Defending Research: The Politics of the Pentagon's Research Budget

Working Paper

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Introduction

The Pentagon, the home of the Defense Department as well as the armed forces of the United States, wields a larger research budget than any other agency in the federal government. With a budget of $64 billion in 2015, it dwarfs other research funding agencies like the National Institutes of Health ($30.1 billion) and the National Science Foundation ($7.3 billion).

Scholars analyzing research funding typically separate defense and non-defense budget outlays. The rationale is that the bulk of the Pentagon's dollars are spent on testing and development of new weapons systems, rather than on the sort of fundamental science that might lead to critical breakthroughs.

The exception to this view has been DARPA, the Defense Advanced Research Projects Agency. The agency, which was founded as ARPA during the Cold War to accelerate U.S. science and technology advancements against the Soviets, has had an incredible influence over the evolution of a number of areas of inquiry, including most prominently the development of computing.

While the academic literature on DARPA has explored the development of many of that agency's technical achievements, it has mostly ignored the agency's budget as well as the wider environment for research at the Pentagon. This lack of deep study is partly a function of the classified nature of America's defense complex, but a simpler explanation is simply that the government doesn't provide easily-accessible datasets to evaluate these defense appropriations. Unlike the NSF or NIH, there is no public institutional research arm that actively seeks input from scholars on the performance of these agencies.

This opaqueness makes it difficult to evaluate the quality of these research programs as well as their efficiency. With concerns from many scholars that defense spending can crowd out other areas of critical research in basic science, this sort of analysis is crucial for getting a handle on the current environment for research funding in the United States.

Fortunately, the Pentagon does provide extensive budget materials to Congress as part of the annual appropriations process. Although not readily analyzable, these documents do provide ways to index defense research funding across different appropriations years. Using a dataset constructed from these documents, I was able to begin evaluating trends in defense research finance over the last twenty years, the historical budget data available from the Defense Department's comptroller.

Through this paper, I analyze this dataset to investigate the Pentagon's research funding agenda, evaluating three different cross-sections of the data. First, I look at overall aggregate data in order to probe the political environment that the military has faced across three different presidencies. Unsurprisingly from media coverage of projects like the Missile Shield, I find that the Bush years led to a large increase in funding to development and demonstration that has since disappeared under the Obama administration.

However, despite that surge in highly-applied science, I find that the Pentagon's basic science funding actually grew slowly but steadily during the Bush administration when looking at individual research programs. Furthermore, since the arrival of Obama in 2009, basic science funding has increased significantly and recently reached a peak in 2014, contradicting the perception that the Pentagon has moved away from fundamental science. Finally, I analyze the appropriations that are separately attributed to the Army, Navy, Air Force, and Defense departments, finding that all four departments have seen their share of overall research stay almost perfectly flat over the past twenty years.

This paper begins with a background of defense research funding. Then, I will describe the methodology for creating the dataset used in this paper (Python computer code is located in an appendix). I will then discuss my findings, with a conclusion that offers several possible extensions of this work.

Background

Since the publication of "Science: The Endless Frontier," Vannevar Bush's famous treatise on the importance of government funding of basic science, there has been a constant debate about the shape and nature of the U.S. research enterprise.[1] Following World War II, Bush wanted to build an elite agency that would only fund the most meritocratic research, which came into conflict with representatives in Congress who felt that geographical considerations should have a larger role.[2] The multi-year development of the National Science Foundation was mired in politics and debate for years, but ultimately, Bush won, and the NSF was born with the mission of producing the very best fundamental science.

Despite the perception that it focuses exclusively on weapons, research within the defense community in the United States has been deeply connected to basic science advances. The

[1] Bush, Vannevar. "Science: The Endless Frontier." (1945).

[2] Kleinman, Daniel Lee. *Politics On The Endless Frontier: Postwar Research Policy In The United States.* Duke University Press, 1995.

Manhattan Project, the largest single research outlay ever made by the United States, developed the nascent theory of atomic physics while also building the first nuclear weapons.[3] Outside of that single project, there was wider interaction between early university research labs, the government, and industry, which historians believe was a key element of the Allies victory in World War II.[4] It was partially that fusion of science and security that inspired Bush to found the NSF.

The impression of U.S. technological superiority was shattered in 1957 with the launch of Sputnik, the Soviet satellite, generally regarded as a watershed moment in American science politics. Suddenly, the earlier debates over the NSF faded away in Washington, and instead a new consensus formed on the need to respond to the technological gap between the US and the Soviets.[5] The creation of ARPA (later renamed DARPA) was part of this movement, as was the creation of NASA and the passage of the National Defense Education Act,[6] all of which occurred in 1958.

Thus, the inception of ARPA was fundamentally different from that of the NSF. ARPA was not the visionary agency of a singularly powerful advisor like Bush, but rather a strategic response which afforded this new agency with nearly limitless authority to do what was necessary to build up U.S. science and technology.[7] Over the next decades, this small but powerful agency would take the limelight of the Pentagon's research activities.

Given the classified nature of much of the defense research from this time, the history of the Pentagon's research programs is practically the history of ARPA. Concerns about

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[3] Hughes, Jeff A. *The Manhattan Project: Big Science And The Atom Bomb.* Columbia University Press, 2002.

[4] Kennedy, Paul. *Engineers of Victory: The Problem Solvers Who Turned The Tide In The Second World War.* Penguin UK, 2013.

[5] Killian, James Rhyne. *Sputnik, Scientists, And Eisenhower: A Memoir Of The First Special Assistant To The President For Science And Technology.* MIT Press (MA), 1977.

[6] For more details, see Clowse, Barbara Barksdale, ed. *Brainpower for the Cold War: The Sputnik Crisis and National Defense Education Act of 1958.* No. 3. Greenwood Publishing Group, 1981.

[7] "History." Defense Advanced Research Projects Agency. `http://www.darpa.mil/about/history/history.aspx`

command-and-control vulnerabilities during nuclear strikes forced the agency to consider decentralized, networked based means for communication. In that work, the agency sponsored and promoted ARPANET, which eventually morphed into the modern day internet backbone.[8] ARPA was also key in the development of many components of modern computing,[9] a program led forcefully by J.C.R. Licklider through the Information Processing Techniques Office.[10] On the more applied side, the agency was also pivotal in the creation of the Stealth Bomber and the M-16 assault rifle.[11]

ARPA attempted to distinguish itself from other federal government research funding bodies and even the Pentagon's own research by emphasizing its "high-risk high payoff" approach to science investments.[12] As Richard Van Atta describes in his fiftieth anniversary discussion of DARPA:

> What is important to understand at the outset is that in contrast to the then-existing defense research environment, ARPA was designed to be manifestly different. It did not have labs. It did not focus on existing military requirements. It was separate from any other operational or organizational elements. It was explicitly chartered to be different, so it could do fundamentally different things than had been done by the military service R&D organizations.

While DARPA has continued this legacy of pathbreaking work, there has been greater concerns that this engine of basic science at the Pentagon has been neutered by a greater emphasis on applied weapons development. As we will see in the analysis of the Pentagon's research budget, testing and development appropriations surged throughout the

[8] Hafner, Katie. *Where wizards stay up late: The origins of the Internet.* Simon and Schuster, 1998.
[9] Ceruzzi, Paul E. *A History Of Modern Computing.* MIT press, 2003.
[10] Norberg, Arthur L., Judy E. O'Neill, and Kerry J. Freedman. *Transforming Computer Technology: Information Processing For The Pentagon, 1962-1986.* Johns Hopkins University Press, 2000.
[11] Van Atta, Richard. "Fifty years of innovation and discovery." *DARPA: 50 Years of Bridging the Gap* (2008).
[12] Ibid.

Bush administration, a consequence of several large projects, including most prominently the Ballistic Missile Shield.

One reason this study looks broadly at the overall defense research budget is that scholars need to be cautious in too hastily dividing these dollars into basic and applied sciences. As scholars like Donald Stokes have pointed out, it is often the combination of these two that creates the most fundamental advances.[13] Furthermore, the kinds of testing conducted by the Pentagon often require concomitant developments in instrumentation, a potentially crucial vehicle for science advancement. While other defense agencies outside of DARPA may be less connected to universities and the academic research enterprise, we should be hesitant before declaring such efforts fruitless for science.

Methodology

As part of its yearly budget request to Congress, the comptroller of the Defense Department submits budget materials documenting all spending the department intends to conduct in the coming fiscal year. The comptroller submits several different documents, including the "green book," which is a summary of all defense spending programs, as well as several highly-detailed documents related to areas such as Procurement Programs, Military Construction, and for our purposes, Research, Development, Test & Evaluation Programs, which is given the identifier "R-1."

Each R-1 lists every program currently being funded through the RDTE section of the Defense Department, including a summary title, a program element number for tracking purposes, and past and current fiscal year budget amounts. The documents also categorize the spending by department of the military (Army, Navy, Air Force, and Defense, which

[13] Stokes, Donald E. *Pasteur's Quadrant: Basic Science And Technological Innovation.* Brookings Institution Press, 1997.

includes agencies like DARPA, the Missile Defense Agency, and the Defense Intelligence Agency). The comptroller also notes whether a specific budget line item is considered classified. Summary totals of spending are provided for a variety of aggregation levels.

These budget documents were accessed through the comptroller's website.[14] Currently, the comptroller provides access to budget documents submitted to Congress in fiscal years 1998 to 2016. I collected all the budget documents in Excel format. Unfortunately, an Excel version for fiscal year 2000 is not provided for the R-1 budget document, making it nearly impossible to extract the data from the replacement PDF file.

I took the Excel files and converted them into comma-separated values format, in order to easily import them for statistical analysis. As part of this process, I removed the summary statistics, notes, and other rows of the file that were unrelated to a specific budget line item. From there, I imported all of the data into a SQLite database, with each row representing one line item in one fiscal year of the budget data.

From my investigation, it appears as though the Defense Department maintains the same program element identification number for each budget item from year to year, making comparisons across time possible. I created time series for each program element based off of this budget data, and compiled the results into a single comprehensive budget table representing all programs and all twenty years of fiscal data.

During the Clinton and later Obama years, the Defense Department reported a separate classified programs aggregate line item. This number can be quite significant. For example, in fiscal year 2015, programs aggregated under program element "9999999999," which identifies classified programs, were valued around $15.7 billion, or approximately 24.3% of the Pentagon's total research budget. This sort of aggregated data is not particularly useful for this analysis, since my objective is to assess the changes to funding at the program level.

[14] `http://comptroller.defense.gov/budgetmaterials/budget1998.aspx`

For all analysis in this paper, I exclusively used data from unclassified programs.

Building the time series data table was not trivial, since the Defense Department's numbers in a current fiscal year are rarely equal to the numbers reported as historical values in future fiscal year reports. For this dataset, I took the most recent fiscal year that reported a given year's data, making an assumption that the actual budget values become more accurate with time.

For example, the 2003 fiscal year budget number is located in the budgets of fiscal years 2003, 2004, and 2005. In this case, I used the reported value from 2005, which takes better account of the actual dollars appropriated from Congress than the projected budget in the actual fiscal year. One area for improvement of this working paper would be to interview a member of the Defense Department budget staff and get a better feel for how these numbers are calculated, particularly in past years to ensure that these assumptions are accurate.

A couple of other issues arose in compiling the data. I replaced the missing 2000 fiscal year data with numbers from budgets in other years. This may have a small impact on the quality of that year's numbers, but I believe it should be minimal. In the R-1 documents beginning in 2009, the Defense Department started separating out its base budget request and its Overseas Contingency Operations budget, which includes funds for the wars in Iraq and Afghanistan. When possible, I used the combined total of the values, although the vast majority of research funds are appropriated in the base budget.

Finally, in 2011, Congress failed to pass a budget, and instead passed a continuing resolution (CR) that funded departments partially through the year until a new budget could be passed. This massively complicates the data from that year, since the CR offered slightly reduced funding, only to accelerate funding quickly in the later part of the year. For this year, I chose the combined total of both the CR resolution and the OCO and base budgets.

After all of these details were worked out, I compiled the completed time series data. From here, I inflated the numbers from the given fiscal year into present 2015 dollars using the Consumer Price Index numbers provided by Robert Shiller and the Bureau of Labor Statistics.[15] All analysis in this report is based on these inflation-adjusted time series data.

Analysis

Aggregate-Level Data

As a first step to getting a sense of how the Pentagon has allocated its research funding over time, it's important to get an overview of the trends in the department's spending. Figure 1 shows the aggregate, inflation-adjusted budget over the years in which data was collected for all unclassified research programs. In addition to the main graph, I have added small vertical lines indicating the terms of Presidents Clinton, Bush, and Obama over the course of these fiscal years.

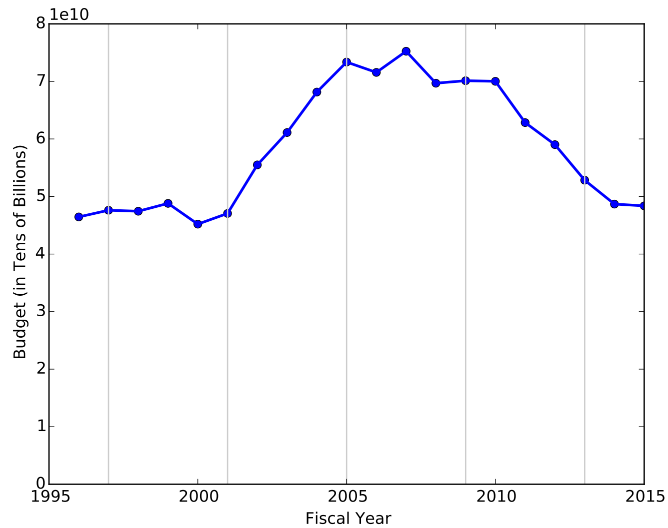
Immediately, it is clear that defense research funding has experienced very different budget environments depending on who holds the presidency. During the Clinton years, the budget is essentially flat, hovering around a mean of $47.3 billion.

This budget consistency is notable given the period. In the mid-to-late 1990s, there was a push from Congress and the President to cut back on defense and intelligence spending to create the so-called post-Cold War "peace dividend." The U.S. intelligence community sustained tens of billions of dollars of cuts during this period, and George Tenet, CIA director from 1997 to 2004, testified in 2004 to the 9/11 Commission that as a result of these cuts "We lost nearly one in four of our positions."[16] Those sorts of cutbacks seem to

[15] http://www.multpl.com/inflation/table

[16] Tenet, George. "Written Statement for the Record of the Director of Central Intelligence Before the

Figure 1: Annual Defense Research Budget, Inflation-Adjusted, Unclassified Programs



have completely missed defense research.

Following the election of George W. Bush, there was an immediate and striking four-year growth period in the size of the defense research budget. Between 2001 when Bush entered office to 2005 at the end of his first term, the budget would rise by 55.6% to \$73.4 billion. Interestingly, this surge in research came just toward the end of the budget doubling of the NIH, which took place from 1998 to 2003. As we will see later, a huge aspect of this funding boom was for the development of a ballistic missile shield, a key policy initiative of the Bush administration. 2007 would end up being the high water mark for defense funding, although the Pentagon's budget for it hovered around \$72.5 billion per year throughout Bush's second term.

The Obama administration has pushed to increase basic science research support, for example funding the ARPA-E office, an Energy Department-sponsored advanced research

National Commission on Terrorist Attacks Upon the United States." 24 March 2004. https://www.cia.gov/news-information/speeches-testimony/2004/tenet_testimony_03242004.html#Budget agency modeled after DARPA which was signed into law by Bush but had never before received funding.[17] The administration has also deeply cut funds to many of the most expensive research projects from the Bush years like the missile shield, while also increasingly classifying research, preventing analysis. The defense research budget was $70.1 billion in 2009, but declined in Obama's first term by 24.7% to $52.8 billion. By fiscal year 2015 – the most recent year of data available – the budget had declined to $48.4 billion. That figure is only slightly larger than the budget in 1996, which was $46.5 billion.

It's important to pause here and stress that this analysis is of the unclassified portion of the Pentagon's research budget. The overall 2015 budget, including classified programs, came to a total of $64 billion. So while there has been a real decline from the heights of the Bush years, it is important to acknowledge that the complete trend is not as severe compared to the unclassified-only budget. Without conducting interviews, it is impossible to determine whether the increasing classification of research that has happened during the Obama administration is a matter of a change in the agency's funding policies (i.e. the agency is spending more on applied military research instead of basic science) or just a matter of government transparency. One area for followup would look more closely at classified research to determine whether there are any trends worth exploring further.

Interestingly, there have been on-going concerns about the level of defense funding for research compared to basic science agencies like the NSF or NIST. However, the preceding analysis should give us some pause. The Pentagon's budget is still the largest in terms of overall dollars in 2015, with NIH coming closest at $30.3 billion. Nonetheless, the armed services have lost almost 40% of their own unclassified budget authority in a decade. While defense still dominates the research spending of the U.S. federal government, it is also clear from this data that its budget does not have nearly the wide support of agencies like the

[17] "ARPA-E History." ARPA-E. `http://arpa-e.energy.gov/?q=arpa-e-site-page/arpa-e-history`

NIH, and has in fact seen its budget decline in the face of austerity.

While looking at aggregate-level data reduces the underlying nuances of these policy changes, it also affords us an opportunity to understand the policy motivations of different administrations. This data makes clear that there is a real political element to the Pentagon's research budget, but that the politics is not strictly along partisan lines, as evidenced by the limited cuts of the Clinton years.

Program-Level Evaluation

Before diving into the program-level budget data, some sense of the scope of the Pentagon would be appropriate. Figure 2 shows the number of separate line item programs in the defense research budget for every year of data available. The comptroller has recognized 1721 line items across these two decades, with the average year holding approximately 725 line items. Clearly then, there have been massive shifts in funding over the years as the Pentagon redirects money to different research priorities.

There is incredible variation in the expenditures by line item. Some line items are as small as a few tens of thousands of dollars, while others have received tens of billions of dollars. Table 1 lists the top 10 expenditures by line item. What is clear from this table is that most of the top-spending items in the Defense Department's portfolio are applied technology development projects, such as several of the new air platforms for the Air Force as well as missile defense. On the flip side, two of the smallest line items at the Pentagon are Small Business Innovative Research programs, which received a total of $8,497 (0605502D8W) and $91,422 (0605502T).

To get a better handle on how this money is spent, we can investigate the budget categorization that the comptroller uses. The Defense Department has devised seven categories for its line items, the descriptions of which are available in Table 2. Analysis of line items

Figure 2: Number of Unclassified Line Items (Annual Budget)

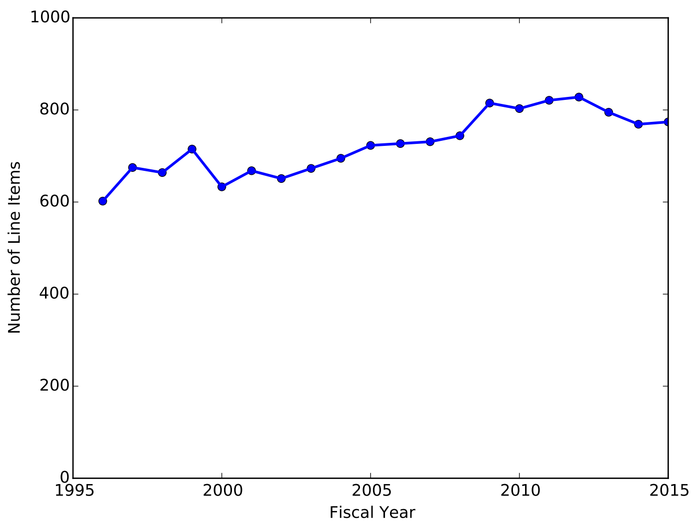


Table 1: Top 10 Line Item Expenditures (1996-2015)

Expenditures	Line Item
\$35,730,582,209	Ballistic Missile Defense Midcourse Defense Segment
\$22,231,459,543	Joint Strike Fighter
\$21,881,397,404	F-35
\$19,458,315,251	F-22
\$12,013,617,177	Aegis
\$11,964,435,587	Space Based Infrared Architecture
\$11,353,879,137	Armored Systems Modernization
\$11,313,061,085	Test And Evaluation Support
\$9,826,018,049	Ballistic Missile Defense Terminal Defense Segment
\$9,805,565,758	National Missile Defense

is challenging, since the budget code for a particular project can change over its life course, presumably as a project transitions from basic science to applied science and testing. One potential area of followup would be to interview the staff at the Defense Department comptroller's office to understand more about how a particular project is classified, and what happens when there is a mix of types of research being conducted within one particular program. While those details may affect the following analysis, it seems reasonable that the Defense Department is classifying projects as accurately as possible.

Table 2: Pentagon Budget Codes

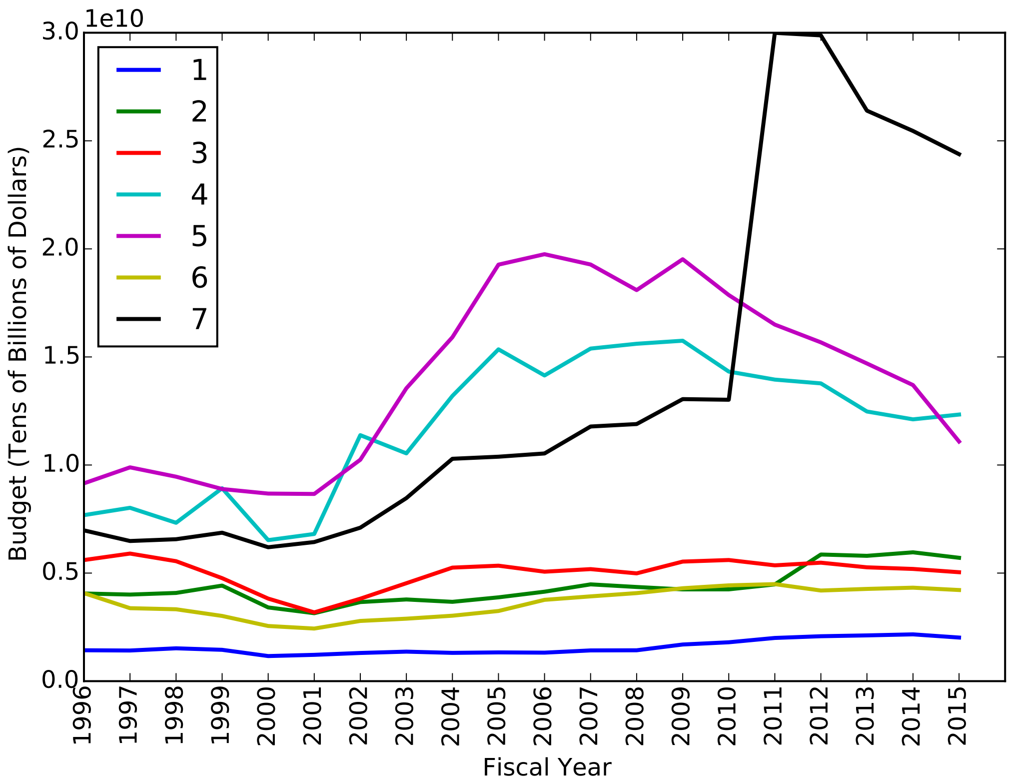
Code	Description
1	Basic Research
2	Applied Research
3	Advanced Technology Development
4	Advanced Component Development & Prototypes
5	System Development & Demonstration
6	RDT&E Management Support
7	Operational Systems Development

I have graphed a time series of the different budget categories over the period of 1996 to 2015 in Graph 3. Category 7, "Operational Systems Development," is oddly traced because this analysis is restricted to unclassified research, and category 7's budget swings wildly depending on the current classification of programs. It is kept here for completeness, although analysis of the trend line is effectively useless without better data about classified programs.

Basic Science Research

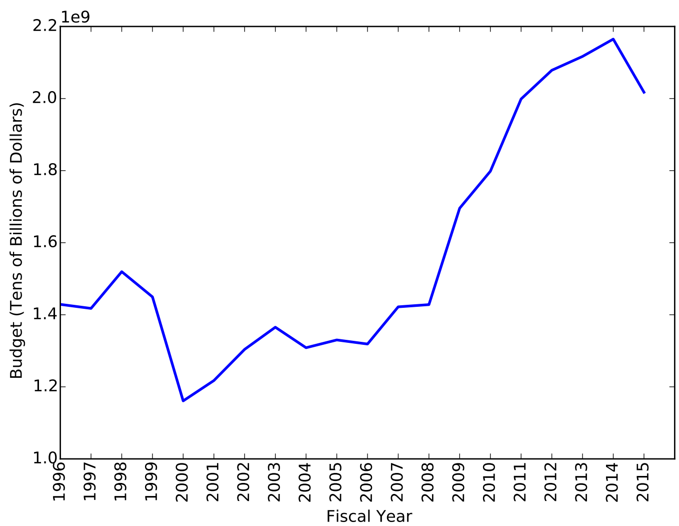
Looking through the other six categories though, we can begin to observe some interesting trends within the defense research agenda. Despite concerns that the armed services have

Figure 3: Annual Budget by Type of Expenditure



backed away from basic science, this analysis shows that they have actually received vast increases in such research funding over the last two decades, as can be seen in Graph 4. The budget for basic science was around \$1.3 billion per year before 2008, but has increased to an average of \$1.9 billion since 2008, a growth of 41%. As a share of the full budget (including classified and unclassified programs), basic science research has seen moderate gains recently, but still remains roughly 2.5% of overall expenditures.

Figure 4: Basic Science Research Expenditures



Given that most of the basic science research being conducted by the Defense Department is considered unclassified, this is a good metric to evaluate how much flexibility the White House has in changing both the levels of defense research as well as the department's mix of basic and applied science. Interestingly, there were fairly substantial cuts to basic science research funding starting in 1998 to 2000, a period that coincided with the initial doubling plan of the NIH. This is particularly notable given that the overall budget was relatively flat throughout the second term of the Clinton administration, and thus, there was a specific policy change in the research mix conducted at the Pentagon.

Basic science research funding increases slowly but steadily throughout the Bush years. However, given the massive expansion of the department's spending, which will be discussed further below, the actual proportion of basic science went down as a function of spending over this period. Gains in basic science accelerated rapidly under the Obama administration, reaching a peak in 2014. Given that this data is for unclassified projects, and the Obama administration has increasingly classified the defense research budget, it seems prudent to say that this acceleration is a conservative estimate of the true increase.

One way to evaluate these shifts is to analyze direct university research funding. The comptroller has multiple line items for basic science funding to universities. After aggregating those line items for every fiscal year, I find that these extramural grants have been essentially flat across all twenty years under study, with an exceptionally strong budget from 1997 to 1999. In those three years, the university basic science budget averaged $735 million, compared to $468 million in later years. These dollars are small compared to the sponsored research budgets of agencies like the National Science Foundation, which is almost four times higher.

In addition to the direct university grants budget, the Defense Department also has more defense-specific basic science research grants, which are generally placed under a "Defense Research Sciences" line item particular for each branch of the military. These grants include both funding for universities and other non-profit research organizations as well as intramural research projects. These four line items are by far the greatest expenditures on basic science, with a combined total of $23.3 billion spent over the last two decades.

To get a sense of what these sorts of line items encompass, let's analyze the Army's budget in fiscal year 2014 for defense research sciences. The total budget was about $217 million, with $78 million going to university single investigators, the single largest component. The next component, which was done intramurally, was for research in "Battlespace Info & Comm Rsc" coming to $21 million. A variety of other parts of the program make up the balance.

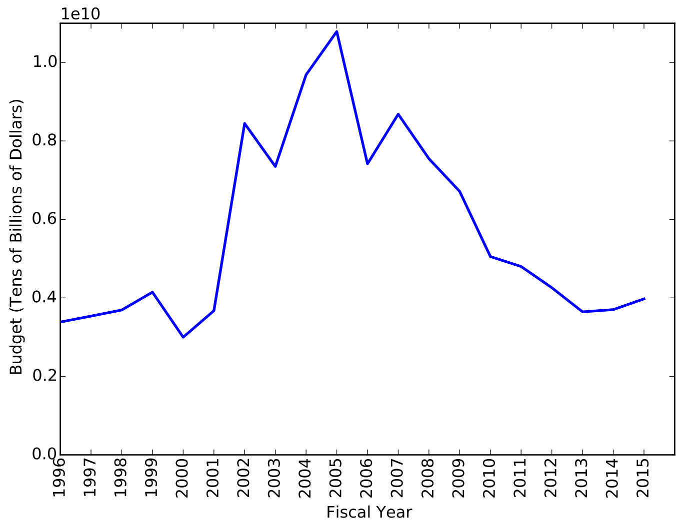
The message from this data is clear. Basic science funding has increased regularly since 2000 on an inflation-adjusted basis, an exception to the trend at many federal government agencies, which have seen cycles in their funding as policymakers surge funding to one agency only to later let the budget languish against inflation. Whether the rapid rise in this budget by the Obama administration can be sustained will be an interesting question to watch over the next few years.

Development and Demonstration

Looking back toward the budget areas in Graph 3, we see that three other areas have tracked basic science research funding fairly closely: "Applied Research," "Advanced Technology Development," and "RDT&E Management Support." All three are worth significantly more than basic science research, around $3-5 billion depending on the year and program. What does pop out from this graph though is the massive funding spent on development and demonstration. Budget areas 4 and 5, "Advanced Component Development & Prototypes" and "System Development & Demonstration" respectively, have traditionally received the bulk of the Pentagon's research funding.

As before with basic science research, there is an obvious political element to these budget components. This type of research was funded relatively flatly during the second term of the Clinton administration, only to see massive growth throughout the Bush terms. From the beginning of the Bush administration in 2001 to the budget's peak in 2006, program development more than doubled from $15.2 to $33.9 billion per year. Those funds started decreasing as soon as the Obama administration took office, and by 2015, the total numbers had decreased to $23.4 billion (with the usual caveat regarding classified expenditures).

Figure 5: Ballistic Missile Shield Research Funding



A look at the components of these aggregate budget figures explains this large shift in resources and the role of politics in the department's planning. The largest component by far was for the development of a ballistic missile shield, which netted a whopping $113.5 billion over the last two decades. A particularly favorite project of the Bush administration, the Defense Department spent heavily under these line items during the mid-2000s, reaching a peak of $10.8 billion in 2005.

Although a massive outlay of financial resources, my analysis doesn't seem to indicate that funding for the missile shield crowded out other research. Much of the growth and later decline of the defense research budget can be attributed to the ebb and flow of the missile shield project. It is clear though that the Obama administration was not nearly as excited by the prospects of the missile shield as his predecessor, and shrunk its budget to a low of $3.6 billion in 2013 – a cut of 67% from the project's peak.

Not all development projects are as long-lasting as the missile shield. Instead, projects often surge funding during key testing phases, and then see their budget authority diminish as research is completed. This pattern can be seen in both the development of the Joint Strike Fighter (JSF) and the F-22. For the JSF, there were heavy increases in expenditures for testing starting in 2001 before later decreasing in 2010 with its introduction into service. The F-22 fighter, developed as part of the Air Force's Advanced Tactical Fighter program, saw its research funding essentially hit zero following its launch in 2005.

Altogether, there are a total of 587 programs that have been funded under these two budget areas over the past two decades. The story of many of the others is the same as for these large fighter platforms, including a ramp up of funding as a program is reaching testing and deployment, and then a rapid series of cuts as development concludes. Some programs, like an "Information Operations Technology" program (0603690F), lasted for as short as a single year.

While the main thrust of these testing programs is to prove that these technologies are ready for the battlefield, there is also a potential gain for basic science. Instrumentation is a key element of testing systems, and such programs have traditionally been rich areas for scientific development and progress. This is an area where the military holds a unique advantage over agencies like the National Institute of Science and Technology (NIST), since the Defense Department is able to continuously engage with both the basic science and testing elements of the defense research agenda, potentially allowing each to inform the other. Thus, while testing may dwarf basic science funding at the Pentagon, we should be careful before judging testing as useless for the advancement of science.

Department-level Analysis

In addition to an overview and a program-level view of defense research expenditures, another cross-section for analysis is possible across the different branches of the armed services. Organizationally, the Army, Navy, and Air Force have their own civilian departments, and they along with Defense send separate appropriations requests to Congress for funding. For this reason, the Defense Department's comptroller categorizes all research funding by which appropriations account it originates from. Although these four departments may work collaboratively on some research projects, ultimately the appropriations process requires one to be held responsible for any given program.

The Defense Department's budget is the most diverse of the four, an aggregation of research funding for almost two dozen separate agencies. DARPA is easily the most well known of the set, but large appropriations for research are also made to the Missile Defense Agency, the Office of the Secretary of Defense, and the Chemical and Biological Defense Program (among the agencies, these were the only four with more than a billion dollars in appropriations in 2015). The armed services are not organized as disjointly, and tend not to separate their budgets any further beyond the comptroller's seven budget areas described before.

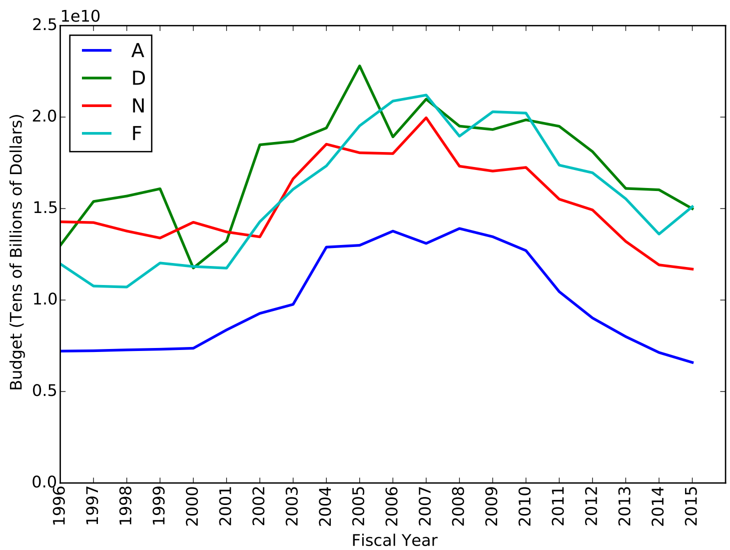
To investigate whether these four departments have divergent funding outcomes under different political environments, I aggregated DARPA's budget data for each department. Table 3 gives a high-level analysis of the total expenditures by department. Interestingly, the expenditures for Defense, Navy, and Air Force are all roughly similar with each other, while the Army has received significantly less research support. Traditionally, the Air Force has been perceived to be the center of the defense research budget because of its flight development programs, however, this top-line view shows that other departments are in fact equally receiving funds.

Table 3: Aggregate Unclassified Spending by Department (1996-2015)

Department	Component Code	Aggregate Spending
Defense	D	$347,779,233,087
Army	A	$197,808,934,956
Navy	N	$316,373,073,431
Air Force	F	$307,139,118,005

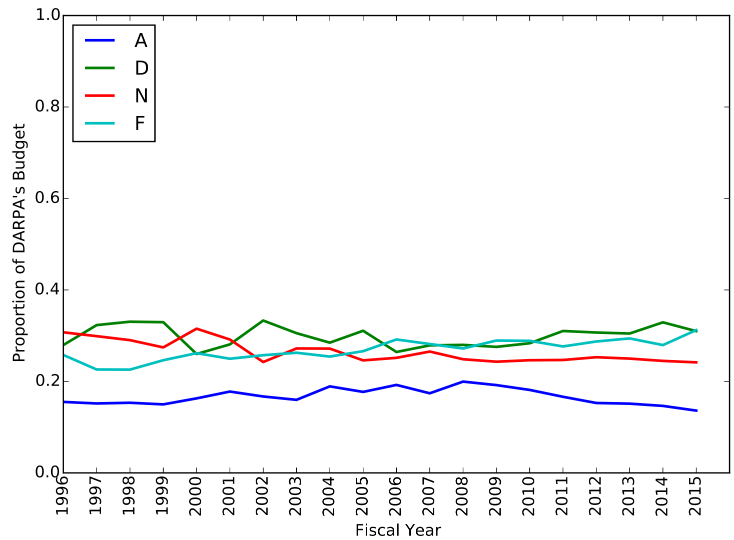
Looking at the absolute and relative time series shown in Graphs 6 and 7, we can start to see the vast changes in the budgets of the different departments over time. As can be seen in Graph 6, expenditures by department mostly follows in line with the overall spending of the Pentagon on research, with a huge surge in spending in the mid-2000s, and smaller budgets in the Clinton and Obama administrations.

Figure 6: Advanced Research Expenditures by Department



What is far more surprising though is that the relative budgets of the departments have barely changed over the last 20 years, despite massive fluctuations in the overall size of

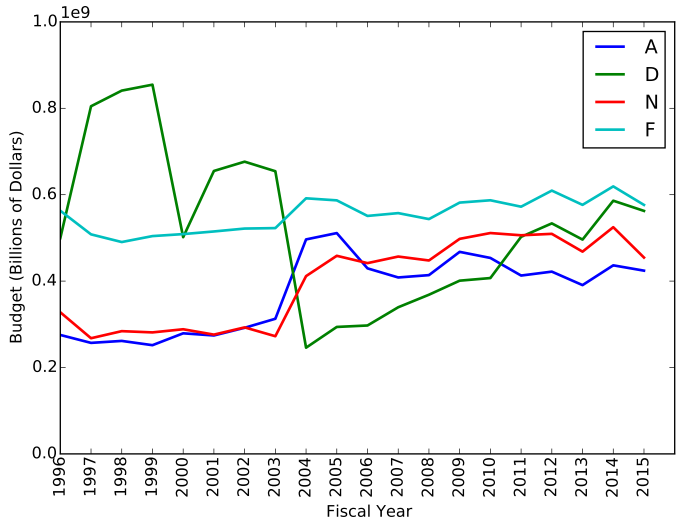
Figure 7: Advanced Research Expenditures by Department (Proportional)



the budget as well as the specific programs that the Pentagon is funding. Throughout this twenty year period, the Army's share of the budget has averaged 16.7%, while the shares for the Navy and Air Force have both averaged around 26.7%. The Defense Department comes in slightly higher at 29.9%. Although these departments certainly coordinate their budgets before sending their requests to Congress, this finding is striking given the independent appropriations processes on Capitol Hill.

One final element of analysis here is around basic science research funding, one of the key motivations for studying this data. Graph 8 charts the levels of basic science research funding conducted at each of the departments. Again, we see that the three military departments have maintained very stable budgets throughout the period under study, although the same cannot be said of the Defense Department. There is obviously large variation over time in its budget, with a surge in the late 1990s that was completely eliminated by 2004. We then see the budget increase steadily over the last decade.

Figure 8: Basic Science Expenditures by Department



This data shows that we need to slightly revise our conclusion about the stability of basic science at the Pentagon. While the budget has been even overall, the source of those funds have shifted quite substantially over time, creating the same sorts of surge and decline cycles seen in other research funding bodies. One of the benefits of the four department structure in defense is that these gains and losses seem to be canceling each other out, so while the Defense Department may be variable, the overall defense budget tends not to be.

Conclusion

The Pentagon remains the largest research funding agency in the United States, with a budget unrivaled by any other country. Despite the massive outlays the Defense Department makes every year though, scholars have tended to ignore the details of its budget, given its lack of comprehensive and easily-accessible datasets. That perception is not valid however, since the agency actually makes extensive data available for analysis through its budget materials to Congress.

Using a dataset constructed from those materials, this paper investigated the department's research trends over the past two decades, with a particular focus on basic science research funding. This working paper is a first exploration of this dataset, which is quite rich in detail. Among the major findings are the importance of the White House in the specific research priorities of the department, the steadily increasing overall support of basic science, as well as the surprising result that the different departments within the defense apparatus have maintained almost completely flat, inflation-adjusted research budgets over the last 20 years.

There are several areas for further exploration. The first, and perhaps most methodologically interesting, is around the department's budget preparation documents. Each year, the Defense Department submits rationales for every single line item in its budget, producing thousands of pages of documentation. One potential avenue for deeper exploration would be to do a content analysis of these documents, investigating whether the language of the agency adapts to different politics on Capitol Hill or in the White House.

My analysis centered around the Pentagon's line items, which are fairly well-defined programs that the department is conducting. However, the department's budget rationales also include itemized budgets even below the line item level, including every single individual research expenditure. This data is not in an easily accessible format (PDF), but with the right content analysis tools, it might be possible to extract this data and find further patterns in the way that the department has funded research.

This paper had to limit its analysis to the unclassified portions of the Pentagon's budgets. This is obviously not the limit of the activities that the agency conducts, and in fact, around 25% of its budget is classified with limited documentation. One possible extension of this research would be to further investigate these classified programs, as well as the politics of classification to see whether different administrations are more or less transparent about defense research funding.

The Defense Department has had a tremendous influence on the development of a variety of critical technologies today. It seems prudent to further explore its approach to funding as well as its resources for conducting that mission.