Funding of Basic Research in Physical Science in the USA

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Introduction

This essay gives a short history of the funding of research in science and engineering by the U.S. Government from about 1940 to 2000. This story is worth telling because it shows the betrayal of creative intellectuals in science and engineering by members of the U.S. Congress and by U.S. Government bureaucrats.

I began my studies in physics in 1967, earned a Ph.D. in physics in 1977 after ten years of continuous full-time university study and research, then worked as an electrical engineer from 1977 until 1990, because there were few employment opportunities for physicists. Because of the annihilation of financial support for scholarly research in all of my fields of science and engineering in 1990 (i.e., the so-called "peace dividend"), I became an attorney in 1998. As a practicing scientist or engineer during the 1970s and 1980s, who was funded mostly by the U.S. military, I personally experienced the effects of the political problems described in this essay. My insight into the motivation of the U.S. military comes largely from my discussions with military officers during the 1980s, particularly during a sabbatical year that I spent at the U.S. Air Force Weapons Laboratory in Albuquerque, NM during 1983-84. To prevent this essay from being considered sour grapes, I do not mention my personal experience in the following essay. I do not have the time to provide oodles of footnotes to sources, although I suggest below, at page 11, where such information can be found.

During the years 1920-45, Robert Goddard was a professor of physics at Clark University in Massachusetts, who was interested in developing liquid-fuel rockets.[1] In 1930, he created a laboratory and test range in the New Mexico desert, near Roswell, where there was little risk of fire to buildings from his rockets. He was continually plagued by difficulties in obtaining financial support for his work. Most of Goddard's early funding came from his own pocket, plus modest grants from the Smithsonian Institution and the Carnegie Institution. Between 1930 and 1941, the Guggenheim Foundation gave him larger grants. The U.S. military repeatedly refused to sponsor his research between the two World Wars, despite the obvious application of such rockets to warfare. German engineers who were developing rockets (e.g., the V-2) during World War II carefully studied Goddard's publications and patents. In the 1950s, the U.S. Government infringed a number of Goddard's patents on liquid-fuel propulsion and gyroscopic stabilization. It seems particularly ironic that the same Government who refused to support Goddard's research, then later wrongfully appropriated Goddard's best ideas. Goddard died in 1945. But, after a nine year legal battle that ended in 1960, his widow and the Guggenheim Foundation received from the U.S. Government what was, at that time, the largest monetary settlement of patents infringed by the U.S. Government. This vignette shows the attitude of the U.S. Government toward scientists: don't support their research, then steal their ideas. Dr. Goddard could have accomplished much more in his short life, if he had been given adequate financial support.

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[1] See the biography at http://www.clarku.edu/offices/library/archives/GoddardBio.htm .

World War II

Prior to World War II, governments rarely directly funded scientific research. Research was something that university professors did in their spare (i.e., nonteaching) time. A few wealthy people (e.g., Benjamin Franklin, Lord Rayleigh) did research that was financed by their personal money.

One lesson learned by all military officers during World War II was the critical importance of technology in military campaigns. During the few years of World War II, a number of important innovations were developed and put into use. Radar allowed ships to "see" in fog and radar gave advance warning of bomber raids and missile attacks. The use of proximity fuses in anti-aircraft artillery shells greatly increased the ability to defend against bomber raids. The development of accurate bombsights contributed to the destruction of Germany and Japan. And, of course, the development of nuclear weapons quickly ended the war against Japan. In short, such technology saved the lives of American military and shortened World War II.

Two famous programs were (1) the Manhattan Project at Los Alamos, NM that developed the first atomic bomb and (2) the Radiation Laboratory at MIT[2] that developed radar systems and microwave electronic devices. Most of the scientists in these two programs were physics professors and graduate students in physics. In other words, these military programs were essentially composed of academics and students, who were temporarily "borrowed" from universities. This began the collaboration between universities and the U.S. military. Incidentally, the University of California held the contract to manage the Los Alamos Scientific Laboratory[3] since 1943.

1950s and 1960s

During the 1950s and 1960s, the U.S. Government, mostly though its military, was responsible for funding an enormous amount of scientific and engineering research. Much of the research was "pure", not directed at solving a practical problem of interest to the military. But even this allegedly irrelevant "pure" research played a vital need in the defense of the free world by continuing to keep university professors working on the cutting edge of their field and by paying for graduate education of many scientists and engineers who worked on research projects sponsored by the military. Many of the young graduates then began a career working for industry, or in government laboratories, producing new weapons technology.

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[2] For a history of the Radiation Laboratory, see http://rleweb.mit.edu/radlab/radlab.HTM .

[3] For the history of LASL, see http://www.lanl.gov/worldview/welcome/history.html .

The USSR, which threatened Europe along the Iron Curtain, and communist China, which threatened South Korea and Southeast Asia, both had armies that were enormously larger than the army of the USA. The USA planned to defeat either the USSR or communist China in battle, by using advanced technology that made each one of our soldiers more effective than the combined effort of dozens of enemy soldiers, a doctrine known in American military jargon as "force multipliers".

The senior officers in the U.S. military during the 1950s and 1960s were acutely aware of the role that physics professors had played during World War II in developing critical military technology, and these grateful officers saw these professors as a national resource. By generously funding basic scientific research, the U.S. military kept these professors ready to contribute to a future war effort, and encouraged universities to expand physics and engineering departments.

Decline in 1970s, 1980s, and in 1990

Four unrelated events in the 1970s and 1980s merged and caused the decimation of financial support for basic scientific research in many areas of physics and engineering.

1. Vietnam war

The disenchantment with the military in the 1970s, during the Vietnam War, lead to drastic reductions in research sponsored by the U.S. military. In the early 1970s there were many protest demonstrations on university campuses that opposed the university's acceptance of contracts or grants from the Department of Defense, regardless of the topic of the research. That shift away from military sponsorship would have been of little consequence, except that there was no corresponding increase in funding by civilian agencies, such as the National Science Foundation (NSF) and NASA. I mention in passing that the environmental movement that flourished in the 1970s often simplistically portrayed science and technology as the cause of pollution,[4] which may have contributed to some people's reaction against science and engineering.

2. Retirement of World War II era officers

A young military officer who was 22 y old in 1941 was 65 y old in 1984. The senior officers who were personally grateful for technology in World War II retired, and then were no longer able to insist on generous financial support of scientific research. Their younger replacements had always been around transistors, radar, rockets, nuclear weapons, and other military technology, so they did not appreciate the role of creative scientists and engineers in producing this essential

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[4] A more accurate statement would be that pollution is caused by the *mis*use of science and technology. Science gives us opportunities, and people may choose — through ignorance, greed, or apathy — to misuse those opportunities.

technology.

3. Gramm-Rudman-Hollings Act

President Ronald Reagan presided over large military spending, much of it for the pipedream of the so-called "Star Wars" shield against incoming ballistic missiles. As a result of continuing, large federal budget deficits, the Gramm-Rudman-Hollings Act[5] was passed in December 1985 that promised to balance the federal budget by October 1990. The Gramm-Rudman Act is a now forgotten failure: despite the promise of that Act, the U.S. Government did not have a single year with a balanced budget until the year 1998, *eight years* after the Gramm-Rudman target. What the Gramm-Rudman Act did accomplish was to drastically reduce the federal government's financial support for scientific and engineering research, because there was no articulate and politically powerful voice that defended research from the budget axe. As a result of the Gramm-Rudman Act, many U.S. Government agencies did not have enough allocated funds to honor their past contractual obligations to universities and other research organizations, so few new research contracts were funded during 1986-87.

4. End of Cold War in 1990

The end of the Cold War around 1990, with the economic and political collapse of the former Soviet Union, the fall of the Berlin Wall, and the merger of East and West Germany, was seen by many politicians in the USA as an indication that we no longer needed a large military. Many politicians gleefully declared a "peace dividend" and further reduced the funding for both the U.S. military and scientific research. Ironically, the defeat of the USSR came, *not* because of the technical superiority of our weapons, but because their economy collapsed before the American economy collapsed.

Effects of these budget cuts

These reductions in financial support for scientific and engineering research led to *un*employment of large numbers of scientists and engineers who were employed in private companies, both for-profit defense contractors and nonprofit research institutes.

During the 1950s and 1960s, universities expanded the number of science faculty members beyond the number needed to teach undergraduate classes and the basic graduate-level classes. The salaries and research expenses of these professors was paid by contracts and grants between the U.S. Government and each university. When the Government began to decrease financial support for research, universities were stuck with large numbers of tenured scientists and engineers, whose employment could not be terminated, but whose services were no longer needed

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5 Named after its two sponsors, Senator Phil Gramm of Texas and Senator Warren Rudman of New Hampshire, and a cosponsor, Senator Fritz Hollings of South Carolina.

by the universities. This shift in Government funding for research caused financial crises at many universities.

Most people in the USA are unaware that ten<u>s</u> of thousands of creative scientists and engineers were suddenly without financial support for their continued research. Many of these scientists and engineers are now either unemployed (euphemistically called "early retirement" or "downsizing") or employed in jobs that do not use their special intellectual skills (e.g., driving a taxi cab, instead of doing scientific research). Adding additional injury to such large-scale unemployment of American-born scientists and engineers, the U.S. Government has declared a shortage of scientists and engineers, thus allowing immigration of scientists from third-world nations, such as India, Pakistan, and Eastern Europe. While many of these immigrants are highly-skilled and diligent workers, their immigration has exacerbated the unemployment problems of scientists and engineers who were born in the USA. Simply put, a rational immigration policy would take care of our own people before creating opportunities for foreigners.

During the 1990s, the U.S. Government has funded scientific research projects in the former Soviet Union, to keep their scientists employed, and to encourage their scientists *not* to emigrate to rogue nations, where the former Soviet scientists could develop advanced weapons that would threaten our security. At the same time, the U.S. Government has been deaf to the plight of U.S. citizens who devoted ten<u>s</u> of years of their life to doing scientific or engineering research that was sponsored by the U.S. military, and who are now either *un*employed or employed in occupations that do not use their scientific knowledge, talent, and experience.

Motivation: military vs. something else

Let me digress for a moment to discuss the motivation for funding scientific research. The motivation presented above was essentially military: scientific discoveries fed technological advances that made superior weapons. Not only did we win World War II, but the development of stealth aircraft that were nearly invisible to radar and precision-guided bombs led to quick victories against Iraq in 1991 and again in 2003. The lesson is clear: those who do not invest in military technology will have their battlegrounds and their cities littered with their dead bodies.

Continued military superiority is reason enough to justify a country spending money on scientific research. However, there is a better reason: scientific research produces new ideas that enables engineers to develop new technology, which, in turn, fuels the economy of modern nations. For example, funding from the U.S. military created ARPANET, the predecessor of the Internet. Funding from the U.S. military was also essential in seeding the development of integrated circuits, which led to microprocessors, inexpensive computers, and a plethora of smart appliances in people's homes. Radar and satellites were initially military inventions, but the modern use of those inventions is to make weather forecasts so that hundreds of people no longer die in a surprise hurricane or flood.[6] In short, investment today in scientific and engineering research makes a more prosperous and safer future.

A more idealistic motivation would be to fund scientific research because knowledge is inherently Good. With the prevalent anti-intellectualism in the USA, it is probably hopeless to convince a majority of politicians and government bureaucrats in the USA to support scientific research for such an idealistic reason.

What matters most is that scientific research receives funding that is both adequate and long-term. *Why* a government provides money to scientists is less important, since the utility of knowledge and inventions does not depend on their motivation. And *which agency* in government disburses the money to universities, nonprofit corporations, or individual scientists is not important.

Elsewhere,[7] I have remarked on the need for consistent funding of scientific research for ten<u>s</u> of years, while the reality in the USA is that funding is limited to short periods of time (e.g., typically one to three years) because of political cycles in the U.S. Government. Inconsistent funding of scientific research not only spoils scientists' careers, but also wastes money on beginning significant research projects that are never finished.

Scientists are easy for politicians to ignore

The scientific and engineering community certainly understood the importance of continued research. So why did this community remain silent during the 1970s and 1980s and allow research funding to be ended? Annihilating financial support for scientific research was an easy thing for politicians to do, because few scientists and engineers have been politically active, and no one with significant political clout spoke for the necessity of expanding scientific research in the 1970s and 1980s.

Scientists and politicians live in completely different worlds. Physicists publish their work in scholarly journals that are filled with results of measurements and complicated mathematical calculations. It takes at least seven years of full-time university education in physics to be able to understand such publications. On the other hand, nearly all politicians went through high school and undergraduate college taking the minimum amount of science and mathematics classes, and as

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[6] We need to be reminded that more than 8000 people died in a hurricane that hit Galveston, Texas on 8 Sep 1900, and more than 600 people died in a hurricane that hit New England on 21 Sep 1938. As a result of modern forecasts that provide several days of warning, in modern times a major hurricane rarely kills more than two dozen people, and most of these dead defied warnings from scientists.

[7] Ronald B. Standler, *History and Problems in Weather Modification,* 2002, http://www.rbs2.com/w2.htm#anchorSupport .

a result of their ignorance, politicians are *un*able to understand even simplified science (e.g., published in *Scientific American,* which does not use equations and which has lots of pretty colored graphics). Scientists write in sentences that are literally true; politicians use lots of hyperbole and politicians are sloppy with their "facts". Scientists are interested in Truth; politicians are interested in being re-elected and in getting goodies for their constituents. Aside from these intellectual differences between science and politics, creative scientists are often loners,[8] while politicians love to work in committees. It would be heresy for a scientist to compromise about Truth, while politicians routinely negotiate compromises. Scientists speak of their measurements or calculations, while politicians have opinions that generally agree with the most recent opinion poll, which opinions may be based on dogma, prejudice, superstition, ignorance, greed, ...

When scientists complained about decreases in financial support for their research, they published their complaints in scientific magazines that are read only by other scientists (e.g., *Physics Today*). A few famous scientists testified before Congressional committees, which was a largely futile exercise, since few Congressmen were aware of — or cared about — the substance of such testimony.

The image of politicians as ignorant, anti-intellectual people is perhaps best shown by the debacle of the cancellation of the Superconducting Super Collider in the year 1993. At that time, about two billion dollars had been spent on preliminary construction and many scientists and engineers had moved to the facility to accept employment there. The politicians whooped for joy that the intellectual scientists — whose work was beyond the comprehension of politicians — had gotten a pasting, and the taxpayers had saved lots of money. The reality is that many scientists' careers were disrupted or destroyed, because they had trusted the assurances of the government about the future of this facility.

failure of universities

While I believe that politicians are the most blameworthy group for the failure of our society to adequate support research in science and engineering, the academic community has also failed in two ways:

1. Since the mid-1960s, universities in the USA have credentialed people as "educated" by giving them a bachelor's degree, without those graduates understanding calculus, differential equations, introductory physics, and introductory chemistry. This is a serious erosion of traditional academic standards that included science and mathematics in the core curriculum. Further, understanding both science and mathematics is essential to making good choices in the use of technology that is now ubiquitous. Ironically, the military academies in the USA require *all* their cadets to take classes in calculus, physics, and chemistry! People must

[8] See, e.g., Ronald B. Standler, *Creativity in Science and Engineering,* 1998, http://www.rbs0.com/create.htm .

understand the nomenclature of mathematics and science, as well as understand elementary facts and laws of science, before they can understand new scientific discoveries. And if nonscientists find learning mathematics and physics to be difficult, then perhaps those nonscientists would treat scientists with more respect and deference. It is *not* my desire to stuff *every* college graduate full of the latest scientific knowledge: calculus was invented more than 300 years ago, most of the material taught in introductory physics classes was discovered more than 100 years ago — this old material is now part of what should be general knowledge. And I advocate reciprocity: science majors should take many humanities classes.[9]

2. Scientists and engineers in universities continue to publish their work in academic journals that are accessible to few people outside major universities. The failure of academics to get their work at least partly understood by intelligent people outside universities fosters the illusion that academics live in an "ivory tower" and do nothing of practical importance to "real world" society.[10] Given this self-imposed isolation of academics, it's not surprising that society has responded by marginalizing academic research.

I do not blame scientists for their failure to be engaged in politics, because skill in scientific research seems to be orthogonal to skill in politics. There are only a few academic administrators and managers of industrial research laboratories who have both an understanding of science and political skills. In my opinion, scientists should do scholarly research, and society should give adequate financial resources to productive scientists and universities. It is extraordinarily difficult to be a competent and creative scientist, so let's not make it even more difficult for scientists by demanding that scientists *also* be politically astute.

politics

There is something strange with the American political process that explanations by scientists, engineers, and university administrators of the practical importance of scientific research is dismissed as self-serving propaganda by recipients of government money. On the other hand, any attempts to reform the U.S. Government's Social Security program is met with howls of protest by affected retirees, which are taken seriously by Congressmen and *not* dismissed as self-serving propaganda. Similarly, any attempts to end entitlements and preferences for racial minorities in the USA would be met with howls of protest by affected people, which prevent Congress from ending those preferences.

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[9] Ronald B. Standler, *Liberal Arts Colleges as Preparation for a Career in Science,* 1998, http://www.rbs0.com/college.htm .

[10] Toward the end of my essay, *Evaluating Credibility of Information on the Internet,* 2003, http://www.rbs0.com/credible.pdf , I criticize academic administrators for rewarding publication in peer-reviewed scholarly journals (which few people outside research universities read), while denigrating publishing at websites that are accessible to everyone.

Should the scientific community hire the AARP or NAACP to lobby Congress? I believe the problem is not the quality of lobbying, but the perception of *need* by politicians. Politicians understand that retired people *need* more money, to avoid a miserable life. Politicians conventionally understand that racial minorities *need* entitlements, in order to compensate for many generations of discrimination by the white majority. The needs of retired people and the needs of minorities are easier to understand than the needs of research scientists. Moreover, politicians see scientists as arrogant and aloof from ordinary people, and politicians seem to enjoy a sense of Schadenfreude at seeing unemployed scientists.[11]

Scientists are not seeking charity. Scientists deserve financial support for their research, not because of personal fullfilment of aspirations of individual scientists, but because the results of scientific research benefits society. Open publication of the results of research is repayment for society's investment in research. Of course, not every research project is worth the money spent on it, but — because research involves exploring the unknown — it is not possible to predict the results of a research project or the long-term impact of those results on society. Because scientific research benefits *all* of society, governments *should* provide adequate financial support to research.

Honesty compels me to observe that many of the civil rights laws that gave preferences and entitlements to racial minorities in the USA were the result of riots in ghettos in the USA during the 1960s and 1970s. On the other hand, scientists and engineer did *not* riot, and they are a small, nonvocal segment of the population, thus they are easy for politicians to ignore (unlike retired people and unlike minorities).

Links to Other Resources

The following webpages are *not* a bibliography for my essay, but do offer other perspectives on the decline of funding for scientific research. The dates are largely meaningless, since the following webpages may be revised.

Andrew M. Odlyzko, *Decline of Unfettered Research,* 20 pp., http://www.dtc.umn.edu/~odlyzko/doc/decline.pdf , revised 4 Oct 1995.
A wonderful essay that laments the disappearance of pure scientific research, driven by curiosity of scientists, and not by desire for either corporate profits or military power. An HTML version is posted at: http://www.math.washington.edu/Commentary/science.html .

L. Larrabee Strow, *Random Observations on Federal Funding for Physics, Astronomy, and Earth Science,* http://asl.umbc.edu/~strow/Notes/funding.html , revised 2 April 2001.

[11] See the specific example of the Superconducting Super Collider, mentioned above at page 8.

Claude R. Canizares, testimony at National Research Council, 15 pp., http://www.aau.edu/research/NRCDoDBasicResCom.pdf , 6 May 2004.
Professor Canizares identifies three "areas of significant concern regarding basic research":

(1) "The roughly flat federal funding for the physical and engineering sciences, and its relative decline compared to biology and medicine.

(2) "The relative shift toward applied and away from basic research, particularly within the funding for physical science and engineering.

(3) "The increased attempts by federal agencies to apply inappropriate restrictions on fundamental research thereby undermining the unrestricted environment that MIT and most universities view as an irreducible core principle."

Information and comments on current and recent U.S. Government budgets for scientific research is available at:

- the American Institute of Physics, http://www.aip.org/
- the American Association for the Advancement of Science, http://www.aaas.org/spp/rd/
- the Association of American Universities, http://www.aau.edu/research/funding.cfm .

Conclusion

It would make a nice thesis project for a graduate student in an American History department or a Government department to collect citations to the following sources:

1. Forecasts by the U.S. Government during the 1950s and 1960s that we would *always* have a shortage of physicists, mathematicians, and engineers. Statements by politicians and government officials urged young people to major in science or engineering in college. Such forecasts and statements were widely reported in the news media, such as *Newsweek, Time,* and *U.S. News and World Report,* and influenced the choice of major subjects by students in colleges.

2. Waves of massive unemployment amongst physicists and engineers during the 1970s, 1980s, and early 1990s, caused mostly by sudden reductions in military spending on new weapons systems and also caused by reductions in financial support for scientific or engineering research. Such effects were chronicled in, e.g., *Physics Today, Chemical and Engineering News,* and *Aviation Week and Space Technology* magazines.

3. Examine the economic consequences on scientific research of the Gramm-Rudman Act, as chronicled in the sources mentioned in item 2.

This document is at **www.rbs0.com/funding.pdf**
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