Dear Senator Wicker, Senator Cantwell, Representative Johnson and Representative Lucas:

We write to you out of deep concern over the impairment to America’s competitiveness that is signaled in the FY20 proposed research and development (R&D) budget—and in particular for the impact of the proposed cuts in R&D investments on national security, the creation of quality jobs and the health of the nation’s citizenry.

The wellbeing of America and its individual citizens depends heavily on the strength of America’s economy; and the strength of America’s economy depends heavily on research and development. Without a strong economy, jobs disappear along with the tax receipts needed to provide healthcare, social security, education and homeland and national security. A number of studies, including two that won Robert Solow and Paul Romer Nobel Prizes in Economics in 1987 and 2018 respectively, concluded that as much as 85% of the long-term growth in America’s economy (measured by Gross Domestic Product, GDP) is attributable to advancements in just two closely-related fields: science and technology (S&T).

Yet during or near the year 2018, China overtook the U.S. in investment in R&D (Figure: Gross Expenditures in R&D).

Does it matter? And does anyone care?

Five years ago, a study committee we co-chaired for the American Academy
of Arts and Sciences wrote a report on the state of American innovation policy, “Restoring the Foundation: The Vital Role of Research in Preserving the American Dream.”¹ We were honored that Congress considered our recommendations in drafting the bipartisan American Innovation and Competitiveness Act, which was passed by Congress by unanimous consent in December 2016 and signed into law in January 2017 by President Obama. That legislation represented real progress for American science and engineering, and we remain deeply grateful for your support.

The Academy and other organizations also worked with corporate leaders to issue a call to action focused on S&T, “Innovation: An American Imperative,” which was signed by over 500 businesses, universities, scientific societies and other major organizations.² While we are encouraged by this strengthening of our national understanding of the importance of R&D, it is clear that the challenges—declining public investment in R&D and restrictions on foreign scholars in the U.S. coupled with rising government investment by China—remain the same. A forthcoming update to “Restoring the Foundation” will present a thorough examination of this situation and provide policy recommendations to ensure that the U.S. does not lose its pre-eminent position in discovery and innovation. For your consideration and in view of the time-urgency of the situation, we are providing the following letter report to preview factors that underpin the updated paper.

**THE ISSUE**

Surveys reveal that more than 75% of Americans agree that government funding of basic research pays off, while only 54% agree that the U.S. leads the world in scientific achievements. Yet this topic does not receive much attention in most political campaigns. America’s investment in basic research as a fraction of GDP (“research intensity”) has remained stagnant at about 0.2% for nearly half a century. Federal spending (annual outlays) for R&D has remained generally flat at about 4% of total federal spending, and 10% of discretionary spending, for over 30 years. With the federal government’s re-definition of development in 2017 these percentages become even lower. Meanwhile, other nations, especially China, have accelerated their investments. As a consequence of America’s tepid response to rising competition from abroad, the U.S. has fallen to 10th place among OECD nations in investment in R&D (public and private) as a fraction of GDP (Figure: The U.S. has Fallen to 10th Place in R&D Investment).³

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1 www.amacad.org/restoringthefoundation
2 www.innovationimperative.com
3 Because of past variations in its definition of R&D, Switzerland has not been included in the figure. Were it to be included, the U.S. would be in 11th place.
Since reforming its economy more than 40 years ago, China has increased the size of its middle class such that it is now larger than the entire population of the U.S. It is widely projected that China’s GDP will exceed that of the U.S. in absolute terms by 2030. Indeed, if a purchasing power parity (PPP) correction is applied, China’s GDP already passed that of the U.S. in 2014. China has also established the goal of equaling or surpassing the U.S. in military capability by 2050. Chinese leadership establishes long-term goals for its economy, including R&D investments, and measures progress within that extended framework. This forward thinking is reflected in a recent major restructuring of its S&T enterprise to make it more efficient and competitive with the U.S. and other economically developed nations by creating research funding agencies more in line with Europe’s research councils and U.S. funding agencies. However, these advances have been accompanied by concerning developments, including China’s suppression of individual freedom and privacy, increasingly through applications of AI and other advanced technologies.

R&D in the U.S. and China are clearly on very different trajectories. As China’s commitment to R&D coincides with its emergence as a global power, so should America’s disengagement from R&D raise concerns about America’s commitment to international cooperation. With strong leadership, America can reestablish its preeminence in the evolving world environment that is increasingly shaped by the outcome of innovation through S&T. And it must do so with urgency.

Innovation through S&T has four fundamental interrelated components: (1) human capital, (2) knowledge capital, (3) an ecosystem conducive to innovation, and (4) financial capital, the latter a foundational ingredient in the success of the other three.

1. HUMAN CAPITAL

America’s foundation in science, engineering and technology was enhanced by scores of immigrants from Europe during and after World War II. America’s R&D enterprise today would barely function were it not for foreign-born individuals who studied in America, received their degrees in America, and elected to remain and pursue job-creating research and technology in America. Over 50% of U.S. engineering faculty members are foreign born, as is about 30% of America’s overall S&T workforce. About 50% of U.S. foreign born S&E faculty are Asian. Almost one half of all American Fortune 500 companies were founded by U.S. immigrants or their children. Openness to international collaboration has historically enriched America’s businesses and universities. When individuals are found to knowingly violate the law, appropriate actions should be taken. But, federal policy ought to continue to encourage the open transnational flow of talent and ideas.

Compared with the situation in most developed nations, relatively few American youth are interested in careers in science and engineering (S&E). In the case of engineering, 33% of baccalaureate degrees in China are awarded in engineering, 15% in Europe and 6.3% in the U.S. The most recent study on the topic indicated that in the fraction of baccalaureate-level degrees awarded in the field of engineering, the U.S. ranks 69th, comparable to Kenya, Saudi Arabia, and Cambodia.
A major reason for the lack of U.S.-born citizens pursuing S&E careers is the inferior quality of the nation’s public pre-K-12 education system, particularly in the critical fields of reading, math and science. While America has many fine public schools, many fine teachers, and many fine students, on average its public schools are simply not competitive with those of other developed nations. Further, its position continues to erode, particularly in math and science.

In contrast, America’s higher education remains second to none, but China continues to make progress. American universities have become increasingly dependent upon foreign students, many from China, particularly in the academic disciplines that have typically driven innovation. In terms of the total number of doctoral degrees in S&E fields granted by U.S. universities in 2017, students on temporary visas earned approximately one-third of all S&E PhD degrees and over half of engineering PhD degrees. The countries sending the largest number of students to the U.S. for doctorate training are China, India and South Korea. Over the past ten years, students from China earned more than 43,000 PhD degrees in S&E fields from U.S. universities.

Challenging America’s standing, China has been steadfastly moving up the rankings. In 2014, China awarded over 1.7 million bachelor’s degrees in S&E compared with the U.S. number of about 740,000 (many to foreign nationals). China’s projections are for its number of graduates to increase substantially, while corresponding degrees to U.S. citizens are relatively flat.

Some 260,000 Chinese students are currently pursuing degrees at universities in America, an increasing fraction of whom are electing to return home after completing their education—or are being driven from the U.S. by wide-sweeping immigration limits. At the same time China is aggressively recruiting Chinese-born scientists working abroad, as well as non-Chinese-born students who wish to continue their education in China and accept jobs with Chinese companies. China has indicated its aim to become Asia’s top destination for international students, targeting 500,000 foreign students enrolled per year by next year—2020. Under its “Thousand Talents Plan,” China is actively recruiting established foreign scientists to work in China.

As China emphasizes the scale and quality of its universities, U.S. states have largely elected to disinvest in their public universities, cutting funding by an average of 30% per full-time student (even after adjusting for inflation) between 2000 and 2014, thereby essentially privatizing many institutions that do not have large endowments. Concurrently, the federal government has burdened the nation’s most highly regarded private institutions by imposing a tax on their endowment earnings; earnings that otherwise could have been allocated to scholarships and research. Last year, the federal government was narrowly deterred from taxing the tuition waivers awarded to graduate students to conduct research that is an integral part of their education—and a significant contributor to the nation’s progress in S&T. The contrasting attitudes of the Chinese and American governments towards supporting the pipeline for innovation could hardly be more clear-cut.
2. KNOWLEDGE CAPITAL
There are a variety of quantitative measures of knowledge capital, including papers published in peer-reviewed journals, numbers of patents, and funds invested in research, particularly basic research. While no single measure is adequate to assess the quality of research, publications in the top international journals are significant. By that measure, the current trend in China towards higher quality research is strongly indicated by the rising prominence of its university researchers in the publication of highly cited scientific papers.

An indicator of research output and, importantly, the application of that research, is patent applications. China is seen to be excelling by this measure as well (Figure: Total Patent Applications). In terms of the overall quantity of researchers, China passed the U.S. in 2006. This is significant in that a greater number of qualified scientists performing suitably funded research can be expected to produce greater output at any given level of quality.

3. INNOVATION ECOSYSTEM
A key component of Chinese innovation through S&T is its strategy to provide stability through the government’s commitment to long-range plans, including growth of its R&D investments, intended to position China in a leadership position by specific dates. Examples include “Made in China 2025,” and “China’s 13th Five Year Plan (2016).” The latter identifies 16 specific “megaprojects” intended to place Asia in a leadership position in critical fields by 2030. The U.S. does not have a long-range strategy for R&D, nor even a mechanism to develop one. Currently, there is no means in U.S. policy making of prioritizing the federal government’s overall investments in research. The result is a glut of wasted opportunity: today, due to the lack of funding, only about 20% of grant proposals deemed competitive by NSF and NIH can be pursued.

In addition to failing to take advantage of America’s outstanding research capability, outdated and burdensome federal regulations are imposed on the small fraction of researchers who do receive funding. One survey conducted by the National Academy of Science, Engineering and Medicine (NASEM) indicated that 42% of the research time of U.S. principal investigators is spent on “associated administrative tasks”—that is, time away from conducting research.
The collective effect of Chinese and American policies is to establish the two nations on very different trajectories. Compared with the 2017 index, the World Intellectual Property Organization’s 2018 ranking of the most innovative economies drops the U.S. from 4th to 6th place and elevates China from 22nd to 17th in just this one year.

4. FINANCIAL CAPITAL

Federal investment in R&D as a percentage of GDP has been declining since the end of the Apollo era (Figure: U.S. Federal R&D Investment), decreasing from the previous year in 21 of the past 27 years. The American Association for the Advancement of Science (AAAS) reports that in FY2017 federal funding for R&D in the U.S. fell by over 20% in the past decade alone. The FY 2018 budget increased federal R&D investment by nearly 13% and FY 2019 budget increased it again by 6%, which are promising steps, but the U.S. still has substantial ground to recover from two decades of reductions. And the FY20 proposed budget for R&D represents an enormous step backwards.

As if to create a “perfect storm,” an existential constraint is on the horizon. Future year projections of annual deficits and growing debt by the non-partisan Congressional Budget Office (CBO) offer no indication that the overall long-term downward trend in R&D is likely to reverse. The federal government is now confronting the consequences of decades of placing consumption above investment in its budgetary planning priorities. One result is that, based on CBO data, in the year 2028, under current law, the entirety of federal revenues will fund only two budget categories: (1) already legislated “mandatory” spending, and (2) interest on the federal debt. This implies that there will be no funds for such things as infrastructure, national defense and R&D, other than those obtained through additional borrowing—thereby further increasing annual deficits, the federal debt and interest of payments. The President’s FY20 request proposes deep cuts in research and education at a time these endeavors are in serious need of strengthening.

ADDITIONAL CONSIDERATIONS

Observers not unfairly ask why the government should fund R&D, particularly when U.S. industry is a significant beneficiary of its results. Industry now funds about two-thirds of all R&D compared with the government’s share of one-third—a complete reversal of shares since the mid-1960s. Accompanying this shift has been a transition in industry wherein the highest priority is placed on development, not research. As a result, most of America’s great corporate research institutions have shuttered—Bell Laboratories, the home of eight Nobel Laureates, being the canonical example.
In the past the U.S. has benefited from its possessing very substantial sources of private equity for start-up firms. However, the financial markets upon which business depends for resources are increasingly seeking near-term returns, with the average corporate shareholder now holding their shares for only about four months rather than the eight years of a few decades ago. In the case of day traders and arbitragers, the holding period can frequently be measured in nanoseconds. In such an environment, the government becomes the funder of only resort, the default funder, for long-term, high-risk endeavors that serve the citizenry as a whole—such as basic research—and not necessarily the investor or performer.

China, meanwhile, has addressed this issue by establishing sizeable government funds to support innovation, including substantial investments in promising American firms that have been unable to obtain domestic funding. For example, China is investing tens of billions of dollars in arguably the most important element of the ongoing technological revolution, the semiconductor integrated circuit, through the recent establishment of its Integrated Circuit Investment Fund.

China is of course not without its internal challenges. These include large groups of restive citizens in several areas of the country, backlash over constraints on everyday life, an aging population, an environmental crisis, and a currently slowing economy, causing many Chinese workers to lose their jobs. But its performance over the past decade in innovation through S&T cannot be denied, and the Chinese government has given no indication that it plans to alter its growth strategy for R&D. For the U.S. to embrace an R&D investment strategy that depends on China imploding would seem fanciful.

It is unlikely that China will neglect R&D and overlook promising opportunities in S&T. China has a history of having scientists and engineers at the top echelons of its government. President Xi Jinping and his predecessor Hu Jintao hold engineering degrees from Tsinghua University in Beijing. Scholars estimate that approximately 80% of government leaders at all levels in China have degrees in science or engineering. In contrast, the 535-member U.S. 116th Congress includes eleven engineers, one physicist, one animal scientist, one chemist and one businessperson with a PhD in mathematics. The health of America’s S&T enterprise has received little or no attention in the debates attending recent elections—in part because there are so few individuals knowledgeable of the fields at the highest echelons of government.

The competitiveness of the U.S. in the world could shift rapidly in the next several years. Given the enormous scale and rate of progress of Asia, particularly China, once America begins a downward slide it will be very difficult to reverse.

The following policy recommendations are offered as important elements of support of the nation’s competitiveness strategy.
RECOMMENDATIONS
We reassert the prescriptions and implementing actions offered in the American Academy of Arts and Sciences’ “Restoring the Foundation” report of five years ago. In order to account for events that have transpired since then, we urge that particular attention be devoted to the following recommendations:

➢ The nation should increase R&D investment (public and private) as a fraction of GDP from 2.7% to 3.0% within 5 years and 3.3% within 10 years.
➢ Federal basic research funding should be increased at a sustained real rate of at least 4% per year, with the long-term goal of raising federal basic research funding as a percentage of GDP by 50%, from 0.2 to 0.3% by 2032.
➢ The Office of Science and Technology Policy (OSTP), in cooperation with the Office of Management and Budget (OMB) and other government funding agencies, should prepare a rolling five-year integrated federal R&D funding plan for each of the agencies that support R&D, including overall funding targets for the categories basic research, applied research and development.
➢ A capital budgeting process should be established to provide resources for federally-funded R&D facilities.
➢ U.S. R&D budgets should be appropriated on (at least) a two-year cycle, rather than annually.
➢ The number of H1-B visas should be doubled, and immediate family members appropriately accommodated.
➢ Regulations, policies, and reporting requirements currently imposed on the conduct of R&D should be reviewed with the intent of eliminating constraints that do not offer demonstrable benefits.
➢ Universities should revise their policies on intellectual property to better reflect the original intent of the 1980 Bayh-Dole Act. Companies and universities should explore mechanisms that enable more effective partnerships and encourage transdisciplinary joint research. The federal government should revise tax laws to encourage stronger university-industry partnerships.

In addition to updating these recommendations from the 2014 “Restoring the Foundation” report, we append the following suggestions:

➢ The recommendations in the 2005 NASEM “Rising Above the Gathering Storm” report pertaining to pre-K-12 education should be implemented, including creating each year 10,000 federally-funded four-year scholarships in science, technology, engineering and mathematics (STEM) fields to be competitively awarded to U.S. citizens in exchange for a commitment to teach STEM in a public school for at least five years following graduation.
➢ States should return to sustainable funding of their public universities, at least at the levels (allowing for inflation) in place prior to the 2008 recession.
➢ The recent tax placed on the earnings of endowments of (private) universities should be repealed.
We recognize that many of the above recommendations will require additional funding if they are to be implemented. But we do not accept the notion that, for example, an additional 0.1% of GDP cannot be allocated to the federally-funded basic research that is so vital to promoting progress in America. We have been encouraged by the bipartisan support for American science and engineering in recent years; the issue at hand is principally one of priority.

**FINAL OBSERVATIONS**

U.S. citizens currently enjoy a GDP per capita that is nearly six times that of the average of all other citizens on the planet. This is substantially a consequence of past investments in R&D, higher education and related fields. The declining position of the U.S. in S&T has not occurred overnight, nor has it been imposed upon the U.S. by others. It was not China that reduced the nation’s investment in R&D; allowed the continuing decay of our pre-K-12 education system; reduced the number of foreign graduates from U.S. universities who can remain and work in America; or disinvested in our public universities. Decisions made, or not made, at this inflection point in America’s competitiveness status will determine whether we, unlike all prior generations of Americans, leave to our children and grandchildren a lower standard of living than we enjoyed.

We would be happy to follow up with any additional information or assistance.

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**Norman R. Augustine**

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