INSTITUTE FOR DEFENSE ANALYSES

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September 2019

IDA Document D-10885
Log: H 19-000508

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About This Publication

This work was conducted by the Institute for Defense Analyses (IDA) under contract HQ0034-14-D-0001, Project AI-2-4382, "Review of Defense University Research Instrumentation Program (DURIP)," for the Director for Basic Research in the Research Directorate of the Office of the Under Secretary of Defense for Research and Engineering (USD(R&E)). The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.

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Executive Summary

Background

The Defense University Research Instrumentation Program (DURIP) is a funding mechanism for purchasing research instrumentation and equipment with the general goal to modernize U.S. research infrastructure to promote high-quality research in areas of interest to the DoD. DURIP's intent to enable or facilitate research is related to but distinctly different from research grant funding in that instrumentation grants are to build capabilities while research grants are to execute research (i.e., use the research capability).

The Department of Defense (DoD), Office of the Director, Defense Research and Engineering (DDR&E) established DURIP in 1997 with oversight by the Basic Research Office of ASD(R&E). Since 2004, the awards have been funded through each of the Service's basic research office with coordination through OSD Basic Research. Proposals are subjected to competitive evaluation of the scientific and technical merit, first by DoD program managers who know the specific research domains and the current research efforts and capabilities. The selection process is then addressed at a more strategic level where Service leads and lab directors rank the qualified proposals. DURIP awards are made to research institutions with current DoD basic research grants and range from $50,000 to $1.5 million.

Key Findings and Conclusions

It appears as though DURIP is achieving its intent to fund the purchase of equipment that will then be used to conduct DoD research, which increases the research capability for DoD-funded principal investigators. Based on interviews with stakeholders, the overwhelming opinion is that the DURIP program is important for DoD in that it facilitates quality, groundbreaking research. The equipment seems to be heavily used and stays in use for a long period of time (i.e., a decade or more is common). The impact of DURIP is expansive: since 1997, there have been almost 4,000 DURIP awards, totaling over $800 million, awarded to 280 different institutions, in all 50 states as well as Puerto Rico and the District of Columbia. The awardees include both traditional research universities and universities that are working to build their research capacity, among them approximately 40 institutions identified as Historically Black Colleges and Universities and Minority Institutions. The funding level for DURIP varies across Services and across years, but on average is approximately one-fourth the funding level of Multidisciplinary University

Research Initiative and accounts for about 3.3% of DoD's basic research funding across all the Services.

The DURIP application and award process is influenced by the Service PMs, who will have discussions with potential PIs to discuss possible proposals; the PMs are the first level in the multilevel review of the proposals. The proposals are also reviewed by the Service hierarchy with a view toward strategic perspective across research domains, inter-Service coordination, and OSD approval before final awards are made. The influence of PMs, because of their detailed knowledge and understanding of research domains, seems appropriate; higher levels of DoD research management provide the strategic perspective for DoD across research domains.

Principal investigators and program managers indicated that DURIP facilitates higher quality research than would be possible without DURIP. Equipment purchases appear to have long-term impact (10+ years), which outlasts any single research grant. It also appears that DURIP awards tend to be given to researchers who are in the prime years of their research productivity and that they tend to be more productive in conducting DoD research after they receive the DURIP awards than research funded by other organizations. A comparison of pre- and post-research productivity (e.g., publications and citations) indicated that researchers tended to produce more research after a DURIP, and this research was more likely to be funded by DoD than other funding sources, suggesting that the research was relevant to DoD.

Six other equipment/instrument programs were identified for comparison, with two of those being by U.S. Government agencies and four by other countries. All the instrumentation programs suggest that such funding improves research capabilities, though there is little published evaluation of equipment-grant programs. One difference between DURIP and the other U.S. programs was that the other programs have a longer reporting period to capture actual research impacts, which is something that DoD should consider.

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1. Introduction

The Defense University Research Instrumentation Program (DURIP) is a funding mechanism for purchasing research instrumentation and equipment so that university labs can conduct high-quality research. DURIP funding functions as an enabler of research; that is, the DURIP funds are awarded to researchers who propose that the additional instrumentation will enable them to conduct new types of research or to conduct higher quality research than they could without it. The general goal is to modernize U.S. research facilities and infrastructure to promote higher quality research in areas of interest to the DoD.

DURIP's intent to enable or facilitate research is related to, but distinctly different from, most other research funding in the DoD. Other standard funding mechanisms like the Multidisciplinary University Research Initiative (MURI) or single-investigator university research grants are awarded to accomplish a research plan (i.e., conduct research activities). While potential research activities are described in a DURIP proposal, the funds awarded are only for the purchase of equipment, not for conducting the activities.

This distinction between research grants and an instrumentation or equipment grant may be explained with an analogy of food preparation. Obtaining instrumentation for a lab through DURIP is like buying an oven for a kitchen. The oven enables food to be cooked, but without an oven, the meals coming out of a kitchen would be limited to those that don't need to be cooked. For a single meal, you can't incorporate the entire cost of the oven because the price for the meal would be exorbitantly high. You need an oven before you can start cooking meals, and having a quality oven will let you make better meals. All ovens (i.e., instrumentation) are not the same (e.g., microwave, gas, electric, convection), and knowing what oven to buy depends on what type of meal (i.e., research) you want to prepare. Likewise, most laboratory research depends on specific instrumentation. Some types of research are impossible to perform without a particular instrument, so not having the instrument restricts the type of research that a laboratory can do. Obtaining the necessary instrument thus enables a laboratory to perform new research, or to more efficiently perform research, and the instrument can be used for many projects over many years.

This report is intended to be a review of DURIP within the context of DoD basic research. Because research instrumentation is used to conduct research, a review of DURIP cannot be done properly in isolation and must address the context of a broader research perspective.

A. Program Overview

The DoD, Office of the Director, Defense Research and Engineering (DDR&E) established DURIP in 1997 with oversight by the Basic Research Office of ASD(R&E). Since 2004, the awards have been funded through each of the Service's basic research offices with some coordination through OSD Basic Research. The DURIP efforts are selected through a competitive evaluation of the scientific and technical merit of submitted proposals. DURIP awards, which are made to research institutions with current DoD basic research grants, range from $50,000 to $1,500,000.

The expectation is that awards will augment current capabilities or develop new research capabilities in support of research that is important to DoD. Examples of awards include the following:

- Electroencephalogram (EEG) to measure the electrical activity of auditory nerve and auditory portions of the brain to better understand different types of hearing loss that may be due to brain injury versus auditory sensors in the ears.
- State-of-the-art high-speed video cameras that assess volumetric understanding of fluids that can be applied for autonomous vehicles seeing through rain and snow.
- Ultrafast, highly tunable laser systems that can be used to better understand skyrmions, which may be used in quantum computing.
- A next-generation DNA sequencing system that can be used to understand the mixture of genetic markers of microhaplotypes.
- Software-enabled satellite communication receivers that can be used to better understand space weather and instabilities in the ionosphere that disrupt radio communication.

The DURIP program is administered by the basic research agencies of the three Services: the Army Research Office (ARO), the Office of Naval Research (ONR), and the Air Force Office of Scientific Research (AFOSR). The program is coordinated by OSD's Office of the Director for Basic Research. Accredited, degree-granting U.S. institutions of higher education with programs in science, mathematics, or engineering are eligible to apply for this award. For-profit organizations are not eligible. Applicants must already be associated with a DoD grant to be considered for a DURIP award.

A central purpose of DURIP is to provide funding to acquire research equipment or instrumentation in support of research in areas of interest to the DoD. Thus, proposals can be for equipment that is not within the budget of a typical single-investigator award, to augment current research or to develop new capabilities. Multiple pieces of equipment can be purchased with a DURIP award, as long as the items comprise a "system" used for a unified research purpose.

B. DURIP Process

The DURIP award procedure is currently structured as a bottom-up process with initial determination of proposal merit beginning with program managers (PMs) in the Services' basic research offices. Relative merit of proposals are then assessed by basic research division or directorate leaders before final determination of awards are approved at the OSD Basic Research Office level.

While the funds used for DURIP awards are provided directly to the Services, there is coordination across the Services when research domains overlap. Applicants are permitted to submit proposals to multiple administering agencies, but if selected, only one agency will fund each proposal. There are no limits on the number of different proposals each applicant can submit or on the number of awards a single applicant organization can receive.

Equipment purchased by DURIP awards becomes the property of the university that receives the award; this research infrastructure may be shared across the university or even across multiple universities. Cost-sharing by the receiving institution is not required for this award. Applicants are not prohibited from including voluntary matching or cost-sharing in their proposal, but it is not considered in the evaluation. In addition to the equipment itself, allowable costs include reasonable costs for design, construction, assembly, or installation of equipment and computers for DoD-relevant research programs. DURIP awards do not cover the cost of construction or modification of buildings or support systems such as heating, ventilation, air conditioning, plumbing, or electrical; fixed equipment such as clean rooms or fume hoods; equipment purely for instructional purposes; general-purpose computing facilities, direct salaries of faculty, postdoctoral associates or students; and costs that are not allowable under Title 2 Code of Federal Regulations (CFR) 200 Subpart E – Cost Principles. This subpart of 2 CFR 200 describes the specific principles on the use of federal funds.[1]

Applications are evaluated using three criteria of equal importance:[2]

1. The impact of the proposed equipment or instrumentation on research the DoD currently funds, or plans to fund, and/or the likelihood of the proposed equipment to enhance current research capabilities or establish new research capabilities relevant to DoD's areas of interest.
2. Importance and priority of the DoD missions the proposed equipment or instrumentation will support.

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[1] https://www.law.cornell.edu/cfr/text/2/part-200/subpart-E.

[2] 2018 DURIP Program Announcement PA-AFRL-AFOSR-2017-0001.

3. Potential of proposed equipment or instrumentation to enhance institutions ability to educate future scientists and engineers through research conducted in disciplines important to DoD missions.

C. Purpose of Report

The purpose of this DURIP review is to provide an overview of the program, describe and analyze the selection methodology, and provide some highlights of additional research capabilities made possible through DURIP. During interim briefings, the sponsor suggested a few aspects of DURIP that IDA could attempt to analyze as part of the assessment. This includes the relative funding levels of DURIP versus MURI and how PMs influence the award process.

2. Methodology

For this review we employed a variety of quantitative and qualitative analysis methods to gain a broad and comprehensive perspective on DURIP. These methods included quantitative analysis of the grants awarded, research productivity of those who received awards, a quantitative analysis of the DURIP budget, structured interviews with stakeholders (from university and government perspectives), and qualitative comparisons with similar funding mechanisms employed by other U.S. agencies and foreign countries.

A. Quantitative Data Analysis

We employed several metrics involved in the review of DURIP. These include an analysis of the all awards to universities and principal investigators (PIs) (1997–2015), the budget for DURIP as well as research budget levels when the funding was provided directly to the Services' basic research offices (2004–2018), and research productivity measures for PIs that might have been influenced by receiving DURIPs.

1. Awards and Recipient Universities

The OSD Basic Research Office provided a listing of all DURIP awardees between 1997 to 2015 to IDA, specifying the awardees' names (i.e., PI), their university affiliation, state where the university was located (represented as two-letter postal code), the title of the award, and the funding level; these were organized by year of the award. These data records were processed and cleaned to allow for more accurate analysis. As part of this process names were standardized (PI and university name) to eliminate multiple spellings. Also, obvious typographical errors in the data were corrected. For example, two awards were attributed to the state of Alaska (AK) instead of Arkansas (AR) when the PIs and the universities listed were from Arkansas. To the best of the team's knowledge, all these errors were cleaned prior to analysis.

The analysis of the awards data included a depiction of year-by-year trends for the average award, the minimum and maximum award, and the standard deviation of the award size. The affiliations of DURIP recipients were also analyzed to determine the types of universities (e.g., R1 research universities, Historically Black Colleges and Universities/minority serving institutions) and the geographic distribution of awards across the United States.

2. Budget Analysis

The budget history of DURIP was collected from the enacted congressional budgets included on the R1 (funding at higher level program description of requirements) and R2 (funding description and justification at the program element and includes subprogram elements) forms for the execution of programs on an annual basis. This included line items for each of the Services' DURIP programs for the years 2004–2018. Budget information was obtained from the DoD Comptroller's Office website.[3] Also included in this analysis were the funding levels for the MURI program along with other basic research program elements (e.g., 601101 – In-house Lab Independent Research, 61102 – Defense Research Sciences, 6011030 – University Research Initiatives, 601104 – University and Industry Research Centers) to provide a comprehensive perspective on DURIP as a component of basic research funding.

3. Research Productivity Metrics

As a measure of research output, IDA analyzed data from Scopus (i.e., the scientific publication database owned by Elsevier) for publications and citations of work by DURIP recipients. While Scopus is not a complete collection of all scientific papers, its coverage is well regarded, and it had the largest amount of relevant data obtainable by IDA.[4] Furthermore, Scopus disambiguates author names and collects relatively complete sets of publications by individual researchers. This allowed IDA to automate searches for DURIP recipients by name and institution and then obtain data on each of their publications indexed by Scopus. Several analyses were then attempted to quantify various aspects of the DURIP program.

While these methods involve what is likely a significant portion of the research output by DURIP recipients, there may be four potential sources of unknown bias and limitations on the conclusions that may be drawn from this data. First, there are large unknowns concerning the data that IDA was unable to collect. Given the nature of Scopus's collection and the complications of searching a large dataset with only a limited amount of information supporting each query, there may be bias in these results toward research in certain fields, at certain institutions, or by researchers with certain types of names (Martín-Martín et al. 2018).

Second, because DURIP is not a research grant and due to the multifaceted natures of most researchers' output, determining the specific papers that relied upon DURIP equipment was not possible. The presence of numerous collaborators on papers means that it is challenging to consistently determine which role each author and piece of

[3] https://comptroller.defense.gov/Budget-Materials/#linkstoBM.

[4] https://www.elsevier.com/__data/assets/pdf_file/0017/114533/SC_FS_overview_WEB.pdf.

instrumentation played in the research output. While some standard practices exist for the ordering of author listings by level of contribution, they vary widely across fields. Therefore, IDA could not quantify the level of contribution of a DURIP recipient or the use of DURIP equipment on any specific publication. Also, many PIs have ongoing research in multiple areas that may or may not be related to DoD funding or their DURIP-funded instrumentation, which may exacerbate this problem.

Third, a natural increase in productivity over time is likely for professors seeking research funding and building a research program. This effect makes it difficult to identify the specific impacts of DURIP equipment on academic publishing versus other factors that may have influenced research productivity. IDA attempted to assemble a large group of similar PIs who did not receive DURIPS in an attempt to control for this aspect of the analysis. But using Scopus data, it was not possible for us to develop a logical comparison group of researchers who were similar to DURIP awardees in all other relevant factors except they had not been awarded a DURIP or benefited from DURIP (e.g., being professors at similar institutions, in similar fields, with similar research grant funding, while not being beneficiaries of DURIP equipment. Given the expansive nature of DURIP equipment and how long lasting DURIP equipment is, it is highly likely that professors at similar institutions, in similar fields, and with similar research grant funding as a DURIP awardee has benefited from DURIP despite not winning one, thus making a comparison group heavily biased or skewed. It was not possible using Scopus data to tease apart a professors who may collaborate with a PI who has won a DURIP and thus may have access to DURIP equipment but did not win a DURIP themselves. In fact, as will be discussed as part of the interview results, heavy sharing of DURIP equipment across fields, professors, and institutions was common. Due to these and other similar issues with crafting a logical and appropriate comparison group, the IDA team decided to forgo such a comparison using Scopus data.

Finally, biases are potentially introduced when analyzing publication databases relative to a certain year (or distribution of years). Scopus's collection has evolved over time, and earlier publications have also had more time to accumulate citations.

IDA sought to quantify various aspects of the DURIP recipients such as their affiliations, their funding profiles, and any changes in their publication portfolios before and after receiving DURIPs. Using the DURIP awardee list from 1997 to 2015, we performed an automated series of Scopus searches for each author. The series began with searches to find the PI from the given information (starting with a full name and institution but progressively broadening to just the author's last name if no valid results were found) and continued with retrievals of detailed information on their publication histories. Checks were added to ensure the returned authors had at some point been affiliated with the institution listed in the DURIP award list and that their name resembled the name given to IDA. If no good match to a DURIP recipient was found, the PI was not considered in the

subsequent analyses. While a perfect matching was not be guaranteed, manual checking suggests that the error rate was well below 5%.

Overall, IDA was able to collect data on 2291 of 2502 PIs (91.6%) and 373,192 unique publications from an original list of 3649 DURIP awards. The information collected included number of publications per PI for each year they published, the number of citations for the publications authored by the each PI, and the funding acknowledged for the PIs for each of their publications. The results section gives further information on the subsequent analyses performed on these data.

B. Structured Interviews of Stakeholders

A range of stakeholders were interviewed to gain the perspective of DURIP from both the university and the government. The university stakeholders included PIs who had been awarded DURIPs, PIs without DURIPs, and representatives from universities' supported research office. The range of universities included universities with very strong research funding and large endowments, as well as those with much smaller research funding and smaller endowments, including some universities considered Minority Serving Institutions. The government stakeholders included PMs, Service program coordinators, and a manager involved with promoting research across Historically Black Colleges and Universities and Minority Institutions (HBCU/MI).

The interviews were conducted with only one university or government representative at a time. At least two IDA research staff members participated in each interview. This arrangement allowed one IDA staff member to follow the set of questions in the structured interview protocols and the other to take detailed notes and assist with follow-up questions when needed.

The interviewees were initially contacted by email to ask them if they were willing to participate. To provide context for the interview, a brief listing of the interview/discussion topics was included in the email request. If they accepted, a more detailed set of general topics and questions was included in an email to set the date/time for the interview.

For each type of person interviewed (i.e., PI, office of supported research, government PM, Service program coordinator) there was a set of questions outlined to provide a consistent structure for the interview. This allowed for similar information to be gathered from interviewees with similar roles in DURIP. Table 1 gives summaries of the questions for each interviewee type.

A total of 33 interviews with stakeholders were conducted, which included 24 that provided a university perspective and 9 that provided a government perspective. Of the 24 interviewees from universities, 20 were PIs who had received DURIPs: 7 had received 1, 3 had received 2, 6 had received 3, 2 had received 4, and 2 had received 5 or more. They also represented awardees from all three Services. Two of the interviews were with

university researchers who were familiar with DURIP, had applied but had not been awarded a DURIP; as a result, they had an understanding of the program but had not directly benefited from it. In addition, two interviewees worked for the universities' office of supported research. The nine government interviewees represented a sample that had experience covering all the Services, five being currently active PMs that had detailed knowledge of their specific area of research and four having a higher level perspective that involved the strategic use of funding, including DURIP, to accomplish broad objectives of the Services or DoD.

Table 1. Roles of Interviewees and the Topics Covered with Each during the Interview

Role of Interviewee	Questions and Topics Covered in Interview
Principle Investigators	• General experience with the DURIP • How did you learn about DURIP? • Interactions with DoD PMs during application/proposal process • Link between DURIP and your DoD research programs • Reporting requirements • Impact of equipment you bought with DURIP funding • Use of equipment beyond the original proposal • Use of equipment by students or other faculty
Program Manager	• General experience with DURIP • Process for awarding DURIPs • Interactions with PIs as they apply for DURIP and after the award • Impact of DURIP awards on DoD research, research capabilities of a university, and broader scientific progress • Reporting requirements • Research with DURIP equipment leading to follow-on projects for DoD or others.
Program Coordinators	• General experience with DURIP • Describe the application/award process • Developing merit list of proposals • Signs of a well utilized DURIP award • Impact of DURIP awards on science (e.g., scientific breakthroughs, trained technicians/students, new capabilities) • Impacted of DURIPs on research capability at universities • Reporting requirements
University Supported Research Office	• General experience with DURIP • Describe the application/award process • Impact of DURIPs on research capability at universities (e.g., conducting research, attracting and training students) • Reporting requirements

A thematic analysis of the interviews was conducted to draw out relevant points made by the interviewees; these points were organized by the type of interviewee (e.g., PI) providing the perspective, as shown in Table 1. After each interview the IDA researchers who conducted the interview discussed the session and consolidated notes on a spreadsheet that was organized by interview topics. After all interviews were completed, the responses were analyzed to elicit common and relevant points across a type of interviewee; those points are presented in the Section 3.

C. Review of Relevant Comparison Funding Mechanisms

The DURIP program is specifically designed to fund research infrastructure in the form of instrumentation as opposed to grants to fund research activities. This type of funding is not unique to DoD in that other U.S. Government research organizations (e.g., NSF and NIH) have funding mechanisms for research equipment and instrumentation. In addition, other national governments (e.g., China, Germany, Japan, and United Kingdom) also have funding mechanisms for equipment and instrumentation. The intent of the review of comparison funding mechanisms was not to empirically assess how well an organization executed its instrumentation funding, but rather to provide a relative perspective on how other organizations work toward similar goals.

The comparison of funding mechanisms in other organizations was conducted using publicly available information. Finding this information required broad internet searches for organizations that execute instrumentation funding programs. Once organizations were identified, a refined information search attempted to uncover additional details about the program through public records such as strategic plans, program reviews, budget documents, and application process documents. Each organization had a different structure, and the levels of information sharing varied across countries. The findings of this review of comparison funding mechanisms are presented to address issues that are of relevance to DURIP, including intent/goal of program, actual funding levels and percentage of research funding, and application/award processes.

3. Findings

The review of DURIP employed a mix of research methods and analyzed DURIP from multiple perspectives. These include a description of how the awards were made across years (1997–2015), a comparative analysis of the DURIP budget in relation to MURI and other DoD research efforts, the impact of the awards on PIs' productivity, the use of DURIP equipment by PIs, and a comparison of DURIP to other non-DoD programs with a similar goal to purchase research equipment.

A. Description of DURIP Awards

From 1997 to 2015, there were over 3600 DURIPs awarded, representing approximately $795 million in total awards. Figure 1 shows the mean level of funding across years for the data IDA received (note there was no data for 2006) from the OSD Basic Research Office. To provide some context for the distribution and variability of awards the SD bars in the figure represent plus/minus one standard deviation of the mean, and the dashed blue horizontal lines represent the minimum and maximum values of awards. There is a relatively steady increase in the average award across years: the average award amount in 1997 was $163,128 ($243,825 in 2015 dollars), rising to $301,414 by 2015.[5]

[5] According to Bureau of Labor Statistics calculator for consumer price index, https://www.bls.gov/data/inflation_calculator.htm.

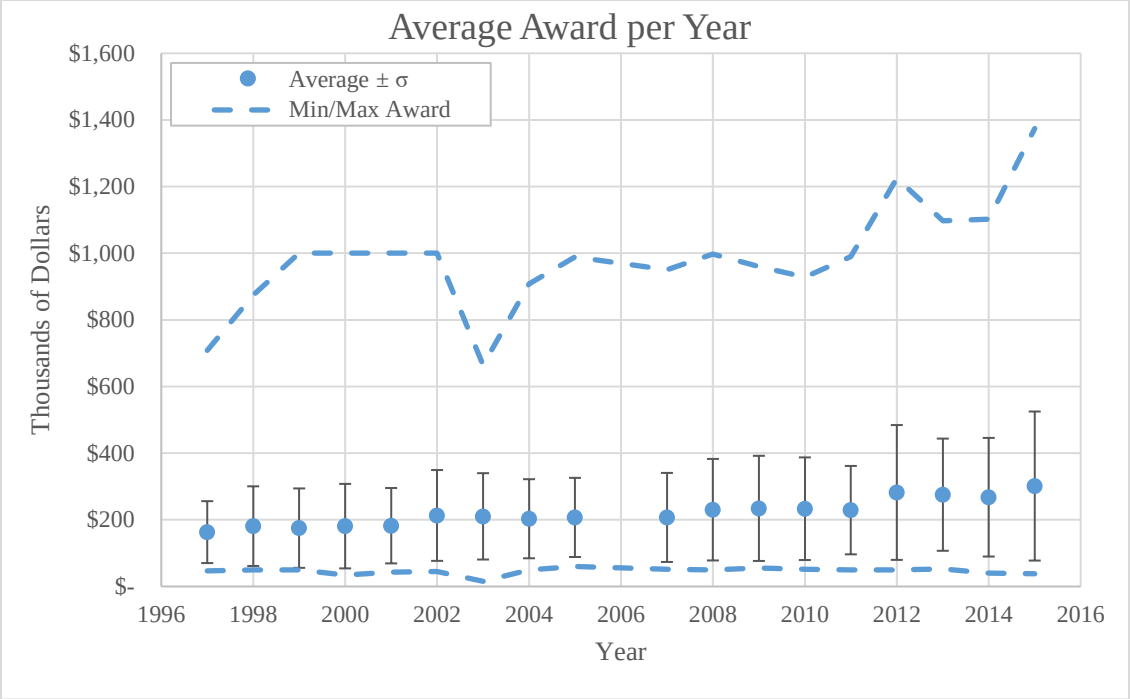

Figure 1. The Average Value of Awards (blue circles) along with the Minimum and Maximum Award Per Year (dashed blue lines). The SD bars indicate plus/minus one standard deviation of the from the average award funding (blue circles).

1. Distribution across Universities

The awards during this period went to 280 different institutions. The awards are predominately to universities with very strong research backgrounds, specifically R1 (doctoral universities with very high research activity) and R2 (doctoral universities with high research activity) institutions. These two research categories include institutions that awarded at least 20 research/scholarship doctoral degrees and had at least $5 million in total research expenditures.[6] There are other universities that conduct research and have received DURIPs, but are not be considered R1 or R2 universities because of their focus (i.e., more on professional practice doctoral degrees than research degrees), as well as master's colleges and universities (i.e., those focusing on master's degrees over doctoral degrees) and baccalaureate colleges (i.e., those focusing on bachelor's degrees, but they may have a few doctoral programs). Table 2 provides a listing of the 20 institutions that have received the most DURIP awards during the 1997–2015 time period, all of which are universities with strong research capabilities.

[6] http://carnegieclassifications.iu.edu/classification_descriptions/basic.php. Reported from the National Science Foundation (NSF) Higher Education Research & Development Survey.

Table 2. Top 20 Research Institutions That Have Been Awarded the Most DURIPs during 1997–2015

Institution (top 20)	Total # of Awards
Pennsylvania State University	114
University of California San Diego	98
Massachusetts Institute of Technology	96
University of Washington	90
University of Maryland College Park	79
Georgia Institute of Technology	78
University of Michigan	74
University of Arizona	70
Stanford University	65
University of Texas Austin	65
University of California Los Angeles	61
University of Illinois Urbana-Champaign	61
Purdue University	59
North Carolina State University	58
Virginia Polytechnic Institute and State University	58
Woods Hole Oceanographic Institution	56
California Institute of Technology	55
University of Central Florida	55
University of Southern California	53
Northwestern University	52

A strong majority (~70%) of the schools that received DURIP awards were rated as R1 or R2 research universities, but some awards went to schools that conduct research but do not have a research-focused tradition. This suggests that DURIP may not only be helping to increase the research capabilities of universities that routinely conduct research but also expanding the number of universities with research capabilities by funding research infrastructure improvements. For example, interviews the IDA team conducted with a PI DURIP winner at a minority-serving institution (MSI) and the Program Director of DoD HBCU/MI revealed that while some schools currently might not have a central research focus, awards like DURIP help build capabilities and establish a school in a particular research area.

A total of $48 million was funded through 295 DURIP awards to 42 universities classified as MSIs during the 1997–2015 time period, and 23 MSI schools received more than one award. MSIs are schools that either have been identified through legislation as traditionally serving a particular minority group (e.g., HBCUs, tribal colleges and universities) or meet specific enrollment-based criteria for serving a high percentage of

students from specific minority groups (i.e., Black/African American, Hispanic, Asian/Pacific Islander, and American Indian/Alaska native) (Li 2007). Because the enrollment statistics for schools change over time, the listing of schools that are considered MSIs may also change over time as well.

To provide a perspective on the range of fields that received funds to develop research capabilities at HBCU/MI schools, IDA categorized the awards to HBCU/MI schools based on the primary department that the PIs were associated with. In the case of several PIs who were associated with more than one department of a university, we selected only one department for this categorization, either the one that they were originally assigned to or where it appeared they conducted the bulk of their research. Because university departments are not uniformly named or organized, we attempted to group similar department or field names together as seemed logical. Table 3 displays the range of fields of study and the total dollar amount of awards for each that were awarded to HBCU/MI institutions.

Table 3. Fields of Study That Received DURIPs That Were Awarded to HBCU/MI Institutions

Field of Study	Total per Field
Engineering	$ 12,822,797.00
Physics and Astronomy	$ 12,049,752.00
Computer Science	$ 7,070,746.00
Materials Science	$ 5,201,744.00
Earth and Planetary Sciences	$ 2,503,112.00
Chemistry	$ 2,483,513.00
Biochemistry, Genetics and Molecular Biology	$ 1,303,908.00
Medicine	$ 694,494.00
Agricultural and Biological Sciences	$ 393,867.00
Mathematics	$ 199,987.00
Social Sciences	$ 159,131.00
Economics, Econometrics and Finance	$ 148,982.00
Immunology and Microbiology	$ 120,677.00
Environmental Science	$ 110,145.00
Energy	$ 86,271.00
Not Categorized	$ 2,673,448.00

2. Geographic Distribution

DURIP has a broad geographic distribution, having been awarded to universities in all 50 states as well as the District of Columbia and Puerto Rico. Figure 2 and Figure 3 show the geographic distribution for 1997–2015 awards, excluding Alaska, Hawaii, and Puerto Rico. (Note that Alaska received no awards between 1997 and 2015, but did receive awards in 2017 and 2019.) Figure 2 shows the total dollars of DURIP awards for each state,

and Figure 3 shows the population-normalized funding level for each state. Normalizing for population reduces the disparities across states, although Massachusetts still receives a considerable proportion of award funding.

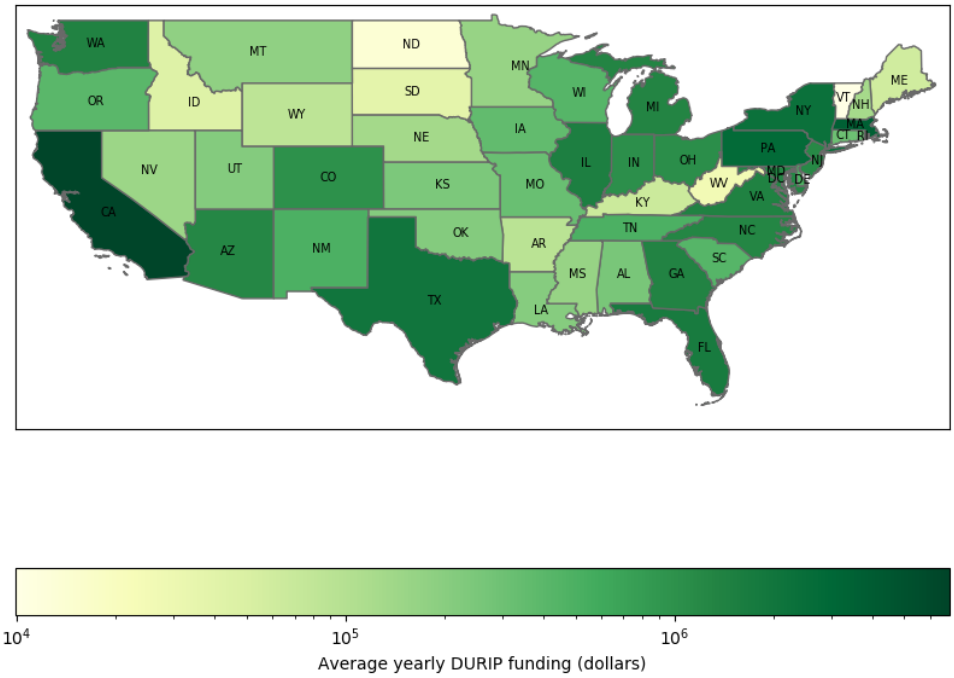

Figure 2. Average Yearly DURIP Funding by State. Alaska, Hawaii, and Puerto Rico Are Not Shown

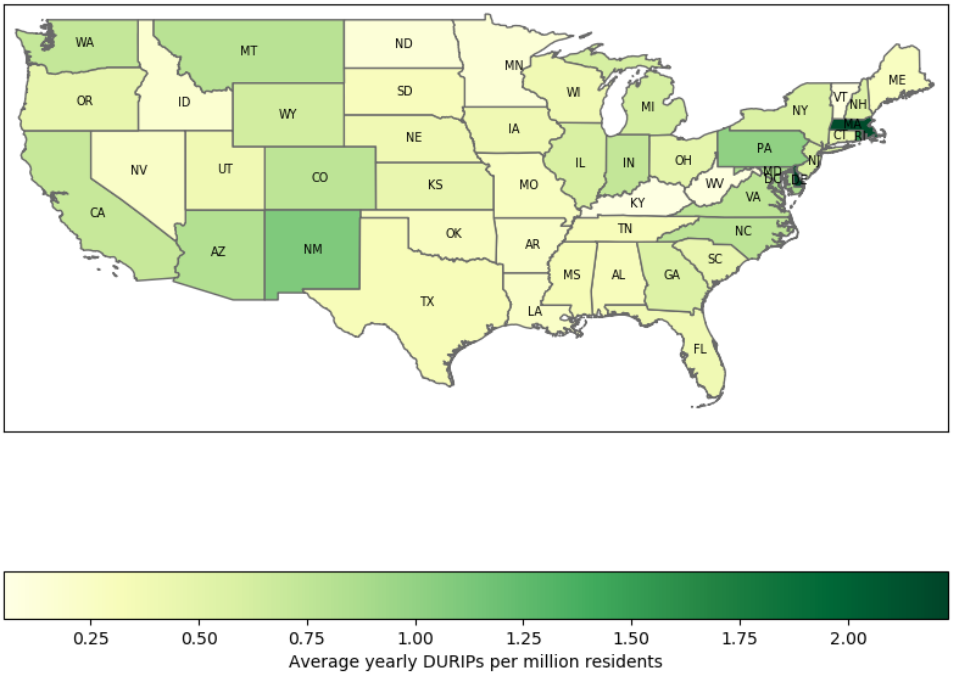

Figure 3. Average Yearly DURIP Awards by State per Million Residents. Alaska, Hawaii, and Puerto Rico Are Not Shown

B. Budget

This section provides a broad overview of the budget trends for DURIP.[7] We attempt to show where the DURIP budget sits within basic research and the larger DoD research, development, test, and evaluation (RDT&E) enterprise. Funding authorized through the National Defense Authorization Act (NDAA) is 2-year money for Budget Activity 1 in RDT&E that is aimed at scientific study and experimentation directed toward increasing fundamental knowledge in physical, engineering, environmental, and life sciences. The RDT&E program has the ability to adjust spending based on requirements each year. In any single year, the funding is used for new awards and does not contribute to continuing payment of previous awards. DURIP proposals may request $50,000 to $1,500,000. Starting with the budget for FY2004, DURIP was transitioned from OSD to the program element titled "University Research Initiatives for Basic Research" for each of the Services. This process has stayed consistent from 2004 to the current FY2020. The data below are for fiscal years 2004–2018.

[7] Budget information was obtained from: https://comptroller.defense.gov/Budget-Materials/#linkstoBM.

1. DURIP within the Services

The budget for DURIP has a different range and distribution across the Services and can fluctuate from year to year, sometimes significantly, depending on the Service as shown in Figure 4. The Navy's budget, which averages $21,367,000, has the highest variance/spread of annual budget (SD = $4,948,000) and largest range ($17,255,000)—the peak funding year was 2016 ($33,454,000), and the lowest funding years were 2006 and 2011 ($16,199,000 and $16,200,000, respectively). The Army (average = $11,293,000) and Air Force (average = $13,697,000) are more consistent over time and have smaller standard deviations and ranges. The Army varies a bit more (SD = $2,005,000) than the Air Force, and the Army also has a slightly larger range ($6,376,000); the peak budget year was 2014 ($13,700,000) and the lowest budget year was 2011 ($7,324,000). The Air Force varies the least (SD = $1,329,000) and has the smallest range ($4,513,000); the peak was in 2014 ($15,822,000) and the lowest point was in 2008 ($11,309,000).

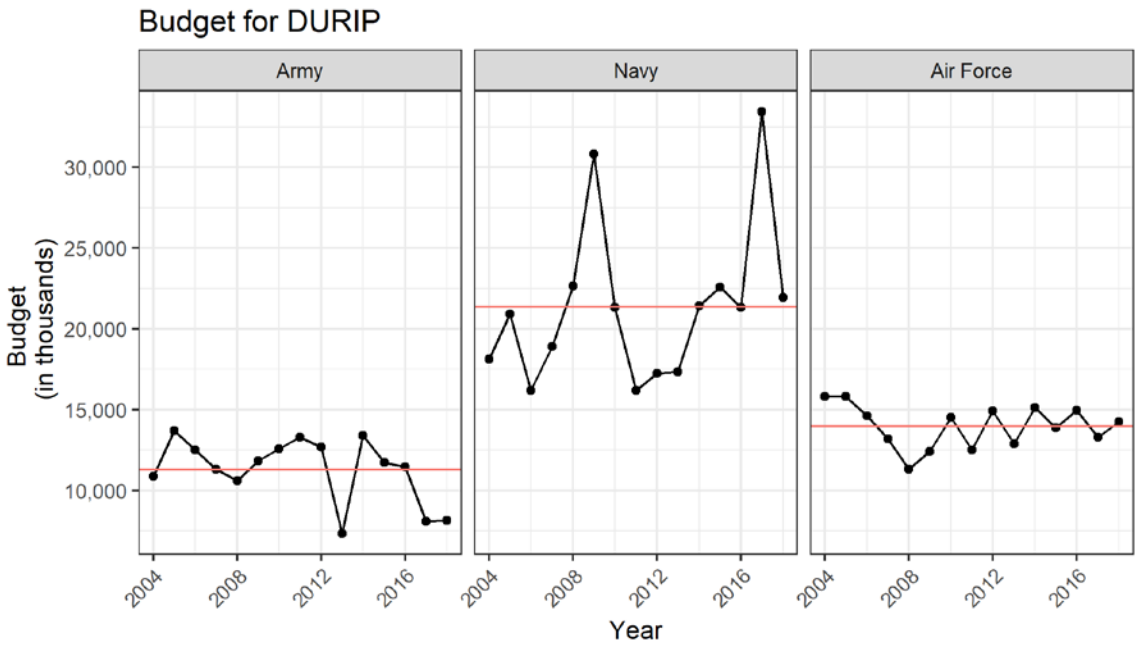

Figure 4. Budget for DURIP across Services from FY2004 to FY2018. The red line marks the mean DURIP award amount for each Service.

2. DURIP as a Part of University Research Initiatives

The program elements 601103X (i.e., 601103A for Army, 601103N for Navy, and 601103F for Air Force), University Research Initiatives, support defense-related basic research in a wide range of scientific and engineering disciplines. The budget for research instrumentation (i.e., DURIP) falls under this program element along with MURI, a program the sponsor requested that we analyze so that the relative funding levels of DURIP and MURI could be compared. The 601103X program element for some Services or for

some years also includes the Presidential Early Career Awards for Scientists and Engineers (PECASE), the National Defense Science and Engineering Graduate Fellowship (NDSEG), and Minerva (social science research program that began in 2009 and was eliminated in FY18–19) programs; these programs were not directly compared to DURIP. The data indicate that DURIP is a smaller component of the University Research Initiatives program element than MURI. From 2004 to 2018, DURIP is on average approximately 14% of the total University Research Initiatives budget for the Army, 20% for the Navy, and 11% for the Air Force. During the same time period, MURI is on average approximately 69% of the Army's University Research Initiatives budget, 62% for the Navy and 52% for the Air Force.

The duration of funding for DURIP (i.e., 1-year grants) is different from MURI. MURI funds teams of researchers for 5 years to investigate high-priority topics and aims to accelerate research progress. This difference affects the potential fluctuations in funding in that with DURIP, all the funding for a grant is from a single fiscal year, whereas MURI awards cross fiscal years and have to be budgeted for in the subsequent 4 years after the initial award. This requires a funding tail for MURI, in that before new awards can be made, the existing MURI awards need to be funded. Although there is fluctuation across Services and years, the budget for DURIP has been about one-fourth the budget of MURI (from FY2004 to FY2018, DURIP mean = $15,542,000, MURI mean = $62,751,000); see Figure 5.

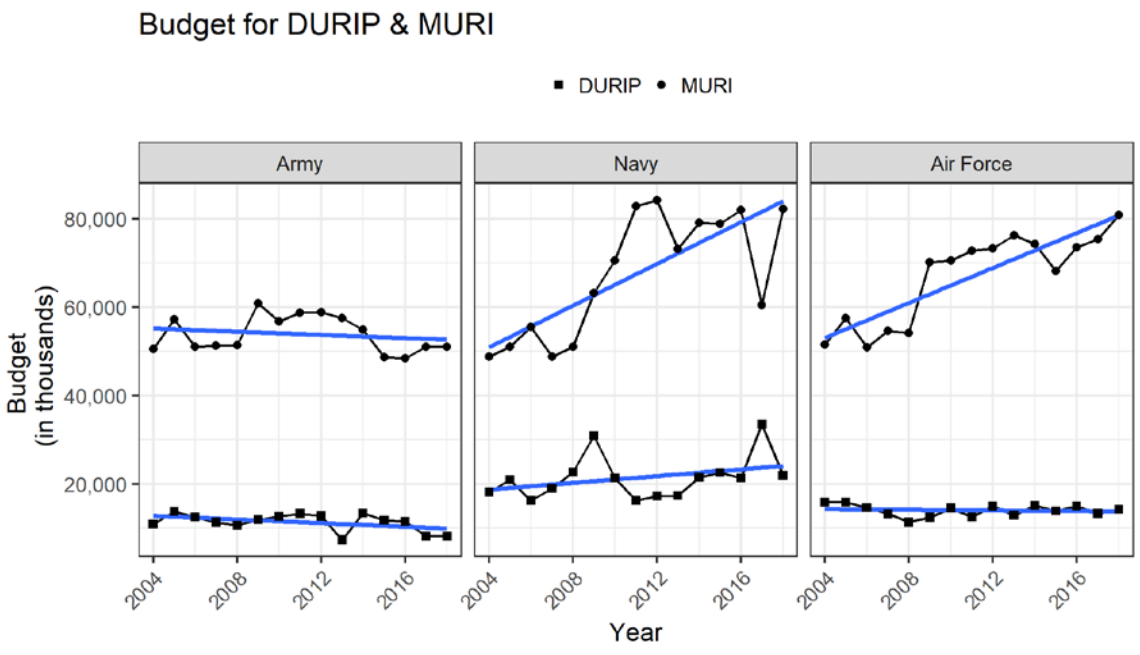

Figure 5. Budget for DURIP and MURI across Services. The blue line is a linear trend line.

The ratio of DURIP and MURI to university research initiatives varies across Services and years, but on average the breakdown is 20% for DURIP and 80% for MURI. Table 4 shows the variation of the DURIP and MURI budgets and a percentage comparison of DURIP and MURI funding across the three Services for years 2004–2018. On average, the Army ratio of DURIP to MURI across all years is 17% (low: 11% in 2013, high: 20% in 2006 and 2014), the Navy ratio is 24% (low: 16% in 2011, high: 36% in 2017), and the Air Force ratio is 17% (low: 14% in 2013, high: 23% in 2004).

Table 4. The DURIP and MURI Funding Levels for Each of the Services for Years 2004–2018 ($thousands)

	Army				Navy				Air Force			
Year	DURIP	%	MURI	%	DURIP	%	MURI	%	DURIP	%	MURI	%
2004	$ 10,858	18%	$ 50,501	82%	$ 18,123	27%	$ 48,788	73%	$ 15,806	23%	$ 51,577	77%
2005	$ 13,700	19%	$ 57,189	81%	$ 20,920	29%	$ 51,068	71%	$ 15,822	22%	$ 57,512	78%
2006	$ 12,488	20%	$ 51,011	80%	$ 16,199	23%	$ 55,460	77%	$ 14,630	22%	$ 50,913	78%
2007	$ 11,303	18%	$ 51,287	82%	$ 18,911	28%	$ 48,817	72%	$ 13,180	19%	$ 54,657	81%
2008	$ 10,594	17%	$ 51,374	83%	$ 22,670	31%	$ 51,006	69%	$ 11,309	17%	$ 54,117	83%
2009	$ 11,819	16%	$ 60,820	84%	$ 30,843	33%	$ 63,177	67%	$ 12,413	15%	$ 70,144	85%
2010	$ 12,574	18%	$ 56,781	82%	$ 21,332	23%	$ 70,555	77%	$ 14,530	17%	$ 70,483	83%
2011	$ 13,287	18%	$ 58,766	82%	$ 16,200	16%	$ 82,908	84%	$ 12,521	15%	$ 72,765	85%
2012	$ 12,677	18%	$ 58,872	82%	$ 17,239	17%	$ 84,222	83%	$ 14,910	17%	$ 73,237	83%
2013	$ 7,324	11%	$ 57,529	89%	$ 17,342	19%	$ 73,202	81%	$ 12,873	14%	$ 76,248	86%
2014	$ 13,397	20%	$ 54,829	80%	$ 21,437	21%	$ 79,104	79%	$ 15,118	17%	$ 74,259	83%
2015	$ 11,711	19%	$ 48,660	81%	$ 22,596	22%	$ 78,896	78%	$ 13,870	17%	$ 68,129	83%
2016	$ 11,450	19%	$ 48,387	81%	$ 21,317	21%	$ 82,039	79%	$ 14,974	17%	$ 73,554	83%
2017	$ 8,091	14%	$ 51,083	86%	$ 33,454	36%	$ 60,435	64%	$ 13,291	15%	$ 75,355	85%
2018	$ 8,134	14%	$ 51,032	86%	$ 21,925	21%	$ 82,224	79%	$ 14,258	15%	$ 80,831	85%
Total	$ 169,407	17%	$ 808,121	83%	$ 320,508	24%	$ 1,011,901	76%	$ 209,505	17%	$ 1,003,781	83%

3. DURIP as a Part of Basic Research

The DURIP program may also contribute to the applied research and advanced technology development that are part of the larger DoD research enterprise. Therefore, we show how DURIP's budget fits into the larger DoD research and development budget. Table 5 shows the RDTE and Basic Research budgets for each Service for years 2004–2018 and displays the percentage of those budgets that is spent on DURIP. In general, on average, the budget for DURIP is approximately 3% of the basic research budget and 0.1% of the total RDTE budget for the years 2004–2018.

Table 5. The total RDT&E Budget and the Basic Research Budget (in $1,000's) for Each Service for Years 2004–2018

	Army					Navy					Air Force				
Year	TotalRDTE	Basic_research	DURIP	DURIP/RDTE %	DURIP/BR %	TotalRDTE	Basic_research	DURIP	/RDTE %	DURIP/BR %	TotalRDTE	Basic_research	DURIP	DURIP/RDTE %	DURIP/BR %
FY2018	11,633,461	464,187	8,134	0.07%	0.02	18,465,332	604,634	21,925	0.12%	0.04	33,077,597	491,502	14,258	0.04%	2.9%
FY2017	8,852,507	473,216	8,091	0.09%	1.7%	17,851,955	549,384	33,454	0.19%	6.1%	28,381,681	521,594	13,291	0.05%	2.5%
FY2016	7,861,744	450,831	11,450	0.15%	2.5%	18,333,041	648,642	21,317	0.12%	3.3%	25,243,981	510,673	14,974	0.06%	2.9%
FY2015	6,744,134	447,868	11,711	0.17%	2.6%	16,067,423	634,410	22,596	0.14%	3.6%	23,619,628	538,586	13,870	0.06%	2.6%
FY2014	7,124,298	425,321	13,397	0.19%	3.1%	14,946,053	604,155	21,437	0.14%	3.5%	23,823,510	510,830	15,118	0.06%	3.0%
FY2013	8,010,810	384,636	7,324	0.09%	1.9%	15,553,447	567,496	17,342	0.11%	3.1%	23,163,315	460,881	12,873	0.06%	2.8%
FY2012	8,705,075	408,842	12,677	0.15%	3.1%	17,723,271	590,619	17,239	0.10%	2.9%	26,630,843	493,609	14,910	0.06%	3.0%
FY2011	9,760,396	388,660	13,287	0.14%	3.4%	17,865,538	538,716	16,200	0.09%	3.0%	27,421,360	476,425	12,521	0.05%	2.6%
FY2010	11,710,796	420,190	12,574	0.11%	3.0%	19,948,370	543,850	21,332	0.11%	3.9%	27,917,273	473,588	14,530	0.05%	3.1%
FY2009	12,078,895	422,136	11,819	0.10%	2.8%	19,733,741	525,075	30,843	0.16%	5.9%	26,691,777	446,388	12,413	0.05%	2.8%
FY2008	12,553,720	373,403	10,594	0.08%	2.8%	18,486,652	490,457	22,670	0.12%	4.6%	26,346,815	403,995	11,309	0.04%	2.8%
FY2007	11,354,176	353,401	11,303	0.10%	3.2%	19,724,109	482,290	18,911	0.10%	3.9%	24,491,745	395,300	13,180	0.05%	3.3%
FY2006	11,682,886	364,043	12,488	0.11%	3.4%	18,970,169	466,944	16,199	0.09%	3.5%	22,190,943	374,335	14,630	0.07%	3.9%
FY2005	10,576,058	392,802	13,700	0.13%	3.5%	17,076,795	478,406	20,920	0.12%	4.4%	20,477,909	373,798	15,822	0.08%	4.2%
FY2004	10,202,221	369,208	10,858	0.11%	2.9%	14,773,169	468,358	18,123	0.12%	3.9%	20,232,781	325,798	15,806	0.08%	4.9%
Total	**148,851,177**	**6,138,744**	**169,407**	**0.11%**	**2.8%**	**265,519,065**	**8,193,436**	**320,508**	**0.12%**	**3.9%**	**379,711,158**	**6,797,302**	**209,505**	**0.06%**	**3.1%**

C. Analyses of Research Output

Our analysis of publication data through Scopus provided information on the research history of PIs with DoD, their link to other funding agencies, their publication and citation rates before and after DURIP awards, and their acknowledgment of DURIP in publications.

1. Relationship between DURIP Awardees and DoD

IDA analyzed the extent to which DURIP recipients had relationships with DoD agencies before and after receiving their DURIP awards. This question is challenging to answer from the Scopus data for several reasons. First, metadata on funding is absent from roughly 75% of publications, and only one funding source can be associated with a paper in Scopus. This sparsity severely limits the conclusions that can be drawn from the data. Also, the funding relationship includes any acknowledged funding on any paper the DURIP PI was ever a coauthor on, including as a graduate student when the PI may have had little to no actual relationship to the funding agency. Despite these concerns, IDA found it elucidatory to investigate these relationships for a general picture of DURIP PIs' history with DoD funded research. Many of these findings are confirmed and expanded upon by the interviews.

Overall, IDA found DoD funding data on at least one paper for 1847/2291 PIs (80.6%). Figure 6 shows that most DURIP awardees (66.6%) had a prior relationship with DoD research funding as acknowledged in a journal publication (see the large area under the black line to the left of the right dotted center line at 0). The pattern for the Services (orange, blue, and purple lines) is similar to the black line, and the black line includes all the Services and also other DoD agencies. The mean interval between this first known relationship to DoD and the author's first DURIP award was 5.5 ± 9.7 years, with a median of 4 years. About one-third of PIs (616 of 1847, or 33.4%) were found to be associated with DoD funding for the first time in the year of their first DURIP or later. Note that the timing of the relationship between acknowledgment and funding may be influenced by the lag time between conducting research and publication of research findings, along with the relative sparsity of funding acknowledgment data for older publications listed in Scopus.

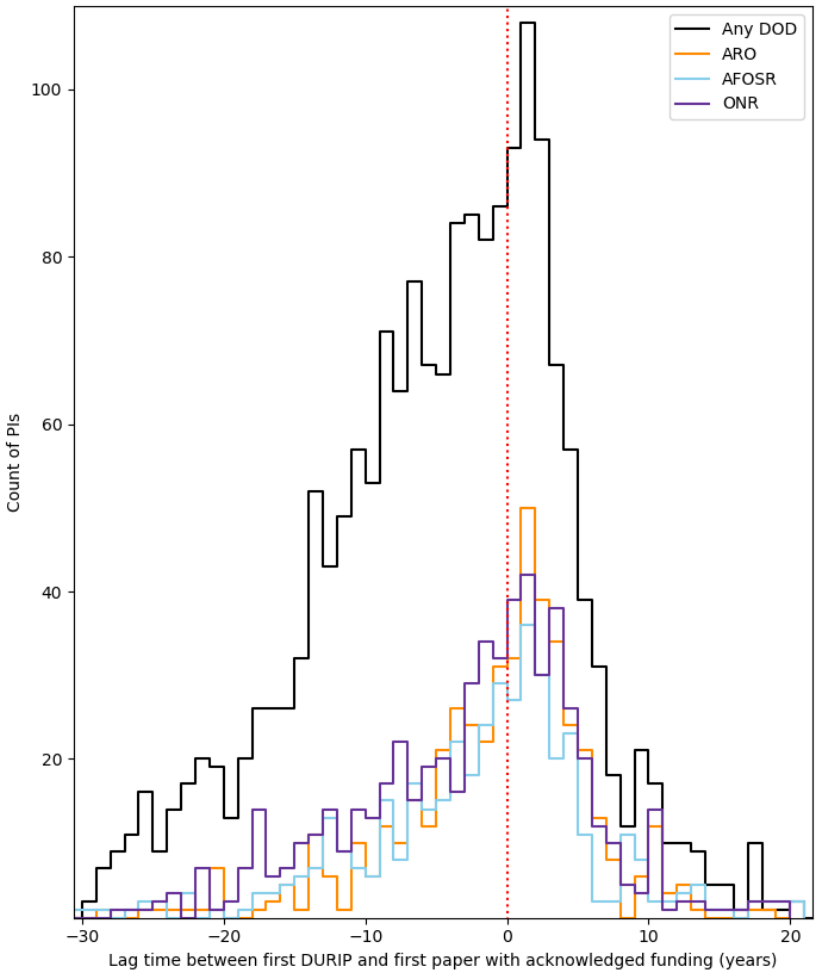

Figure 6. The Historical Relationship between DURIP Awardees and Their Acknowledgment to DoD Funding in Scopus Publication Data. The red dotted line represents when a PI first received a DURIP award. To the left of the red line represents PIs with DoD funding before getting a DURIP.

2. Funding Sources Acknowledged in Publication Data

Approximately 90,000 (24%) of the papers and articles by DURIP PIs in Scopus have metadata on an associated funding source. Roughly 3,700 unique funding agency names are cited, but this number may be inflated by multiple names being used for a single funding agency. Although this dataset is far from clear and comprehensive, and it spans PIs' entire careers, the assumption that funding metadata are available for a relatively random sample reveals some general aspects of the wider funding environment available to DURIP recipients. IDA parsed these data for variations of names and divisions of larger organizations, categorizing funding for each paper into the tables below.

A total of 21,789 publications (24.2%) by DURIP awardees acknowledge some DoD funding. Table 6 shows that the Air Force accounted for the highest percentage of acknowledgments (31.5%), closely followed by the Navy (29.7%), and then the Army

(22.6%), with an additional set of acknowledgments from other DoD agencies that were not Service specific (16.3%).

Table 6. The Breakdown of DURIP Awardees Acknowledgment in Publications of DoD Research Funding

Organization	Count	Percent (of identified)	Percent (of DoD)
AFOSR	6859	7.62%	31.5%
ONR	6466	7.19%	29.7%
ARO	4918	5.47%	22.6%
Other DoD	3546	3.94%	16.3%
All DoD	21789	24.22%	100.1%

The data shown in Table 6 represent only a portion of acknowledged funding sources by DURIP recipients in their publication history. Table 7 shows a wider range of funding acknowledgments in publications by DURIP recipients; most (75.89%) of the publications with available data in Scopus have *no* identified funding acknowledgment (i.e., only approximately 24% of publications have funding acknowledgment). Of U.S. Government agencies funding DURIP recipients, the highest percentage of acknowledged funding comes from NSF (24.6%) and DoD (24.2%). The "Other" category includes many private foundations or university funding acknowledgments.

Table 7. The Breakdown of All Funding Acknowledgments for DURIP Recipients

Organization	Count	Percent	Percent (of identified)
NSF	22130	5.93%	24.60%
All DoD	21789	5.84%	24.22%
DOE	5758	1.54%	6.40%
NIH	2518	0.67%	2.80%
NASA	2162	0.58%	2.40%
Other	35606	9.54%	39.58%
Identified	89963	24.10%	100.00%
Unidentified	283229	75.89%	—
Total	373192	99.99%	-—

3. Changes in Publication Output

While it is extremely difficult to gauge the quality, novelty, and importance of published works en masse, some aspects of publication output can give broad indicators of research trends and productivity. In the case of DURIP, where the construction of an

adequate separate control group is problematic, IDA decided to compare the DURIP cohort's research output to itself between two time periods—before and after the award—creating a pre-/post-DURIP publication output comparison. Figure 7 shows data for each PI and is based on the year of the DURIP award (first DURIP if they received multiple) centered at zero. The blue bars represent the number of PIs whose most prolific year is X-years before or after their DURIP award; the orange line is the total number of publications from all DURIP PIs published in that year (relative to first DURIP). The figure shows that the peak publication years are the first few years after PIs receive their first DURIP, indicating that DURIPs are awarded to researchers who are (1) generally in the prime of their research career and (2) usually entering their most productive years.

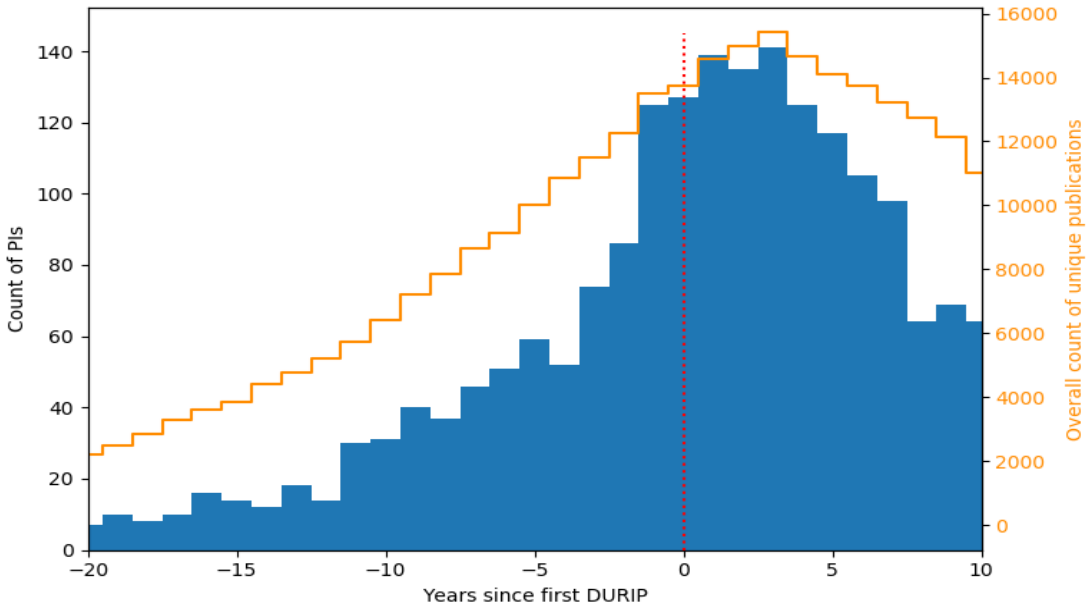

Figure 7. As an Indicator of Research Productivity, the Blue Bars Indicate the Number of PIs Whose Most Productive Publication Year Was Either before or after the Award of Their First DURIP. The orange line indicates the number of publications that were authored in a year by DURIP awardees as compared to the year of their first DURIP award.

While the number of publications (especially publications with metadata on funding sources) is likely to increase over time in Scopus for any pool of researchers similar to the DURIP group, IDA logically posited that a grant's impact on productivity could be analyzed by considering publications in the context of funding source. Because the DURIP is most specifically targeted to aid research for DoD, IDA grouped all the roughly 370,000 papers contributed to DURIP awardees according to the primary funding agency listed in Scopus (as was done above). The research output of DURIP researchers was then compared between the period of 5 years before receiving a DURIP (their first, if they received more than one) and 5 years after receiving a DURIP, inclusive of the period of the DURIP award

year. These cutoffs were used to allow time for instrumentation ordering, experimental setup, and the publication process. A shorter cutoff may not have allowed for enough time for new equipment to produce published results, and a longer cutoff would preclude the analysis of the earliest and latest DURIP awards due to the availability of data. Regardless, IDA found that the results were not overly sensitive to variations in the cutoff period length. If multiple DURIP recipients were listed as authors on any one paper, the first one to have received a DURIP was the only one connected to that paper in the analysis.

Figure 8 displays the percent change in research productivity measures between the 5 years prior to a researcher's DURIP award (first award if the research received more than one award) versus the 5 years post award (including the year the award was won). Using acknowledged funding source to differentiate the reference to DoD or non-DoD research enterprise, we found there was a larger increase in total papers and total citations for the publications that DURIP awardees produced for DoD compared with publications with non-DoD or unknown funding sources, as shown by the green and gold bars. This suggests that DURIP awardees focused more on DoD-relevant research than on non-DoD research and that the research could be categorized as more productive in that it led to more total papers and citations. There is a 100% increase in categorized DoD-sponsored research output between the pre- and post-DURIP publication windows, compared with a 64% increase in other research with known sponsors and a 26% increase overall. In addition, the DoD research generated over the later period garners 69% more citations, compared with a 26% increase in citations for research with other known sponsors.

Some of the data in Figure 8 are not clearly distinguishable as an impact of DURIP on research productivity. For example, the number of citations per paper decreased across the pre- and post-DURIP 5-year periods. However, this may be due to the shorter time available for those newer papers to be cited. Likewise, it is not clear how the number of coauthors per paper may or may not have been influenced by DURIP. Although increasing one's research collaborations is sometimes thought of as an indicator of research influence, this indicator is highly dependent on research discipline.

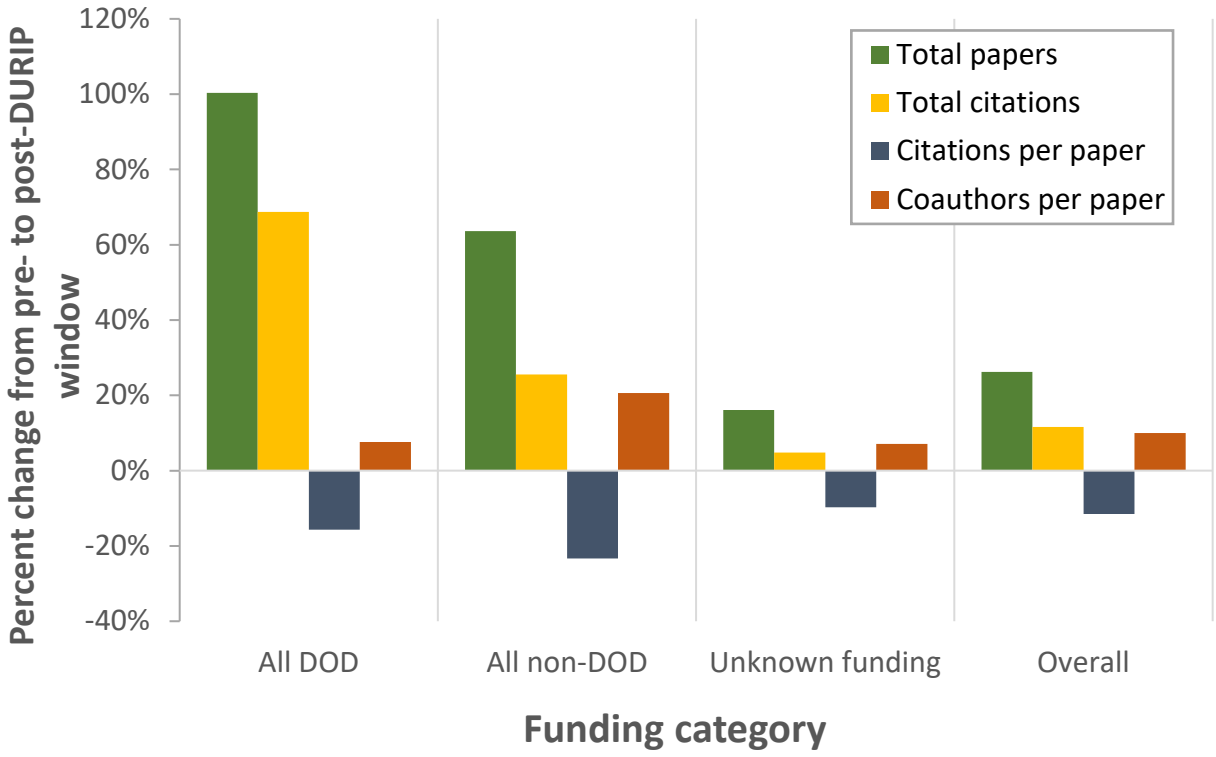

Figure 8. Percentage Change in Academic Publishing Metrics from the 5 Years before DURIP to the 5 Years after DURIP for Publications of Various Funding Categories. This plot compares changes in four metrics (total papers published, total citations, number of citations per papers, and number of coauthors per paper) for approximately 130,000 papers with broadly categorized known or unknown funding data worked on by DURIP recipients. The bars show the percentage change from the 5 years before an attributed author received his or her first DURIP award to the year of award and the four following years. Note that the fraction of papers in the Scopus database with funding data generally increases over time.

Table 8 provides more detail on research productivity, showing absolute numbers for publication, citation, and coauthor metrics by agency between the 5-year pre- and post-DURIP period for all unique papers authored (at least partly) by DURIP recipients. Using the collection of all non-DoD papers with attributed funding as a baseline should help control for general trends in productivity and data availability.

Table 8. Detailed Information Regarding the pre- and post-DURIP Award Total Number of Publications, Citations, Citations per Paper and Coauthors per Paper. This includes a breakdown by agencies.

	Total publications		Total citations		Citations per paper		Coauthors per paper	
Funding agency	Pre-DURIP	Post-DURIP	Pre-DURIP	Post-DURIP	Pre-DURIP	Post-DURIP	Pre-DURIP	Post-DURIP
AFOSR	847	1551	42154	60820	49.77	39.21	3.07	3.39
ARO	652	1419	32655	53377	50.08	37.62	2.78	3.40
ONR	810	1593	35205	56571	43.46	35.51	3.03	2.96
Other DoD	378	818	19085	47075	50.49	57.55	4.03	4.05
DOE	487	880	22140	33281	45.46	37.82	4.18	5.27
NASA	305	435	11662	15927	38.24	36.61	2.95	4.19
NIH	262	400	19931	18067	76.07	45.17	3.97	5.30
NSF	2760	4499	137082	193425	49.67	42.99	3.11	3.83
OTHER	3790	6228	235749	274710	62.20	44.11	4.26	4.96
All DoD	2687	5381	129099	217843	48.05	40.48	3.13	3.36
All non-DoD	7604	12442	426564	535410	56.10	43.03	3.78	4.55
Unknown funding	47863	55567	1953175	2047716	40.81	36.85	3.35	3.59
Total	58154	73390	2508838	2800969	43.14	38.17	3.40	3.74

4. Rate of DURIP Acknowledgment

It is impossible to say how many of the collected papers were enabled by DURIP equipment, though based on the interviews with PIs (next section), it appears that a considerable amount of research is enabled through the purchases made with DURIP funds. Furthermore, the DURIP program does not require researchers to cite DURIP equipment in their papers. As an elucidatory exercise, however, IDA examined 17,220 recent papers on which a DURIP recipient was a coauthor with funding metadata in Scopus for mentions of DURIP funding or equipment. Slightly over 1% of papers cited DURIP in the text of the acknowledgments section of the paper, well below the approximately 32% of all papers that mentioned other sources of DoD funding. Although this number cannot be taken as the actual DURIP citation rate, it does suggest that acknowledging DURIP is not the norm in publishing among its recipients.

D. Qualitative Findings from Interviews with DURIP Stakeholders

This section describes qualitative results from interviews conducted by the IDA team with DURIP stakeholders. To gain a comprehensive perspective of DURIP, the results presented here should be viewed as complementary to the quantitative data results. For many of the interview results, we were able to confirm what was found in our exploratory quantitative data analysis, while also providing additional nuanced qualitative findings. To collect a wide range of perspectives on DURIP in general, the process of applying and

receiving the award, reporting requirements post award, and other research equipment funding mechanisms, four IDA researchers interviewed a range of people related to DURIP. In total, the team interviewed five different types of people: (1) PIs who have won DURIP awards, (2) PIs without a DURIP award, (3) office of supported research staff, (4) DURIP PMs, and (5) Service leads. Interviews lasted from 25 minutes to 1 hour and on average were about 45 minutes. The interviews are organized into two groups, university perspective and government perspective.

1. University Perspective

The university perspective was provided through interviews with PIs who received DURIPs, some PIs who did not receive DURIP but were still successful researchers, and some university representatives for the office of supported research.

a. Principle Investigators with DURIP Awards

Twenty DURIP PIs were interviewed from 11 different research institutions. On average, the 20 PIs won 2.5 DURIPs (the range was 1 to 6), and they purchased a wide variety of equipment spanning several fields. Some equipment was commercial off the shelf, other equipment was customized by commercial entities that sold the equipment, and still other equipment was put together by the research lab and PI. The following are examples of each of these three types of equipment funded by DURIP:

- Commercial off-the-shelf equipment
  - An EEG machine intended to expand the university capability and to facilitate training
  - Computer equipment that enabled capabilities to handle large datasets
- Customized equipment
  - A towing tank
  - Gust generating system
  - Software-defined receivers of satellite communication signals
- Equipment purchased and assembled
  - Imaging equipment for a network of space-weather monitoring
  - Equipment to set up a propulsion lab (e.g., large tank, vacuum pump, power supplies, and micropropulsion tanks).

In general, all PIs interviewed had positive things to say about DURIP and stated that it significantly improved their research capabilities. Interview comments about DURIP in general can be summarized into five main outcomes: (1) PI accomplishments, (2)

investment in infrastructure, (3) enabling of future research, (4) uniqueness of the DURIP award, and (5) DURIP award/execution process.

1) PI Accomplishments

DURIP is often transformational for PIs; most PIs noted that it propelled their careers and directly influenced tenure appointments. One PI stated that DURIP was the "main driver" for his career and for science. Echoing this sentiment, another PI noted that DURIP enabled her to take her research in directions that never would have been possible without the equipment purchased with DURIP, adding that "DURIP is the lifeline for experimentalists in the country…." DURIP also advances PIs' careers by opening additional funding doors in the DoD; for example, a PI said that DURIP was a key enabler of his career and led to his Vannevar Bush Faculty Fellowship (VBFF) award. Many other PIs have ongoing funding from all the Services; this also confirms what was found in the quantitative analysis where PIs have a relationship both before and after DURIP awards.

2) Investment in Infrastructure

In addition to general research success, DURIP is pivotal for building research infrastructure. A number of PIs called DURIP an investment in infrastructure that is instrumental for science, enabling a wide range of research capabilities and keeping PIs as worldwide leaders in their individual fields. For research areas that require a lot of equipment infrastructure, DURIP builds this infrastructure, enabling research avenues that would otherwise not be able to function. One such example was a purchase of a multi-component set of equipment (a towing tank, gust generating system, and special customized instrumentation to study micro-air-vehicle gust response) that created a one-of-a-kind research facility in the United States, complimenting infrastructure capabilities found in only one other facility in the world, located in the U.K.

DURIP is a funding mechanism that can be used to build research infrastructure for institutions without well-established research infrastructure, expanding the number of universities that can conduct quality research for DoD. One PI stated that DURIP infrastructure was "good for small schools" and allowed his lab to be more independent, no longer having to rely on other research labs to use equipment. Another PI at an MSI noted his DURIP award greatly enhanced the university's material science program and it went from unrated to 28th in the world.

3) Enabling Future Research

Investing in infrastructure is tightly linked to enabling current and future research. Most PIs interviewed stated that equipment purchased with DURIP lasts for a very long time, spanning 6–20 years of research use, and most reported between 10 and 20 years of continued, daily use—oftentimes far beyond the original proposal of stated use. During

this time span, some PIs mentioned that the equipment enabled them to pursue new research avenues that were not originally on the horizon (or even existed) at the time of the original DURIP award. Further, DURIP equipment is often shared between researchers and not exclusively used by only the award-winning PI. In this way, DURIP enables long-term, wide-reaching collaborative research. For example, one PI quoted about 14 other researchers (internal to their university and from other U.S. and international universities) who consistently use the nanoindenter that was purchased through DURIP. Similarly, another PI noted that the infrastructure put in place by DURIP equipment allowed "a lot of additional" research at her university.

To showcase some of the research outcomes DURIP has enabled, PIs gave some examples of their research successes. Some highlights include using an EEG machine to better understand the cognitive aspects of hearing and hearing loss; software-defined receivers (SDRs) of satellite communication signals that enabled a better understanding of electron density in the atmosphere; an inverted microscope that detected the structure of interfaces (e.g., biological materials like mussels and barnacles attaching to ships), in addition to medical equipment that resists bacteria; and a nanoidenter that enabled the detection of the structure of a mantis shrimp shell that led to the development of a carbon fiber structure that had 50% less impact damage compared with the field standard.

In addition, DURIP equipment aided in the training of the next generation of scientists; many of the interviewed PIs stated that the DURIP equipment contributed to several PhD graduates who went on to prominent academic positions or work in DoD labs. For example, one PI said that over his 22 year career, all his 35 PhD students worked on DURIP equipment and went on to significant faculty positions; another PI noted that 3 of 8 of her former students work for the DoD or DOE as researchers. In addition, DURIP equipment attracts technically minded students, who are oftentimes encouraged to maintain equipment and are tasked with running labs. Many PIs see a huge education benefit to fostering highly technical maintenance skills in students. For example, one PI requires that his students either build or fix equipment before they are allowed to begin doing research. Another PI recalled that a piece of equipment required maintenance that would cost around $50,000, and instead of paying the company to fix it, a graduate student learned the system and gained the skills to be able to repair it.

4) Uniqueness of DURIP

DURIP is considered by most PIs interviewed to be unique and flexible in that it is the only funding mechanism that exists for instrumentation for DoD researchers; many PIs mentioned NSF Major Research Instrumentation (MRI) as a similar equipment funding mechanism, but noted how it is much more restrictive and requires larger teams and equipment needs. Further, some PIs emphasized that DURIP fills a gap for intermediate

levels of equipment, whereas other funding mechanisms like NSF-MRI require larger equipment purchases.

5) DURIP Award/Execution Process

In general, several PIs said that the application process for DURIP typically started with a conversation between the PI and a PM who was aware of the researcher's capabilities and the field of research. Many PIs noted that the DURIP process from the initial discussion with a PM to the final report was generally smooth and straightforward. In general, the process seemed to work best when there was good communication between awardee and PMs. A few PIs said that there was sometimes a lack of clear, consistent communication with the PM and would have preferred more direction in the process and a better understanding what a successful DURIP application should include. Only one PI seemed concerned with the PI–PM relationship and noted that he thought the DURIP program was linked to what the PMs in the Services thought was appropriate and not to a larger DoD strategy.

Since DURIP is a 1-year award, PIs must purchase their equipment within 1 year of receiving the award. Most PIs noted that the timeline to purchase equipment was adequate. Other PIs who discussed not having enough time to purchase the equipment due to university bidding requirements, equipment customization, or manufacturing delays also said that the DURIP process was very flexible and that getting a no-cost extension was straightforward.

Connected with the 1-year timeline to purchase DURIP equipment is the requirement for PIs that a report be submitted to the PI's PM at the end of the grant's period of performance (i.e., 1 year after the award is made). While most PIs said that the reporting requirement was simple and mostly not a memorable piece of the process, many also noted that the timeline for reporting was too short; it was typically the case that PIs were only able to purchase the equipment within the 1-year timeframe and had no time to really use the equipment for research. Some PIs noted that due to the short timeline, the submitted reports do not capture the full return on investment of DURIP equipment and suggested extending the reporting deadline by at least 6 months to up to 2 years after the equipment is purchased. Only one PI suggested lessening the reporting requirement.

b. Principle Investigators without DURIP Awards

The sponsor was interested in the counterfactual case of conducting research without support of DURIP funding. Therefore, the IDA team interviewed two PIs who have never won a DURIP award and one PI who had won DURIP awards in the past, but had not won one since 2012, even though he had applied a number of times since then. The intent of these interviews was so to get a more objective perspective on the DURIP award process. The interviewees were asked their general opinion of DURIP, how they purchase and/or

access equipment, how long the equipment is used, and the ratio of equipment costs to other research-related costs.

In general, the PIs echoed sentiments expressed by the PIs who had won DURIPs, noting that DURIP is an "essential program for DoD" and that it fills a need for equipment purchasing. One PI said that for the United States to stay competitive in science research, worldwide investment in infrastructure is highly important. The perspective of one of the PIs about DURIP is that the program is mostly driven by PMs who have an understanding about the long-term direction of a domain of research and how the pieces of this research domain work synergistically. PMs with a command of their research area guide applicants efficiently and effectively; however if a PM does not have a clear research perspective then the program is not efficient. For the program to be effective, PMs must be in the position to know the potential impact of equipment purchases.

The two PIs who have never won DURIP awards purchased equipment using startup funds from their individual universities (ranging from $350,000 to $400,000). They also use shared equipment, and one PI had an NSF-MRI; some equipment was also built internally. The lifespan of equipment purchased by the two PIs without a DURIP is similar to equipment purchased with a DURIP award—between 10 and 20 years. In terms of costs, one PI noted that it was about a 3:1 ratio of personnel and other research costs to equipment fees and consumables. Another PI noted that he spent 10% of his research funds on equipment and instrumentation and the rest on consumables and personnel.

c. Office of Supported Research

Two university representatives (from different universities) from the Office of Research Support were interviewed to gain a higher level perspective on the role DURIP plays at universities. Their perspectives were that DURIP has a significant impact on the ability of PIs to expand their research capabilities and that the equipment is used beyond the original DURIP equipment award, echoing statements from PIs themselves. They described the DURIP application process as being driven by PIs who interact with the DoD. From the office of supported research perspective, the application process was straightforward and no problems were identified. They also indicated that the equipment was shared across the university (the purchased equipment becomes a university capability), so it has a beneficial effect beyond the PI who is the awardee. The only comparable program the two representatives were aware of was the NSF MRI program, but that the MRI focused on larger awards; DURIP fills a gap for intermediate grants (between standard equipment needs and large institutional grants). Another difference noted was that with NSF, the focus is on the number of researchers; DURIP is focused on scientific capability. One of the offices of supported research noted that DURIP was helpful to universities with small endowments and that may lack internal sources of funds that could be critical for starting a line of research by a PI. They also indicated that once the

equipment was purchased, the university supports the ongoing maintenance and overhead costs of equipment, which may be addressed through follow-on PI grants or university overhead.

2. Government Perspective

The government perspective is based on interviews with PMs with DURIPs from all Services, Service leads from Air Force and Navy, and two people with an OSD perspective. The PMs' areas of research were wide reaching and included ocean engineering science, autonomous systems, optoelectronics and photonics, and learning, education, and training.

In general, all PMs and Service leads agreed that DURIP is an extremely positive and valuable program that has seen little to no changes since its inception. In particular, one PM said that DURIP is "hugely important" and "creates new experimental capabilities," echoing a similar response by many PIs. This same PM also noted that he hears many PIs express how valuable the scale and scope of the DURIP (and MURI) award is and that the DoD is a model how funding should be done. In terms of the PIs that are supported through DURIP, the program allows the "cream of the crop" to push boundaries and pursue science research with "bold, new approaches" otherwise impossible without the appropriate infrastructure. In fact, one Service lead said that "we would grind to a halt" without the program.

The goal of DURIP is to create science research capabilities via infrastructure, and to this end the collective opinion was that DURIP is an important part of DoD, supporting equipment purchases normally too expensive for grants. DURIP is seen as a strategic program to build long-term science research infrastructure and capability. Specifically, DURIP is seen as a "force multiplier" in that the equipment is used in multiple follow-on projects, is shared among researchers, and is used extensively for extended periods of time. In fact, one AFOSR PM stated that "AFOSR research money would not go as far" without the capabilities enabled through DURIP.

One criticism from one PM is that DURIP funds could be more focused instead of evenly distributed. That is, currently, some programs with a small equipment need get the same funding as those with large equipment needs; instead, funding should be based on institutional focus. It was not clear to the PMs how DURIP was aligned with any broader strategy that might emphasize one area of research over another.

Regarding the DURIP process, all PMs noted that they have ongoing relationships with PIs, and the first step in the DURIP process is to contact the PIs when the announcement is coming out. The Service leads also stressed that the process begins with encouraging conversations between PMs and PIs once the funding opportunity announcement (FOA) is out. Regarding HBCU/MIs, Service leads work with PMs and universities to create awareness of the DURIP opportunity for HBCU/MIs. The PMs

contact PIs whose research they believe would benefit from DURIP and would be useful to the DoD. Specifically, an appropriate DURIP application comes from a PI with a track record for research (though not exclusively) and focuses on a new science capability in a field relevant to the DoD. Often this starts with PMs having conversations with PIs (either the PM or the PI might initiative the conversation) that they have previously worked with and helping them develop useful proposals that articulate a benefit to science, DoD, and the Services. Upon receiving proposals, Service leads filter and distribute them to the appropriate PMs. One Service lead stated that the applications are evaluated with three criteria (following the three listed goals of DURIP): (1) impact to DoD, (2) priority to DoD, and (3) ability to educate future science and engineering researchers. Eventually, the proposals are reviewed with potential external reviewers. PMs also coordinate with other interested PMs, and then the selected proposals are forwarded for cross-departmental review. One PM said that 80% of his DURIP awards go to PIs with ongoing research relationships.

For HBCU/MI institutions, the process has an additional layer since there is a parallel funding program for research that coexists with DURIP. This parallel program aims to create more competitive and capable HBCU/MI institutions and funds instrumentation every other year. This program gives HBCU/MI institutions the initial push ("seed money") to overcome barriers to engaging in research so that they eventually become competitive enough to apply for DURIP awards. Building an institution's capacity in this way (i.e., starting with HBCU/MI seed money and then winning a DURIP) strongly supports the opportunity for collaboration where industry leaders will invest in HBCU/MIs and partner with these institutions.

In terms of the DURIP reporting requirement, most PMs and Service leads said that the reports are standard but not "tremendously useful"; this view is tied to the 1-year time frame for DURIP; there is not enough time for PIs to use the purchased equipment so DURIP reports typically just list the purchased equipment and plans for the future. One of the Service leads expressed interest in extending the reporting requirement time frame so that reports could include more detail on how the equipment was used and how students were working with the equipment. This Service lead also suggested that PMs encourage PIs to cite DURIP funding in publications since this is often not done. Another Service lead was skeptical that a longer reporting requirement would be useful. Similarly, some PMs expressed interest in more meaningful reports that include results from experiments and suggested extending the reporting requirement to 2 years or requiring PIs to submit published papers with research results generated from the equipment. This extended reporting requirement would help PMs better manage their portfolios and also provide a better measure of meaningful science impact.

E. Review of Relevant Comparison Funding Mechanisms

The DURIP program specifically funds research infrastructure in the form of instrumentation, as opposed to grants for research personnel and activities. That is, an infrastructure grant pays for equipment and facilities that enable research but doesn't fund specific research activities. Conversely, a typical research grant has a specific research activity, design, and analysis predetermined in the research grant proposal. In addition, there are some funding mechanisms to develop research centers that may include some instrumentation and other infrastructure. But these funding mechanisms are not comparable in that they go well beyond the funding level of DURIP and therefore are not considered below.

A few brief descriptions of some programs that have the intent to fund the purchase or development of research instrumentation within the United States and in a few other countries with extensive research follow. The only program mentioned during the stakeholder interviews was the NSF MRI program; the programs discussed in this section were not mentioned by DURIP stakeholders as options for purchasing instrumentation.

1. NSF Major Research Instrumentation Program

The closest comparison program appears to be the NSF MRI program, which was also mentioned by several of PIs and PMs that we interviewed. The MRI Program is intended to improve access to scientific and engineering instrumentation and facilitate conducting research and training of research skills at U.S. universities and colleges, along with not-for-profit scientific and engineering research organizations.[8] NSF-MRI awards support the acquisition or development of a multi-user, shared research instrument that may be too costly or not appropriate for support through traditional NSF research grants. The program provides a means to acquire research instrumentation for conducting fundamental science and engineering research in addition to providing the means to develop next-generation research instruments. There is also the expectation that an MRI award will enhance research training of students to become the next generation of researchers.

The program funds proposals up to $4 million for either the acquisition or development of a research instrumentation. There are two tracks for the funding awards. Track 1 MRI awards are for between $100,000 and $1,000,000, and Track 2 are for between $1,000,000 and $4,000,000. Cost-sharing is required for Ph.D.-granting institutions and for non-degree-granting research organizations at the level of 30%. Non-Ph.D.-granting institutions of higher education are exempt from cost-sharing in an effort to promote research at such colleges. Awards are also differentiated by whether they are for instrument acquisition (i.e., purchase of generally available, yet sophisticated,

[8] https://www.nsf.gov/pubs/2018/nsf18513/nsf18513.pdf.

instrumentation to conduct research) or instrumentation development (i.e., development of sophisticated research instrumentation with capabilities that may not yet exist).

The MRI program is part of the portfolio of NSF's Office of Integrative Activities. The 2018 budget was approximately $100 million, which is about 1.8% of the overall NSF budget for research and other programs at colleges and universities. The funding anticipated in the FY19 MRI program solicitation is $75 million for up to 150 awards.[9] Proposers are encouraged to align proposals with the NSF's Strategic Plan for FY 2018–2022. The proposals will be evaluated against two broad criteria: (1) intellectual merit, that is, the potential to advance knowledge, and (2) broader impacts, that is, the potential to benefit society and contribute to the achievement of specific, desired societal outcomes. Proposers may request award periods that are up to 3 years for acquisition proposals and up to 5 years for development proposals.

Awardees are required to submit annual project reports and a final report no later than 120 days after the grant ends. For instrument acquisition awards, the content of the reports should include status of order, delivery, and installation; description of research projects enabled by the instrument; number of students with hands-on experience with demographic information (undergraduate or graduate, gender, ethnicity/race, and disability, field of study); list of the research groups who used the instrumentation; and information on broader impacts activities to date. For instrument-development awards, the content of the report should include all the above for acquisition awards, as well as status of development effort to date, new industrial partnerships, and technology transfer (e.g., design or instrument).

2. NIH ORIP

The National Institutes of Health have a department called the Office of Research Infrastructure Programs (ORIP) that funds capital investments. One of the funding mechanisms managed by ORIP is the S10 Instrumentation Grant Program.[10] S10 grants support purchases of commercially available equipment for NIH–funded investigators to upgrade their research capabilities. The grants are for instruments that are typically too expensive to be included in a research grant proposal for an individual investigator.

The intent of the instrument grant is to provide institutions with capabilities that can have an impact on multiple investigators at the institution. An applicant organization must identify three or more PIs with active NIH research awards who would use the requested instrument to benefit their research. The expectation of the shared-use aspect of the award is to be cost-efficient and benefit a broader set of investigators than if not shared. S10

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[9] https://www.nsf.gov/pubs/2018/nsf18513/nsf18513.pdf.

[10] https://orip.nih.gov/construction-and-instruments/s10-instrumentation-programs.

awards are made to research organizations that may be either domestic public and private institutions of higher education or non-profit domestic institutions such as hospitals and health professional schools. Matching funds from the applicant organization is not required, but the organization is expected to provide appropriate level of support for additional infrastructure, such as laboratory space for the instrument, technical personnel, and ongoing support for maintenance and operation of the instrument.

ORIP plans to fund about 75 awards for approximately $35 million in FY2020. The applications are assessed along two different funding amounts. The Shared Instrumentation Grant Program funds grant awards in the $50,000 to $600,000 range for purchases like mass spectrometers, high-resolution ultrasound imaging systems, cryogenic storage systems, and equipment upgrades. The High-End Instrumentation Grant Program funds grant awards in the $600,001 to $2,000,000 range for purchases like multi-beam scanning electron microscope, high-resolution 3D X-ray imaging system, and magnetic resonance imaging systems. The selection criteria for awards includes alignment with the NIH mission and scientific and technical merit (i.e., justification of need, technical expertise, research to be conducted, management of equipment, and institutional commitment).

The awards are for 1 year. Reporting requirement includes a final research performance progress report that describes the purchased instrument, includes narrative describing research accomplishments, lists all users and publications resulting from use of the instrument, and outlines the value of the instrument to the investigators and to the institution as a whole. Also required are annual usage reports of the instrument for 4 years after the project end date, which will update information provided in the final report.

F. Instrumentation Programs in Other Countries

To assess and compare how some other countries address the issue of funding instrumentation and equipment funding, we looked at countries with large research budgets. The assessment of foreign research funding is not always clear, but according to Wang et al. (2012), the United States spends the most on research and development. China, Japan, Germany, and the U.K. also consistently fund research at high levels. We therefore searched for information that indicates if these countries have programs that specifically fund instrumentation and equipment, to provide a broader understanding of how instrumentation gets funded in other research ecosystems.

1. China

China has rapidly increased its funding of research and development, shaped by the expectation that scientific advancements will improve the national interests (Benner, Liu, and Serger, 2012; Freeman and Huang 2015). The Chinese government developed a mid- to long-term plan for science and technology development for the 2006–2020 period, with the goal of encouraging innovation (Jiabao 2008). The plan emphasizes basic research and

frontier technologies that may benefit developments in energy and environmental protection, along with economic prosperity.

China's main research organization (National Natural Science Foundation of China, NNSFC) has the Special Fund for Research on National Major Research Instruments that fosters the exploratory research and development of instruments and also purchases research instruments and equipment to further science and national needs guided by scientific goals for innovation in China (Liu et al. 2019). The budget for the special fund for instruments was 3.7% (approximately 3.8 billion CNY) of the total NNSFC for the years 2014–2018 (101.9 billion CNY for 2014-2018 budget), as per Liu et al (2019). This percentage of funding that is strictly toward instrumentation does not include all funding of instrumentation, in that some instrumentation or other forms of infrastructure funding may be rolled up into other funding mechanisms like there General Research Program, Basic Science Center Program, and the Fund for Less Developed Regions. The funding appears to be relatively competitive—from 2014 to 2018 only 12.6% of applications for funds were awarded (Liu 2019). The award criteria include looking for creative ideas to expand science along with national interests.

2. Japan

It is generally not clear how equipment funds are distributed in Japan since we couldn't find a specific program that clearly and explicitly funds equipment purchases for basic research. The Japan Society for the Promotion of Science (JSPS) is a component of the Ministry of Education, Culture, Sports, Science and Technology (MEXT). No consistent funding information could be found, but a MEXT (2005) report said that Japan spent approximately 9%–15% of research and development expenditures on tangible fixed assets (i.e., land and buildings, machinery, instruments, equipment, and others), but it is not clear how much of those funds were for land and buildings and how much were for research equipment.

Japan does have a Grant-in-Aid program for Scientific Research on Innovative Areas. This program is intended to foster novel research areas proposed by diverse groups of researchers; the research is expected to lead to development or improvement of Japan's research level in various fields. This research is conducted by collective research efforts through collaboration, scholarly training, and shared use of equipment. Funding research equipment appears to be a growing interest in that since FY 2012 Japan has eased restrictions on Grants-in-Aid disbursed for the purchasing of joint-use equipment. This seems to have been done to support researchers who pool their funds to purchase expensive equipment that would be difficult for one of them to afford (JSPS 2017).

3. Germany

The German Research Foundation (Deutsche Forschungsgemeinschaft, or DFG), the German version of the NSF, funds a broad range of basic research in science, engineering, and the humanities. The DFG has an instrumentation funding mechanism that requires a 50% cost sharing with the university for the purchase of equipment that cost between €200,000 and €5 million. The DFG uses experts in the relevant fields to make determinations of proposal quality based on scientific merit. In an assessment of the grants awarded from 2007 to 2017, some of the most common types of equipment purchased include laser scanning microscopes, mass spectrometers, X-ray diffractometer, lasers, and high-performance computer systems (German Research Foundation 2018).

A study of German researchers in physics found that as the relative availability of funding in university versus government varied, researchers adapted to the sources they targeted for funding and also varied the type of research they would conduct based on the funding they received (Laudel 2006). In interviews, researchers stated that they conducted "cheap" research that was low-risk when funding was limited, avoided research for which the outcomes were was difficult to pre-determine, or searched for new connections between fields. With a trend toward more competitive research funding, some German researchers have lamented the difficulty of conducting quality research without quality instrumentation (Laudel 2006).

4. United Kingdom

The Engineering and Physical Sciences Research Council (EPSRC), part of the British Research Council, is a government agency that funds research grants and postgraduate degrees in engineering and the physical sciences (e.g., physics, biology, mathematics, artificial intelligence, and computer science), mainly to universities in the United Kingdom; it is part of the UK's Department for Business, Energy, and Industrial Strategy. In its 2017–18 report to Parliament, the EPSRC highlighted a program where it invested £20.2 million as part of its strategic equipment program and an additional £6.8 million of research equipment through standard research grants. This funding amount is approximately 2.5% of its £1.1 billion research budget, which in addition to research grants also funds many graduate students. EPSRC encourages researchers to share the equipment it funds to enable increased access and use.

EPSRC commissioned a study on equipment funding and found that such funding has significant impact on research and training. Analysis of investments in mid-range research equipment (i.e., costing between £130,000 and £14 million) found that access to quality equipment is essential for training of world-class scientists. EPSRC's analysis indicated that for every £100,000 of EPSRC funding on mid-range equipment, an additional £212,000 was invested by other sources. EPSRC also found that funding of research equipment had a positive impact on equipment design and production as researchers and

manufacturers worked together as they developed cutting-edge research equipment. Finally, the use of quality equipment also had a positive impact on the training and development of high-end skills by students at the research facilities.

4. Findings and Conclusions

DURIP is a funding mechanism for purchasing research instrumentation and equipment so that university labs can conduct high-quality research. A distinction can be made between DURIP (purchasing equipment) and research grants to conduct research projects. The expectation is that an equipment grant will enable new or improved research capabilities. In general, this appears to be the case with DURIP, though the extent of benefit is difficult to quantify.

A. Findings

Using multiple methods of analyses (i.e., a mix of both quantitative and qualitative), the IDA team analyzed the grants awarded (i.e., size of awards, award distribution across universities and geographic locations), research productivity of those who received awards (publications, citations, coauthors), the DURIP budget specifically and as part of the larger DoD research enterprise, structured interviews with stakeholders (both from university and government perspectives), and qualitative comparisons with similar funding mechanisms employed by other U.S. agencies and foreign countries. The findings are summarized below.

1. Expansive Reach of Program

There have been almost 4,000 DURIP awards totaling over $800 million since its inception in 1997. The awards range in size from $15,000 to $1.3 million. They have been awarded to 280 different institutions, in all 50 states as well as Puerto Rico and the District of Columbia. The majority (70%) of awarded institutions are research-focused universities, Pennsylvania State University, University of California San Diego, MIT, University of Washington, and University of Maryland being the top-five award winners. DURIP has also been used to develop research capabilities at universities lacking more developed research infrastructure In addition, DURIP has expanded access to research capabilities and infrastructure for HBCU/MI institutions; from 1997 to 2015, approximately $48 million was awarded to 41 different universities designated as MSIs.

2. Budget Trends

Funding level for DURIP varies across Services and across years, although the Navy usually funds the most DURIP awards each year. In comparison to the MURI Program, the DURIP budget is usually about one-fourth the MURI budget, but that ratio also fluctuates

from year to year and across Services. As a percentage of basic research funding, DURIP accounts for 3.3% of DoD's basic research funding across all the Services.

IDA also reviewed some other equipment/instrumentation grant programs in the United States and from other countries, and while it is not clear that there is a particular ratio of how much should be spent on instrumentation versus research grants, the size of DURIP seems to be on par with other grant programs globally. The U.S. instrumentation programs (NSF-MRI and NIH-ORIP) might be considered alternatives for instrumentation funding; however, these are focused on research priority areas specific to those organizations, rather than on DoD priorities. One functional distinction between DURIP and NSF-MRI and NIH-ORIP is that they stress sharing of equipment and student use more than DURIP.

Based on interviews with stakeholders, there is an overwhelming perspective that the DURIP program is important for DoD in that it facilitates quality, groundbreaking research. The equipment seems to be heavily used and stays in use for a long period of time (a decade or more is common).

3. DURIP Process

The DURIP application and award process is influenced strongly by the Service PMs. While there is a public announcement for submissions and all submissions are reviewed, the PMs will regularly have conversations with potential PIs to discuss possible proposals. Our quantitative findings supported something similar in that PIs often had a relationship with DoD before receiving a DURIP award. Proposers are encouraged to talk with PMs who fund research in their areas to gain an understanding of the DoD research interests, which can be used to shape their proposals so that they better align with DoD interests. Also, the PMs are the first level in the multilevel review of the proposals; subsequent reviewers work from the initial reviews by the PMs and the perspective of the PMs to gauge how well a particular application might fit into a particular line of research. After the initial PM ratings for merit within a research domain, the proposals then work their way up through the Service hierarchy, which provides a more strategic perspective to the rating across research domains. Then inter-Service coordination and OSD approval must occur before final awards are made.

The influence of PMs seems appropriate for DURIP in that they have the detailed knowledge and understanding of specific lines of research. While higher levels of DoD research management may set a broad strategy for DoD or Service research areas, the merit of DURIPs is the specific research that a specific PI or university might conduct and the subsequent impact of that research. Other countries like the U.K. and Germany are clear that they empower researchers who know their area of research to influence what research may or may not be funded, though there are higher level decision-makers who determine which areas of research should be emphasized.

One other aspect about the grants awards process that was mentioned in interviews was the distinction between research grants and instrumentation grants. In an awards process it is important to have a clear method for rating and comparing proposals, so the process of comparing research grants to other research grants should be kept separate from the process of comparing equipment grants to other equipment grants.

4. Research Productivity

PIs and PMs both consider DURIP as very important to enabling research—most DURIPs facilitate higher quality research than would be possible without DURIP. It was common in the interviews for PIs or PMs to use strong words like "critical" and essential" in describing DURIP and the need for instrumentation grants to conduct quality research to stay competitive globally. Many PIs indicated that a DURIP award they received was a primary enabler for their career and had a long-term impact (10+ years) that would outlast any single research grant.

Precisely measuring research productivity is problematic; however, the standard indicators like publications and citations are currently the leading measures. Using these measures, it appears as though DURIP awards tend to be given to researchers who are in the prime years of their research productivity and that these researchers tend to be more productive in conducting DoD research after they receive the DURIP awards than they are in conducting research funded by other organizations.

Each of the PIs interviewed could describe how his or her DURIP enabled future research that wouldn't have been possible without the equipment. Some examples of awards include: purchase of EEG that led to understanding different types of hearing loss that may be due to brain injury rather than ear injuries in soldiers; high-speed video cameras that led to sensing improvements that enable autonomous vehicles to see through precipitation; laser systems used to understand skyrmions, which may be used in quantum computing; DNA-sequencing system used to understand the mixture of genetic markers of microhaplotypes; and software-enabled satellite communication receivers used to understand space weather and ionosphere instabilities that disrupt radio communication.

5. Impact on Universities and Students

DURIP awardees indicated that the grants were pivotal for building the research infrastructure. Many PIs indicated that DURIP equipment greatly improved their lab infrastructure. This had multiple benefits, the first being new research capabilities, the second being that it also helped them in recruiting talented students and collaborators into their labs (i.e., others wanted to use the quality equipment). It also appears as though many students gain technical skills while using the equipment for conducting research or by learning how to maintain or the equipment.

Researchers cannot expect universities without large endowments to provide extensive startup funds to build a lab; in such cases, DURIP can be used to facilitate lab development. In one particular instance, a PI was awarded a DURIP, and the equipment was a material contributor for that school's materials science and engineering program going from unranked to highly ranked. The universities seem to be willing to maintain the equipment through overhead accounts once the equipment has been purchased, an indicator that the university appreciates the value in the equipment.

6. Comparable Programs

Six other equipment/instrument programs were identified, two of those in other U.S. government agencies and four in other governments. Of the other U.S. programs, both NSF and NIH have multiple categories for equipment funding (i.e., larger versus smaller), both allow multiple years to pass before a final report is due, and both emphasize sharing of equipment with other researchers. There seems to be a range of motivations for the foreign country programs: China is looking to rapidly build a broad research infrastructure to drive innovative research for national interests; Japan is emphasizing the shared use of equipment; Germany is requiring a sharing of costs with the universities; and the U.K. is focusing on the development of new research instrumentation that will lead to advancements in science.

There is a dearth of formal evaluations on these equipment grant programs, in that we could only find one reference to a study that indicated the U.K. investment in equipment by the government led to increased investment by other sources. While we could not find an analytical study that indicated that there was an improvement in research capabilities, their promotional material indicated that the programs were successful in improving the research capabilities.

B. Conclusions

The review of DURIP indicates that it funds the purchase of equipment by PIs who then use that equipment for DoD research for many years. It appears as though there is an improvement in research capability that is enabled by the DURIP program, but we were unable to quantify that improvement definitively.

The process for rating proposals and awarding DURIPs seems to be appropriate. The Service and DoD leaders with a strategic perspective set the high-level distribution of funding levels across research domains, and the PMs with deep understanding of a particular research domain greatly influence the process within their domain. It is not clear how the distribution of funding across research domains is determined strategically. A portfolio analysis of the distribution of awards across fields of research or type of university (e.g., research leader or developing research capabilities), and how that may align to a

higher-level DoD or Service strategy, would be useful; DURIP appears to be functioning as it should, but is it addressing the right issues?

The ratio of DURIP to MURI funding is about 20:80, although that ratio varies across Services and across years. Taking a larger perspective to include all DoD basic research, DURIP awards are approximately 3% of the total budget. In comparison to other research agencies (foreign and domestic), these awards do not have the same structure of delineating funds so they could not be used for a valid comparison. Through the interviews with stakeholders, there was no indication that funding ratios across program types (e.g., research versus equipment grants) were inappropriate or needed to change.

Currently, the grants have a period of performance of 1 year. In this time frame, starting with the reception of funds at the university, the grantees have to update purchase requirements/orders if needed to make sure they are getting the best available equipment, make the purchase and wait for delivery (this may include a long lag time because equipment might be custom made rather than commercial off-the-shelf), then install the equipment in the lab, all before starting to use the equipment for research. The final report is due about 1 year after the award, which does not leave much time for actually using the equipment and determining an impact. Other U.S. agencies appear to have a longer reporting period so that they can capture some of the actual research impacts from the purchase, an approach that DoD could consider.

References

Benner, Mats, Li Liu, and Sylvia Schwaag Serger. 2012. “Head in the Clouds and Feet on the Ground: Research Priority Setting in China.” *Science and Public Policy* 39, Issue 2 (March 2012): 258–70. https://doi.org/10.1093/scipol/scs006.

Flanagan, K., L. Georghiou, P. Halfpenny, J. Evans, and P. Croasdale. 2000. “Research Equipment Needs in UK Universities: A Snapshot Study.” Manchester: PREST, University of Manchester. https://www.research.manchester.ac.uk/portal/files/35316145/FULL_TEXT.PDF.

Freeman, R. B., and W. Huang. 2015). “China’s ‘Great Leap Forward, in Science and Engineering.” In *Global Mobility of Research Scientists*, edited by Aldo Geuna, 155–75. Academic Press.

German Research Foundation. 2018. “Instrumentation Funding: Development in the Years 2007 to 2017.” Bonn, Germany. See https://www.dfg.de/en/research_funding/programmes/infrastructure/scientific_instrumentation/statements_information/.

Hughes, A. 2011. “Open Innovation, the Haldane Principle and the New Production of Knowledge: Science Policy and University–Industry Links in the UK after the Financial Crisis.” *Prometheus* 29 (4): 411–42.

Jiabao, W. 2008. “Science and China’s Modernization.” *Science* 322 (5902): 649.

Laudel, G. 2006. “The Art of Getting Funded: How Scientists Adapt to Their Funding Conditions.” *Science and Public Policy* 33 (7): 489–504.

Li, X. 2007. “Characteristics of Minority-Serving Institutions and Minority Undergraduates Enrolled in These Institutions.” NCES 2008-156. Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Liu Y, Gao Z, Wang H, Wang J, Shen J, Wang C. 2019. “Analysis of Projects Funded by the National Natural Science Foundation of China during the years of 2014–2018. *Ann Transl Med 2019* 7 (12): 267

JSPS. 2017. “JSPS 2017–2018.” Japan Study for the Promotion of Science. https://www.jsps.go.jp/english/aboutus/data/brochure17-18_e.pdf.

Martín-Martín, Alberto, Enrique Orduna-Malea, Mike Thelwall, Emilio Delgado López-Cózar. 2018. “Google Scholar, Web of Science, and Scopus: A Systematic Comparison of Citations in 252 Subject Categories.” *Journal of Informetrics* 12, Issue 4: 1160–77. https://doi.org/10.1016/J.JOI.2018.09.002.

MEXT. 2005. “Annual Report on the Promotion of Science and Technology, FY 2005.” Ministry of Education, Culture, Sports, Science and Technology Japan. http://www.mext.go.jp/en/publication/whitepaper/title03/detail03/1372984.htm.

National Research Council 2006. *Midsize Facilities: The Infrastructure for Materials Research.* Washington, DC: The National Academies Press. https://doi.org/10.17226/11336.

Wang, X., D. Liu, K. Ding, and X. Wang. 2012. “Science Funding and Research Output: A Study on 10 Countries.” *Scientometrics* 91 (2): 591–99.

Abbreviations

AFOSR	Air Force Office of Scientific Research
ARO	Army Research Office
CFR	Code of Federal Regulations
DDR&E	Director, Defense Research and Engineering
DFG	Deutsche Forschungsgemeinschaft [German Research Foundation]
DOE	Department of Energy
DURIP	Defense University Research Instrumentation Program
EEG	electroencephalogram
EPSRC	Engineering and Physical Sciences Research Council
HBCU/MI	Historically Black Colleges and Universities and Minority Institutions
JSPS	Japan Society for the Promotion of Science
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MRI	Major Research Instrumentation
MSI	minority-serving institution
MURI	Multidisciplinary University Research Initiative
NASA	National Aeronautics and Space Administration
NDAA	National Defense Authorization Act
NDSEG	National Defense Science and Engineering Graduate Fellowship
NIH	National Institutes of Health
NNSFC	National Natural Science Foundation of China
NSF	National Science Foundation
ONR	Office of Naval Research
ORIP	Office of Research Infrastructure Programs
PECASE	Presidential Early Career Awards for Scientists and Engineers
PI	principal investigator
PM	program manager
RDT&E	research, development, test, and evaluation
VBFF	Vannevar Bush Faculty Fellowship

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED *(From–To)*
September 2019	Final	

4. TITLE AND SUBTITLE

Review of Defense University Research Instrumentation Program (DURIP)

5a. CONTRACT NUMBER
HQ0034-14-D-0001

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

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Fedele, Emily A.
Fisher, Katherine I.
DeMaio, William A.
Cummings, Melissa

5d. PROJECT NUMBER
AI-2-4382

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882

8. PERFORMING ORGANIZATION REPORT NUMBER

IDA Document D-10885

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Basic Research Office
Office of the Assistant Secretary of Defense for Research and Engineering
4800 Mark Center Drive, Suite 17C08
Alexandria, VA 22350

10. SPONSOR/MONITOR'S ACRONYM(S)

OASD(R&E)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited (1 December 2020).

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Defense University Research Instrumentation Program (DURIP) is a DoD funding mechanism for purchasing research instrumentation and equipment with the goal of modernizing U.S. research infrastructure at universities to promote high-quality research in areas of interest to the DoD. The review results indicate that DURIP is achieving its intent to fund the purchase of equipment that increases the research capability for DoD-funded principal investigators. Through qualitative and quantitative analysis, there appears to be a positive impact of DURIP funding for DoD research conducted at universities. To place the findings in context, an overview of other instrumentation programs in non-DoD agencies of the U.S. government and in other countries were provided.

15. SUBJECT TERMS

instrumentation grants; research funding; research infrastructure

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Nair, Bindu
Uncl.	Uncl.	Uncl.	SAR	56	19b. TELEPHONE NUMBER *(include area code)* 571-372-6460

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18