A relevant subcommittee then conducts hearings on the discussion draft/bill, followed by mark-up hearings, followed by the full committee mark-up hearings. If approved by the committee, the bill is introduced on the House or Senate floor. When a bill has passed both houses, it is referred to a conference committee to develop a bill with an identical language.

Scientists and engineers have opportunities along the way to help influence and shape the national R&D policy. By participating in the legislative process—assisting legislators in drafting bills, discussing the R&D process, and emphasizing its importance to the national economy—scientists and engineers can make a lasting and important impact.

Although policy decisions are important, and require input from scientists and engineers, what is at stake is much more than simply the policies. In fact, policy is only half of the equation, as discussed above. The appropriation of funds to carry out those policies is of equal, indeed perhaps paramount, importance. Therefore, it is exceedingly important that scientists and engineers also understand and participate in the appropriations decisions, and engage with the federal agencies responsible for the administration of funds.

4. R&D funding – Federal/State budget, innovation strategies, public-private partnerships, technology transfer, and committees handling R & D funding bills

This section considers the importance of R&D funding and its multiplying effect on job creation. The 2014 federal R&D budget is then analyzed as a fraction of the
gross domestic product (GDP) and the total federal budget, and in its historical context. This will show the decline in US R&D spending over time, as well as the declining status of the USA as a global R&D competitor. Next, innovation strategy through the use of major prizes is presented, followed by obstacles in technology transfer. Finally, a list of the committees handling various federal agency budgets is presented.

4.1 R&D investment creates jobs
Advances in S&T help drive economic growth, improve human health, and lead to overall prosperity. Since World War II, R&D investment accounts for about 40% of the economic growth in the USA. Economic development and prosperity in the USA stems in part from its ability to transfer basic research into successful businesses (Mansfield 1990; Tassey 2008). The following statistics clearly show the multiplying effect of R&D investments on the economy and jobs:

- R&D spending yields \(\times 11\) the investment in tax revenue.
- R&D jobs have a multiplying effect on the economy, returning \(\times 3.2\) (Anonymous 2014), and directly employed employees create an additional \(\times 2.2\) jobs.
- R&D spending is amplified \(\times 2.9\) (Anonymous 2014), and as R&D spending ripples through the economy, it generates an additional \(\times 1.9\) in indirect economic impact.

From this data, we can definitively state that R&D spending should not be considered an expense. Instead, it is a strong investment in our future. Its continued funding is important to scientists and engineers, as well as the broader economy.

4.2 Federal R&D budget
The financial year (FY) 2014 federal budget was $3.8 trillion (see Fig. 2a) (Anonymous 2013a), and federal R&D funding is the smallest slice compared to all other categories. Regardless of which category is considered a necessary expenditure, R&D seems to be small. In a highly cited report by the National Academies based on a study chaired by Norman R. Augustine (Anonymous 2007), it was recommended that the USA should double its investments in R&D to maintain global leadership. As a result, Congress had incorporated a schedule of doubling of the R&D budget in a reauthorization bill for funding agencies, called the America COMPETES Act of 2007 (P.L. 110-69, August 9, 2007). Funding was increased in the R&D budget in 2008 as a part of the stimulus spending. However, it decreased again in later years due to the economic downturn and sequestration.

The total federal R&D budget for FY14 was about $144 billion (Anonymous 2013a). Fig. 2b shows a breakdown of R&D expenditures by agency. Defense R&D investment accounted for about $70 billion of that budget with the balance comprised of non-defense investment. The remaining $74 billion was broken down into $32 billion for civilian health spending and $42 billion for civilian non-health. The total investment equaled about 4% of the total federal budget or 0.8% of the US GDP. The budget for basic and applied research was $64 billion, which was approximately 44% of the total federal R&D budget. In the executive branch, R&D funds expenditure is coordinated by the Office of Science and Technology Policy (OSTP), which handles execution and reporting.

The division of public/private sector investment is about 30/70. The information and communication technologies
industry is the largest private investor in the USA at about one-third of the total US investment. The total US R&D budget, including federal, industry, and other sources, is about $445 billion (FY14), and this total investment equals about 2.8% of the US GDP.

It should be noted that more than half of the basic research is carried out by academic institutions. In 2005, academic institutions spent about $45 billion on research (Neal et al. 2011). About $29 billion was provided by the federal government, $8.3 billion by state and local government, $8.3 billion by institutions, and $2.3 billion from industry. In 2002, federal labs spent about $34 billion in R&D (Anonymous 2013a).

Decisions on how much money should be appropriated, and for what purpose, are made in Washington, DC. These decisions affect the research infrastructure and the well-being of society. Scientists and engineers need to be engaged in these policy discussions and decisions.

4.3 Historical federal R&D funding

Fig. 3 shows annual federal investment in R&D as a share of the federal budget and of the GDP since 1962. We note a steady decline in R&D expenditures since that time. In 2001, the US investment constituted about 37% of the global R&D investment in absolute dollars (not GDP), and in 2011, the USA contributed about 31%. Despite this downward trend, the USA remains the world’s largest investor in R&D.

Fig. 4 shows national R&D expenditures in the period 1953–2004 by source of funds (industry, federal, and other). In 1980, industrial funding overtook federal funding for R&D. Based on a study conducted by Sargent (2013), federal R&D funding fell between FY09 and FY13 from $147.3 billion to an estimated $130.3 billion, a decline of 5.7% in current dollars. This decline is a reversal of sustained growth in federal R&D funding for more than half a century. Without intervention and
advocacy on the part of scientists and engineers, the trend of declining R&D funding could continue.

Academics, as well as industry workers, have a vested interest in the outcome of these policy and funding decisions. Fig. 5 shows academic R&D expenditures in the period 1990–2003 by source of funds. The largest fraction of funding comes from federal sources. Fig. 6 shows the breakdown of federal funding by disciplines in 2001 and 2011. Although the amount of money invested has changed, the distribution of those funds has remained relatively steady.

4.4 Innovations strategies

Defense R&D spending is about equal to non-defense R&D spending. To provide efficient use of defense research dollars, the development of dual-use technologies should be encouraged. Some examples of successful dual-use technologies include: ARPA net (internet) developed by the Defense Advanced Research Projects Agency (DARPA); jet engines and civil aviation, including the first plane by the Wright Brothers that was paid for out of a grant by the US Army, and National Science Foundation (NSF)/National Aeronautics and Space Administration (NASA)/Department of Defense (DOD) funding of 3D printer technology. While traditionally, the military has been protective of its newly developed technology, any barriers to the commercialization of such defense-led technologies should be minimized.

Prizes have a long record of spurring innovation. Examples of such innovation from historical to modern times include: the 1714 Longitude Prize, which stimulated the development of the world’s first practical method to determine a ship’s longitude; the 1927 Orteig Prize, which inspired Charles Lindbergh to fly nonstop from New York to Paris; and the 2011 Oil Cleanup X Challenge 7, awarded to a company from Illinois that demonstrated more than four times the previous best tested recovery rate for cleaning up oil from the ocean’s surface (Anonymous 2013c). A 2009 McKinsey report found that philanthropic and private sector investment in prizes had increased significantly over several years, including $250 million in new prize money in the period 2000–7 (Anonymous, 2009). These incentive prizes include: the Goldcorp Challenge, the Ansari X Prize, the Netflix Prize, and the Heritage Health Prize Competition. The X Prize Foundation is a leading, innovative, non-profit organization that dispenses and manages public competitions intended to encourage technological development of interest to humanity.

Prizes have an established track record of spurring innovation in the private and philanthropic sectors. They have the potential to facilitate quantum jumps in technologies. The following are some of the high-level benefits of prizes (Anonymous 2013c):

- They only pay for success and establish an ambitious goal without having to predict which team or approach is most likely to succeed.
- They reach beyond the ‘usual suspects’ to increase the number of solvers tackling a problem, and to identify novel approaches without bearing high levels of risk.
- They bring out-of-discipline perspectives to bear.
- They increase cost-effectiveness to maximize the return on taxpayer dollars.

Federal agencies have used prizes for many years. The America COMPETES Reauthorization Act of 2010...
Public Law 111-358, Jan. 4, 2011, Section 105), granted all federal agencies broad authority to conduct competitions to stimulate innovation, solve tough problems, and advance their core missions.

By September 2012, more than 45 federal agencies, departments, and bureaus had conducted over 200 competitions. Under the authority pursuant to COMPETES, seven competitions were held between January and September 2011. In FY12, 27 were conducted by seven agencies, including the Environmental Protection Agency, Department of Commerce, Department of Energy (DOE), Health and Human Services (HHS), Department of Labor, Department of State, and the Small Business Administration. Of these prizes, 18 were given by HHS (Anonymous 2013c). These agencies integrated prizes into a broader innovation strategy that also includes traditional methods. As they develop the expertise and capacity to use prizes strategically and systematically to advance their core mission, more federal agencies will begin to use them. Further, more public–private partnerships should be established to leverage investments and develop market-driven innovations. This would be of primary interest when administering large prizes.

4.5 Technology transfer

World Bank data showing the high-tech exports from various large economies in 1994, 2004, and 2012 are presented in Table 1. The USA was by far the largest exporter of technology in 1994 and maintained leadership up to 2004. In 2012, China ranked first, having achieved that status in 2005, up from 14th in 1994 and 2nd in 2004. The USA took the third slot in 2009, where it has remained. Between 1994 and 2012, the USA has slipped dramatically in ranking and overall funding, and its manufacturing edge is tarnished. Although the USA is the global leader in federal R&D, it is no longer the largest exporter. In order to increase opportunities for technology export, the USA needs to translate basic research into commercial products. This also helps to ensure that the USA obtains the expected impact from its significant investments in basic research. For this, applied and translational research needs to be carried out for technology transfer. Traditionally, translational research has been carried out by industry. Given the ongoing cuts in R&D investment by industry, much basic research is never translated into products. Thus, basic research has not been maximizing its return on investment. Presently, federal R&D funding is lacking to help advance basic R&D such that it becomes less profitable for private investors or industry to launch products.

The disconnect between research and industry is sometimes referred to as the ‘valley of death’:

The term ‘valley of death’ is used by business executives, economists, and venture capitalists to describe the development gap that often exists between a laboratory discovery and the market’s willingness to invest to advance the discovery to a final commercial product. This gap occurs due to a variety of issues, such as technical risk, market uncertainty, and likelihood of obtaining an adequate return on investment. (Sargent 2013)

The gap is also referred to as the ‘missing middle’. It simply represents gaps in funding or support for technology development and manufacturing development: that is, maturing manufacturing capabilities and processes to produce technological jobs. Substantial investment is needed to make the transition through the ‘valley of death’ or ‘missing middle’.

Fig. 7 presents a schematic showing the ‘valley of death’ scenario that research faces if adequate funding for technology transfer is not available. Research and some development occurs in academic labs, primarily funded by federal and state investments. Translational research is funded jointly by federal/state and private funding. Product launch is then carried out by start-ups and funded by venture capitalists or industry. Federal R&D agencies and public–private partnerships need to invest in technology transfer, developing research into a successful product. Technology transfer will drive the economy

### Table 1. High-tech exports for various large economies, 1994, 2004 and 2012 (in current US$)

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<tbody>
<tr>
<td>China</td>
<td>8</td>
<td>14</td>
<td>163</td>
</tr>
<tr>
<td>Germany</td>
<td>50</td>
<td>3</td>
<td>136</td>
</tr>
<tr>
<td>USA</td>
<td>116</td>
<td>1</td>
<td>176</td>
</tr>
<tr>
<td>Singapore</td>
<td>40</td>
<td>5</td>
<td>94</td>
</tr>
<tr>
<td>Japan</td>
<td>96</td>
<td>2</td>
<td>126</td>
</tr>
<tr>
<td>Korea</td>
<td>20</td>
<td>7</td>
<td>76</td>
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<td>France</td>
<td>34</td>
<td>6</td>
<td>66</td>
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and facilitate multiplying the investment in basic research. The idea that we ‘invest here and manufacture there’ exits because the USA economy is not able to provide the necessary investments and incentives for venture capitalists and industries.

There is a multiplying effect from investment in translational research in creating a number of high-tech jobs. The Science Coalition carried out a study to identify 100 start-up companies that can be traced back to research conducted at universities and sponsored by federal agencies (Anonymous 2013b). According to their report, some 81% of these 100 new companies received a total R&D funding of less than $5 million. They also found that they collectively employed 720 people, mostly scientists and engineers, with an average of seven employees per company. This translates to creating high-tech jobs as a result of small investments. Thus, the impact of investment in translational research leading to technology transfer is significant and real. This scenario builds a case for increased funding for technology transfer by federal, state, and public–private partnerships to allow commercialization of university innovations, with federal national labs also playing an active role.

In 1982, the USA initiated the small business innovative research/small business technology transfer (SBIR/STTR) programs. These are multi-agency programs by some 11 federal agencies in both civilian and defense sectors. These programs are coordinated by OSTP according to an individual agency’s budget authority and the Technology Transfer Act and the Small Business Innovation Act. These programs were designed to provide bridge funding to take basic research to manufacturing. The funding mitigates risk to investors, while still encouraging R&D. The USA invests about $3 billion annually. The funding generates about ten patents per day. To date, about $38 billion has been spent. About 11% of awardees annually attract about $65 billion in venture capital and angel money. About 450,000 engineers and scientists are involved in these programs, which represent one of the largest engagements and nurturing of STEM talent. To underscore the importance of SBIR/STTR funding: in a survey, about 20% of companies reported that they started with SBIR/STTR funding. The Small Business Investment Company (SBIC) was initiated in 1958 to provide money to start small businesses. The SBIC spends about $4 billion per year and has spent about $67 billion since 1958. In addition to supporting basic research, the NSF has established various mechanisms to facilitate technology transfer. One of the novel concepts for a research organization is an I Corporation (I Corp). An I Corp provides limited funding and provides the I Corp’s entrepreneurial expertise to potential NSF investigators who wish to develop products and start small businesses. These programs should be strengthened, as they develop intellectual properties, act as incubators, and allow new products to be launched.

Finally, one of the major obstacles to launching new products in the USA is that it has lost manufacturing infrastructure in many areas. In upcoming areas, the USA needs to make sure that it invests in the development of advanced manufacturing infrastructure. Federal, state, and private investments which have been set up since 2010 to revitalize American manufacturing through networks of public–private innovation hubs should help towards the goal. An example of this includes the National Network for Manufacturing Innovation on Additive Manufacturing in Youngstown, Ohio.

With the prevalence of portable electronic communications, many Americans who used to build things in their home workshops do not have enough time to do so. This stifles creative fabrication, which sometimes leads to innovation and new products. The launch of Make Magazine in 2005 created a do-it-yourself (DIY) culture. A grassroots Maker Movement developed in about 2010 out of that DIY culture to encourage hobbyists, enthusiasts, and amateurs to make things. Some makers became entrepreneurs and started their own companies. ‘Maker Faire’ commenced in 2013 at both the state and federal levels to showcase creative products made by all ages of the general public. Further, Maker Communities have sprung up in various cities for the purpose of providing free access to workshops for anyone who would like to build something. The hope is that some of these makers would become entrepreneurs.

4.6 Committees handling R&D funding bills (~$144 billion, FY14)

Within each chamber of Congress, there are three primary committees responsible for R&D policy and funding legislation. The House Committee on Science, Space, and Technology, and the Senate Committee on Commerce, Science, and Transportation handle in their respective chambers civilian non-health R&D, including NASA, DOE Basic Sciences, NSF, National Institute of Standards and Technology (NIST), OSTP, and STEM, with an annual budget of $42 billion for FY14. The House Committee on Energy and Commerce and the Senate Committee on Health,
Education, Labor, and Pensions handle civilian health R&D, including the National Institute for Health (NIH) and others, with an annual budget of $32 billion for FY14. The House Armed Science Committee and the Senate Armed Science Committee handle all defense R&D investment, including the DARPA, with an annual budget of $70 billion for FY14.

It should be noted that, although the committees are bipartisan, the majority and minority in both House and Senate have separate staff working on these committees, and the appropriations committees in both houses fund the programs. This means that scientists and engineers have to cross aisles to engage in meaningful and productive conversations.

5. How do we compare with the rest of the world?

One can clearly see that federal R&D funding has steadily declined over the past several decades. In this section, the federal R&D investment in the USA is compared with that of the rest of the world. Also, as STEM graduates are needed to perform S&E tasks in public and private sector jobs, the number of STEM graduates in the USA is compared to the number in the rest of the world.

5.1 National R&D investments

Fig. 8 shows 2013 global R&D spending as a function of scientists and engineers per million people. The size of the circles reflects the relative amount of annual R&D spending by the countries noted. Table 2 shows international data for 2010 regarding gross domestic expenditures on R&D (GERD) as a percentage of population and GDP. In R&D investment as a percentage of GDP, the USA was near the top, and in investment per capita, the USA was at the top. Various emerging economies may catch up to the USA in R&D investment by the early 2020s, unless the USA increases its focus on R&D.

Fig. 9 shows R&D investment as a percentage of GDP in the period 1995–2011 for the USA as compared to selected developed and emerging economies. R&D investment as a percentage of GDP by the USA remains fairly constant. However, it is increasing for South Korea, Taiwan, and China.

Research output from China has been increasing, and indeed has surpassed the USA in terms of research articles and number of citations (Anonymous 2011c). The number of companies from emerging markets has also increased from 16% in 2005 to 44% in 2009 (Anonymous 2011a). In contrast, a steady reduction in federal R&D investment in the USA may impact technological leadership, innovation, competitiveness, economic growth, and job creation.

5.2 STEM graduates

In addition to the decline in federal R&D investment, another major concern is a steady supply of educated workers. Since 1973, the number of jobs that require at least some college level education has significantly increased, while the opportunities for those with merely a high school education have diminished dramatically.
Graduates with STEM degrees are needed to satisfy demand in basic and applied science and industry. The USA is lacking in both quality and quantity in STEM education when compared to other economies. Fig. 10 shows the percentage of undergraduate degrees in the natural sciences and engineering for Asia, Europe, and the USA. The percentage of undergraduate degrees in science or engineering is highest in Asia. This shows that the USA is lacking in yet another area of S&T readiness and competitiveness with the rest of the world.

Fig. 11 shows scientists and engineers in S&E occupations for various ethnicities. It should be noted that a smaller fraction of women and minorities achieve higher education degrees, including STEM degrees, than white males. We need to do a better job in attracting more students at the high school level, especially women and minorities, to STEM opportunities in higher education. There is a pool waiting to be tapped. In addition to quantity, attention should be paid to quality education at the high school level. This will not only ensure sufficient numbers of workers to satisfy demands, but will also make domestic students competitive in the global supply of employees.

The federal government provided about $3 billion in the FY13 budget for STEM education. It is a multi-agency effort with a dozen agencies funding about 250 activities. The program is coordinated by OSTP according to an individual agency’s budget authority and the STEM Education Act. About 30% of funding was targeted for the specific workforce needs of the science agencies, and the remaining 70% of funding was spent on broader STEM education, roughly equally divided between the NSF and the DOE.
6. My experiences as a fellow: Examples

In this section, I share my experiences while serving as an S&T fellow with the USA Congress. This will show the education I derived, the impact I had, and the major impact that can be made on current and future policies by future S&T fellows, staff and legislators.

I spent a year as the S&T Policy Fellow for the Subcommittee on Research and Technology of the House Committee on Science, Space, and Technology. The subcommittee is responsible for funding for the NSF, NIST, OSTP, and STEM-related programs and technology transfer (Transfer Act). The subcommittee is also responsible for the 21st Century Nanotechnology R&D Reauthorization Act. I was also detailed to the House Committee on Oversight and Government Reform and on loan to the House Committee on Energy and Commerce.

There are many ways in which S&T fellows can influence policy. Staff, including fellows, prepare legislation and conduct hearings on various bills and subjects of interest. Staff participate in the preparation of legislative documents as well as the selection of witnesses for hearings, preparation of questions, and other logistics. Staff occasionally prepare opinion editorials and state-of-art research overviews of various technologies. There are also other ways to become involved, limited only by the interest and persistence of the fellows.

Some of the ways in which I was involved are listed below. I assisted in the preparation of legislation and hearings on major bills and follow up subcommittee and full committee mark-ups. A list of legislation follows:

- Frontiers in Innovative Research, Science, and Technology (FIRST) Act (H.R. 4186), which will reauthorize funding for NSF, NIST, OSTP, and Interagency STEM Programs on November 13, 2013. (Fig. 12 shows the first two pages of the bill.)
- A bipartisan bill H.R. 2996, the ‘Revitalize American Manufacturing and Innovation Act of 2013’, sponsored by Representatives Tom Reed (R-NY) and Joe Kennedy (D-MA on December 12, 2013.
- Private Sector Programs that Engage Students in STEM (STEM Education Act of 2014, H.R. 5031), on January 9, 2014.

### Table 3. Percentage of those aged 25–34 years who had completed postsecondary education in OECD nations in 2008 (OECD 2010: Indicator A1, Table A1.3a), USA ranked 8th)

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<th>Country</th>
<th>Aged 25–34 years with post-secondary education in 2008 (%)</th>
<th>Rank</th>
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<tbody>
<tr>
<td>South Korea</td>
<td>58</td>
<td>1st</td>
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<td>Canada</td>
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<td>Japan</td>
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<td>USA</td>
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![Figure 10. Percentage of undergraduate degrees in natural science or engineering: Asia, Europe, and USA. Source: Adapted from National Science Board, S&E Indicators, 2010; US Census Bureau (1999).](chart1)

![Figure 11. Scientists and engineers in S&E occupations, 2006. Hispanic may be any race. Other includes American Indian/Alaskan Native, Native Hawaiian/Other Pacific Islander, and multiple race. Source: Adapted from Women, Minorities, and Persons with Disabilities in S&E, 2012).](chart2)
A list of hearings follows:

- ‘Prizes to Spur Innovation and Technology Breakthroughs’ on April 9, 2014.
- ‘Reducing the Administrative Workload for Federally Funded Research’ on June 12, 2014.
- ‘Policies to Spur Innovative Medical Breakthroughs from Laboratories to Patients’ on July 17, 2014.

Thus, by serving in Congress, a fellow gains an understanding the legislative process, the role of lobbyists and stakeholders, and can begin to understand not only the party divide, but also the intricate nature of relationships on Capitol Hill. With this understanding, a fellow can influence policy decisions constructively and initiate new policy bills. In addition, staff colleagues gain a better appreciation for working with scientists. The ties which one develops provide invaluable contacts and keep the channels of communication open. Finally, an academic who serves as a fellow can bring the experience back to the classroom and inspire students to pursue careers in S&T policy.
7. Summary and outlook

National S&T policy refers to the federal rules and regulations pursuant to which S&T research is conducted. S&T policy is concerned with the incentives and environment for discovery and innovation. Congress prepares legislation and the President signs it into law. It should be recognized that, as the legislative and executive branches of the government are political institutions, politics play a significant role in S&T policy. A member of Congress is a politician and policy-maker. She or he has her or his constituents to please, as well as trying to conform to the party platform. Thus, policy and politics are intimately connected, and science policy is fully affected by politics. The Appropriations Committee appropriates funds separately from the passing of laws, and these funds are then spent by the executive branch. Therefore, Congress could pass a law without appropriated funds to support its execution.

Legislators often are asked to prepare and make decisions on bills which involve S&T policy components. However, they or their staff may lack expertise in science or technology. Given the variety of bills and issues they handle, it is difficult to employ sufficient breadth, regardless of the background. They do not conduct any town hall meetings or consult experts, and they are heavily influenced by lobbyists. Incorrect information is often incorporated into the bills. Therefore, it becomes critical that scientists and engineers from both academia and industry spend time in Washington, DC to constructively engage in policy decisions. The associations and networks created through this engagement keep open the lines of exchange between policymakers and those affected by policies.

R&D investment creates jobs and helps drive economic growth. The federal government has been a main source of funding for basic research. Although the USA remains the world’s largest investor in R&D, funding has been eroded in the last several decades. In contrast, many developing and emerging economies have either maintained or increased their funding. This puts the future of the US economy in jeopardy. Scientists and engineers need to champion R&D investment in Congress. They have the knowledge, passion, and drive to encourage Congress to make such investments. It is recommended that S&T committees in each party in Congress have a resource of experts.

An honest compromise seems to be lacking. When I suggested compromise, a staff manager told me that they believed in a pyrrhic approach: a victory won at any cost, even if there is blood on the floor. In the end, I was relieved to find out that pushing your way through does not work, even if you have the majority on the floor.

There are many benefits to service as a policy fellow. A fellow gains an understanding of the legislative process, the role of lobbyists and stakeholders, and can begin to understand the party divide and the complex nature of associatins on Capitol Hill. With this understanding, a fellow can influence policy decisions and initiate new policy bills. In addition, staff colleagues gain a better appreciation of working with scientists.

An academic who serves as a fellow can take the experience back to the classroom and inspire students to pursue S&T policy jobs. I teach part of a course on science, engineering, and public policy, cross-listed between the College of Engineering and the John Glenn School of Public affairs. Further, engineering and science departments at universities should initiate a joint Bachelor of Science program in engineering/science and public policy and/or a minor in science, engineering, and public policy. We have established such a minor at Ohio State University. It is also encouraged that more S&T professionals serve as Congressional staff and run for public office to directly affect laws.

Finally, as S&T professionals, it is our social and professional responsibility to participate in the national S&T policy.

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References

Appendix: Fellow’s relationship with Congressional staff

Congressional members have little time to interact with staff and depend upon staff direction to manage day-to-day business. Staff have the ear of their congressperson, so a fellow needs to work closely with staff. Navigating that relationship can be delicate. Due to the fast-paced, competitive, and adversarial environment, as well as the varied nature of their work, staff are called upon to exhibit expertise that they often do not possess. They become used to having a little knowledge about a lot of things, and so feel confident discussing topics that, in reality, they do not fully comprehend. It is up to the fellow to balance the need to educate the staff (and thereby the congressperson) on critical issues with the fragile nature of the egos surrounding the policy.

We now comment briefly on how Congress operates. In 2014, Congress was in session for only 110 days due to elections. When Congress is in session, its week typically starts on Monday afternoon and ends on Thursday evening or Friday at noon. Congressional members travel back to their home states to meet with constituents, campaign, and spend time with their families. They work very hard, and generally are sincere.