NIST GCR 21-031

# NIST PSCR: Economic Impact Analysis

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# NIST PSCR: Economic Impact Analysis

Prepared for
*U.S. Department of Commerce*
*Public Safety Communications Research Division*
*National Institute of Standards and Technology*
*Boulder, CO 80305-3328*

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**Abstract**

NIST's Public Safety Communications Research (PSCR) Division is the primary federal laboratory focused on conducting research, development, testing, and evaluation for public safety communications technologies. Their mission is to accelerate communications innovation in support of public safety communities and the citizens they serve. The 2012 Middle Class Tax Relief and Job Creation Act contained landmark provisions for the development and build out of the Nationwide Public Safety Broadband Network (NPSBN) and established The Public Safety Trust Fund (PSTF) to support the design and implementation of the Network. The Act charged the NIST with utilizing up to $300 million of PSTF allocations to establish an R&D program to support the development and deployment of NPSBN from fiscal year 2016 through 2022. In response to the Act's mandate, NIST PSCR developed the Public Safety Innovation Accelerator Program to augment internal research by providing funds to support a range of research mechanisms that span from external grants and cooperative research agreements to prize challenge competitions. The aim of these research mechanisms is to accelerate communications innovation in support of public safety communities and the citizens they serve.

NIST PSCR contracted Eastern Research Group, Inc. (ERG) of Lexington, MA to conduct an economic impact analysis (EIA) of PSTF investments into NIST PSCR's research mechanisms. ERG conducted an EIA using standard economic input-output multipliers from the Bureau of Economic Analysis (BEA) to show how NIST PSCR's research investments translate into broader impacts to states, focusing on new jobs, earnings, value added, and total economic output. The results of the EIA (presented in 2020 dollars) show that NIST PSCR's investment of $230 million into the suite of research mechanisms generated 4,280 jobs, $262 million in earnings, $431 million in value added, and $513 million in total economic output.

**Key words**

Communications; economic impacts; economic impact analysis; first responders; public safety; research and development mechanism.

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## Executive Summary

In February 2012, Congress' enactment of the Middle Class Tax Relief and Job Creation Act marked an unparalleled push toward next-generation technologies for public safety. The legislation contained landmark provisions for the development and build out of the Nationwide Public Safety Broadband Network (NPSBN), a dedicated, interoperable network for emergency responders. The Public Safety Trust Fund (PSTF) was established to support the design and implementation of the Network. The Act charged the National Institute of Standards and Technology (NIST) with utilizing up to $300 million of PSTF allocations to establish an R&D program to support the development and deployment of NPSBN between fiscal years 2016, when funds first became available, through 2022.

NIST's Public Safety Communications Research (PSCR) Division serves a primary role in fulfilling this Congressional mandate by advancing near- and long-term R&D activities and ensuring that capabilities developed deliver positive operational impacts to responders in the field. NIST PSCR is the primary federal laboratory focused on conducting research, development, testing, and evaluation for public safety communications technologies. Their mission is to accelerate communications innovation in support of public safety communities and the citizens they serve.

In response to the Act's mandate, NIST PSCR developed the Public Safety Innovation Accelerator Program (PSIAP) in 2016. The program augments internal research by providing funds to support range of research mechanisms that span from external grants and cooperative research agreements to prize challenge competitions that focus on creative solutions. These research mechanisms are housed within six research portfolios and crosscutting initiatives to maximize their impact:[1]

- User Interface/User Experience (UI/UX),
- Location-Based Services (LBS),
- Mission Critical Voice (MCV),
- Public Safety Analytics,
- Security, and
- Resilient Systems.

The range of program partners and award recipients across portfolios includes academia, government, industry, and public safety entities. These partners and award recipients collaborate in an effort to foster creative solutions and technological advancements from multiple stakeholder perspectives to benefit the public safety community.

NIST PSCR recently completed an impact report[2] of the work conducted under the first three years of the program (2017-2019) and is interested in further understanding how their investment in the research mechanisms central to the program result in economic impacts that span to the broader, regional economy. For purposes of this study, expenditures are categorized into four research mechanisms:

- ***Grants*** awarded to applicants through topic-specific funding opportunities as well as rolling grants focused on particular NIST PSCR portfolio objectives.
- ***Small Business Innovation Research (SBIR) Program Phase 3 Contracts*** between NIST PSCR and small businesses to help foster the development of products and solutions that align with NIST PSCR's mission.

[1] For purpose of economic impact calculations, "Open Innovation Team" and "Support & Miscellaneous" were treated as portfolios in the analysis. "Support & Miscellaneous" is comprised of miscellaneous projects as well as all projects related to supporting internal research.
[2] https://www.nist.gov/publications/public-safety-communications-research-division-impact-report-fiscal-years-2017-150-2019

- ***Prize challenge competitions*** where participants compete against one another to solve discrete and well-defined challenges that are common in public safety communications. NIST PSCR provides financial awards to the prize challenge "winners."
- ***Internal research*** that consists of a combination of: 1) research projects conducted by NIST PSCR staff on its Colorado and Maryland campuses to support specific research portfolios, 2) management and operational support for the research portfolios and administrative support for external funding mechanisms and 3) payable interagency agreements to support research projects.

These research mechanisms are central to NIST PSCR efforts to support the development and deployment of NPSBN and, ultimately, their mission is to accelerate communications innovation in support of public safety communities and the citizens they serve.

NIST PSCR contracted with Eastern Research Group, Inc. (ERG) of Lexington, MA to conduct an economic impact analysis (EIA) of PSTF investments into NIST PSCR's research mechanisms. This analysis demonstrates how the economic activity created through NIST PSCR's research mechanisms results in other spending and job support in the regional economy. More specifically, ERG conducted an EIA using standard economic input-output multipliers from the Bureau of Economic Analysis (BEA) to show how NIST PSCR's research investments translate into broader impacts to states, focusing on new jobs, earnings, value added, and total economic output. The findings will help NIST PSCR better understand how its investments in the different types of research mechanisms translate into economic impacts as it prepares for the remaining years of PSTF program funding.

ERG developed an Economic Impact Calculation tool to conduct the analysis. The Microsoft Excel-based tool captures and combines NIST PSCR project investment data with the BEA Regional Input-Output Modeling System (RIMS II) detailed industry code multipliers to estimate state-level economic impacts. The tool provides economic impact summary tables that show economic impacts generated by each NIST PSCR research mechanism and portfolio that can further parsed by state.[3] The tool was designed for ongoing use by NIST PSCR, with user-friendly data input tabs, calculations and summary tables that auto-update, and accompanying user instructions.

To assess the economic impact of the NIST PSCR research mechanisms under this project, we performed three main tasks:

- We **collected and compiled existing NIST PSCR data** specific to each research mechanism on total dollars invested by NIST PSCR (e.g., total project dollars, total dollars awarded). This included 65 grants, 2 SBIR contracts, 170 prize challenge winners, and 170 funded internal research initiatives, comprised of 67 unique projects; a total of 407, or 304 unique, award and research projects, including 9 international awards
- We assessed the focus of each grant, SBIR contract, prize challenge, and internal research project (hereafter referred to collectively as "projects") and **assigned an industry sector** to each as defined by the Bureau of Economic Analysis (BEA) to facilitate economic impact modeling.
- We **estimated economic impacts** by combining the investment data we collected from NIST PSCR with BEA RIMS II (input-output) regional economic impact multipliers.



[3] https://www.bea.gov/resources/methodologies/RIMSII-user-guide

## RESULTS

***NIST PSCR research mechanisms generated $509 million in total economic activity and 4,280 jobs.***

Table ES-1 summarizes the estimated economic impacts across the four categories of NIST PSCR research mechanisms considered in-scope for the analysis. ERG estimated these values by collecting data on project costs (i.e., NIST PSCR investment) and then applied appropriate state-level multipliers obtained from the BEA to each project. The first row of the table reports the values provided to ERG from PSCR's investments in its research portfolios. We convert those values to 2020 dollars in the second row to ensure all dollar amounts reflect comparable data. The final four rows of the table present the estimated economic impacts based on applying BEA RIMS multipliers. These estimates are described below.

**Table ES-1**. Estimated Economic Impacts by Award.*

| Category | Grants | SBIR | Prize Challenges | Internal Research | Total |
|---|---|---|---|---|---|
| **NIST Investments** | | | | | |
| Amount Invested ($FY M) [a] | $73.94 | $4.48 | $3.50 | $142.67 | **$224.59** |
| Amount Invested ($2020 M) [b] | $68.07 | $4.48 | $3.44 | $145.71 | **$221.71** |
| **Estimated Economic Impacts** | | | | | |
| Total Output ($2020 M) | $139.49 | $9.13 | $29.10 | $332.12 | **$509.84** |
| Value-Added ($2020 M) | $211.22 | $5.88 | $18.28 | $195.81 | **$431.19** |
| Earnings ($2020 M) | $123.36 | $3.42 | $10.65 | $124.35 | **$261.78** |
| Jobs | 1,967 | 53 | 169 | 2,091 | **4,280** |

[a] This sum reflects dollars invested by NIST PSCR for the original fiscal year of the investment and sums across fiscal years FY16-FY20 rather than putting all dollars in the same fiscal year. This number includes 9 international awards.
[b] This amount invested has been inflated to $2020 and excludes 9 international awards, totaling $7.98 M ($2020). We only included projects with domestic multipliers in the economic impact analysis
*NIST PSCR investment in international-based research is included in the investment totals but is not represented in the reported economic impacts. BEA RIMS II multipliers are state-specific and do not account for international entities.

Overall, NIST PSCR invested $224.6 million in its research portfolios from 2016 to 2020. When converted to 2020 dollars, this amounted to a total investment of $229.7 million. Then, for this analysis, we removed 9 international awards, totaling $7.98 million, leaving $221.7 million. Using this value as a starting point, we applied BEA RIMS multipliers to the investment value. There are four categories of multipliers we looked at:

- **Output multipliers** reflect the change in the output of industries in a region for a one-dollar change in demand for a specific industry. That is, what is the total value of economic activity circulating through the states' economies generated by PSCR's R&D investments? We found that the ***combined total output across research mechanisms, is just over $509 million.***
- **Value-added multipliers** reflect the change in regional value-added (gross domestic product, GDP) for a one-dollar change in demand for a specific industry. That is, value-added indicates how much the regional economies grew over a period of time due to PSCR's R&D investments. Our estimates indicate that the NIST PSCR research mechanisms resulted in ***an increase of just over $431 million in value-added,*** across all states with entities participating in the four NIST PSCR research mechanisms.
- **Earnings multipliers** reflect the total change in household earnings in the region for a one-dollar change in demand for a specific industry. That is, what is the change in household earnings in the

states' economies generated by PSCR's R&D investments? NIST PSCR research mechanisms led to ***an increase of approximately $262 million in earnings***.

- **Jobs multipliers** reflect the change in the total number of jobs (full- and part-time) per a one-million-dollar change in the demand for a specific industry. That is, what is the change in the number of full- and part-time jobs generated by each one-million-dollar change in the states' economic activity due to PSCR's R&D investments? NIST PSCR research mechanisms ***led to 4,280 new jobs***.

Table ES-2 provides a breakdown of NIST PSCR investment and the resulting economic impacts across the six NIST PSCR research portfolios, Open Innovation Team projects, and all internal projects classified as Support and Miscellaneous. When comparing the NIST PSCR investment to economic impacts generated by that investment, the four portfolios that generated the largest economic output per dollar invested were Resilient Systems ($2.6 per $1 invested), Security ($2.5 per $1 invested), and UI/UX and Open Innovation Team (both with $2.4 per $1 invested).[4]

**Table ES-2.** Impact by NIST PSCR Portfolio (Based on Multipliers).*

| | Number of Projects [a] | NIST PSCR Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| Data Analytics | 63 | $16.35 | $37.50 | $48.72 | $27.10 | 450 |
| Location Based Services | 42 | $21.36 | $45.15 | $39.32 | $22.86 | 364 |
| Mission Critical Voice | 62 | $36.06 | $76.35 | $80.78 | $47.45 | 740 |
| Resilient Systems | 55 | $9.28 | $24.45 | $39.31 | $23.50 | 361 |
| Security | 47 | $8.18 | $20.26 | $12.06 | $7.22 | 117 |
| UI/UX | 101 | $22.76 | $54.96 | $64.11 | $38.99 | 626 |
| Support & Misc. Projects [b] | 20 | $94.09 | $218.10 | $127.42 | $81.54 | 1,393 |
| Open Innovation Team | 10 | $13.62 | $33.09 | $19.47 | $13.13 | 228 |
| **Total** | **398** | **$221.7** | **$509.8** | **$431.2** | **$261.8** | **4,280** |

*In some instances, NIST PSCR Prize challenges were associated with all PSCR portfolios rather than a single portfolio. In these instances, the NIST PSCR investment for the project is divided evenly across each of the portfolios in order to evenly distribute the economic impacts of those investments.

[a] This excludes 9 international projects since they are not included in the analysis. Total projects including international projects is 407.

[b] These do not include Open Innovation Team funding and outputs.

Table ES-3 shows the economic impacts by state across all research mechanisms. States with the greatest number of projects include Colorado (CO), Maryland (MD), California, and Texas. NIST PSCR's internal research work is responsible for the high number of projects in CO and MD, as this research takes place at NIST campuses in both states.

[4] The difference in economic impact generated by each portfolio is due to the fact that each portfolio contains a mixture of different project-types associated with different industry sectors, and the work activities conducted for each portfolio occur in different geographies. This means that the PSCR dollars invested in each portfolio filter through economic impact multipliers that are both state- and sector-specific. Thus, the multipliers applied to each portfolio differ, and the application of these differing multipliers result in varying economic impacts for a $1 PSCR investment in a given portfolio.

**Table ES-3.** Economic Impacts by State Across Research Mechanisms.

| State | NIST PSCR Investment ($2020 M) | Number of Projects | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| AR | $0.00 | 1 | $0.13 | $0.09 | $0.06 | 1 |
| CA | $8.30 | 48 | $24.22 | $28.70 | $17.47 | 250 |
| CO | $131.06 | 110 | $304.25 | $183.34 | $117.40 | 1984 |
| CT | $0.14 | 1 | $0.26 | $0.47 | $0.22 | 4 |
| DC | $1.34 | 3 | $1.90 | $1.08 | $0.22 | 3 |
| FL | $0.86 | 12 | $3.02 | $3.94 | $2.45 | 44 |
| GA | $5.89 | 10 | $14.38 | $21.26 | $12.70 | 230 |
| IL | $0.04 | 4 | $1.42 | $0.93 | $0.57 | 8 |
| IN | $8.36 | 13 | $17.43 | $9.91 | $5.96 | 93 |
| IA | $0.01 | 1 | $0.10 | $0.06 | $0.04 | 1 |
| KS | $0.09 | 2 | $0.46 | $0.24 | $0.11 | 2 |
| KY | $0.02 | 1 | $0.22 | $0.11 | $0.05 | 1 |
| MD | $17.25 | 80 | $34.57 | $24.18 | $13.37 | 205 |
| MA | $2.87 | 6 | $6.00 | $7.74 | $4.56 | 64 |
| MI | $4.57 | 7 | $9.20 | $14.28 | $8.76 | 148 |
| MN | $0.00 | 1 | $0.06 | $0.03 | $0.01 | 0 |
| MS | $0.18 | 1 | $0.33 | $0.80 | $0.52 | 10 |
| MT | $0.02 | 1 | $0.19 | $0.09 | $0.05 | 1 |
| NJ | $4.66 | 7 | $10.48 | $17.74 | $9.93 | 144 |
| NY | $6.16 | 9 | $12.12 | $14.56 | $7.91 | 112 |
| NC | $3.89 | 14 | $9.11 | $18.79 | $11.62 | 192 |
| ND | $0.01 | 1 | $0.05 | $0.01 | $0.01 | 0 |
| OH | $1.01 | 6 | $2.60 | $4.56 | $2.48 | 48 |
| OK | $0.02 | 1 | $0.13 | $0.08 | $0.05 | 1 |
| OR | $1.75 | 1 | $3.30 | $4.22 | $2.31 | 40 |
| PA | $4.80 | 11 | $10.21 | $15.03 | $8.97 | 139 |
| TN | $0.46 | 1 | $0.99 | $2.11 | $1.02 | 19 |
| TX | $9.81 | 23 | $24.75 | $38.17 | $22.33 | 375 |
| VA | $6.52 | 14 | $13.85 | $15.00 | $8.37 | 128 |
| WA | $1.62 | 8 | $4.13 | $3.67 | $2.28 | 32 |

## 1. Introduction

In February 2012, Congress' enactment of the Middle Class Tax Relief and Job Creation Act marked an unparalleled push toward next-generation technologies for public safety. The legislation contained landmark provisions for the development and build out of the Nationwide Public Safety Broadband Network (NPSBN), a dedicated, interoperable network for emergency responders. The Public Safety Trust Fund (PSTF) was established to support the design and implementation of the Network. The Act charged the National Institute of Standards and Technology (NIST) with utilizing up to $300 million of PSTF allocations to establish an R&D program to support the development and deployment of NPSBN between fiscal years 2016, when funds first became available, through 2022.

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NIST PSCR recently completed an impact report[6] of the work conducted under the first three years of the program (2017-2019) and is interested in further understanding how their investment in the research mechanisms central to the program result in economic impacts that span to the broader, regional economy. For purposes of this study, expenditures are categorized into four research mechanisms:

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[6] https://www.nist.gov/publications/public-safety-communications-research-division-impact-report-fiscal-years-2017-150-2019

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### 1.1. Report Overview

The remainder of this report is laid out as follows: Section 2 provides a characterization of the participants involved in each the four NIST PSCR research mechanisms included in the economic impact analysis.

Section 3 describes the methods used to calculate the economic impacts of the NIST PSCR research mechanisms based on the NIST PSCR data we collected and using impact multipliers obtained from the Bureau of Economic Analysis (BEA) along with results of the analysis.

## 2. Characterizing Research Mechanisms

This section provides a detailed characterization of each PSCR research mechanism and their participants.



[7] https://www.bea.gov/resources/methodologies/RIMSII-user-guide

## 2.1. Grants

Thirteen NIST PSCR grant opportunities are represented in the data used in the analysis. These topic-specific grant opportunities include (organized by grant award date):

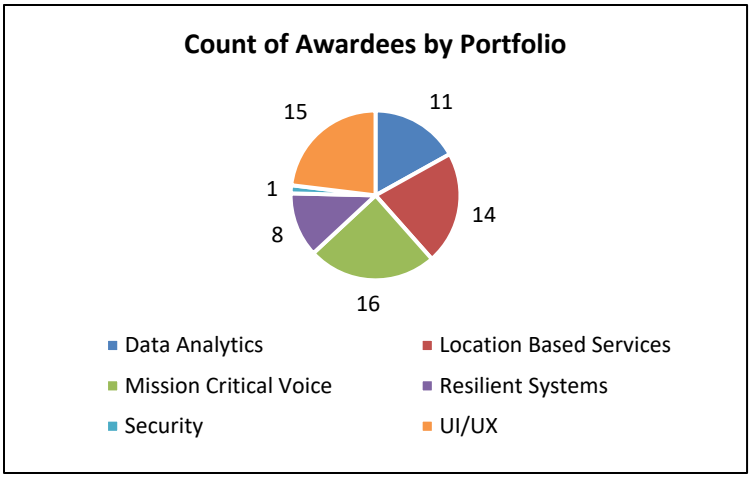


**Fig. 1.** Count of Grant Awardees by NIST PSCR Portfolio.

- **PSIAP 2017** *(Awarded: 2017*), aimed at advancing broadband communications technologies for first responders by supporting the migration of data, video and voice communications from mobile radio to a nationwide public safety broadband network, as well as accelerating critical technologies related to indoor location tracking and public safety analytics.[8]
- **PSIAP Point Cloud City** (*Awarded: 2018*), focused on generating an extensive catalog of annotated 3D indoor point clouds that can be used by industry, academia, and government to advance research and development in areas of interest, such as indoor mapping, localization and navigation for public safety. This grant opportunity also aims to demonstrate the potential value of ubiquitous indoor positioning and location-based information.[9]
- **PSIAP User Interface** (*Awarded: 2018*), aimed to create new or apply current technology that will enable researchers to better assess public safety user interfaces using virtual reality (VR) and augmented reality (AR).[10]
- **PSIAP i-Axis** (*Awarded:* 2019), sought to conduct interactive workshops, summits, exercises, and training to produce technical outputs (i.e., standard operating procedures, best practices guides, implementation templates, etc.), which will be made available to the entire public safety stakeholder community.[11]
- **PSIAP Mission Critical Voice Test Equipment** (*Awarded: 2019*), aimed to support research and development around the creation of a simulator program enabling necessary testing of Mission Critical Services (MCS) technology, such as Mission Critical Push To Talk (MCPTT), Mission Critical Video (MCVideo), and Mission Critical Data (MCData).[12]
- **PSIAP Mission Critical Voice Quality of Experience (QoE)** (*Awarded: 2019*), intended to generate publicly-released data sets and a QoE model correlating impairments in communication systems used by first responders and real task performance by creating test devices to simulate current impairments, developing a test methodology for human testing, and applying these tests to a diverse pool of first responders.[13]
- **PSIAP Augmented Reality** (*Awarded: 2021*), aimed to implement technology that will enable researchers to test and develop user interfaces to enhance public safety by creating new technology or applying current technology to a specific public safety use case.[14]

[8] https://www.nist.gov/ctl/pscr/funding-opportunities/past-funding-opportunities/psiap-2017
[9] https://www.nist.gov/ctl/pscr/funding-opportunities/past-funding-opportunities/psiap-point-cloud-city
[10] https://www.nist.gov/ctl/pscr/funding-opportunities/past-funding-opportunities/psiap-user-interface
[11] https://www.nist.gov/ctl/pscr/funding-opportunities/past-funding-opportunities/psiap-i-axis
[12] https://www.nist.gov/ctl/pscr/funding-opportunities/past-funding-opportunities/psiap-mcv-test-equipment
[13] https://www.nist.gov/ctl/pscr/funding-opportunities/past-funding-opportunities/psiap-mcv-qoe
[14] https://www.nist.gov/ctl/pscr/psiap-augmented-reality

- **PSIAP FR3D** (*Awarded: 2021*), aimed to achieve major upgrades in the performance of sensors and systems for localization and tracking of first responders operating indoors in a variety of building environments without any benefit of pre-deployed dedicated infrastructure.[15]
- **PSIAP 2020 Technical and Business Assistance (TABA) and Demonstration** (*Awarded: 2021*)**,** intended to more rapidly advance public-safety focused communication technology prototypes through needed technical and business assistance or develop a demonstration project with a partnering public safety agency to provide additional testing and research.[16]
- **Measurement, Science and Engineering (MSE) Rolling Grants** (ongoing awards), with grants from Analytics, Mission Critical Voice, Systems Security and User Interface/User Experience Portfolios.

Across these grant opportunities, NIST PSCR funding was distributed via 65 awards to 56 unique entities, 5 of which were international. Figure 1 shows how the 65 grant awards were distributed across the six NIST PSCR research portfolios, with MCV (16), UI/UX (15), and LBS (14) associated with the greatest number of in-scope awards. Geographically, grant awardees were located in 21 states and 3 countries, with the most awardees located in the following states: Texas (6), Michigan (6), California (5), North Carolina (5), and Pennsylvania (5).

### 2.2. SBIR Phase 3 Contracts

There were two SBIR contracts considered for this analysis. Geographically, one business is located in Texas, while the other is located in Virginia. Each collaborator's work is focused on a different NIST research portfolio, MCV and UI/UX corresponding, with the research underway.

### 2.3. Prize Challenges

There were sixteen prize challenge competitions considered for this analysis:

- **The Future of Public Safety Technology 100k Video Series** (*Commenced: 2017*), a challenge to create a series of videos, with corresponding social cut-downs, that will explain Open Innovation and NIST's PSCR Open Innovation Accelerator to the public, while covering each of the key public safety technology programs that are a part of it.[17]
- **Virtual Public Safety Test Environment Challenge** (*Commenced: 2017*), a challenge focused on "measurement environments that use immersive virtual reality tools in conjunction with physical spaces to simulate first responder scenarios for accurate and repeatable testing of new first responder interfaces and technologies."[18]
- **Differential Privacy Synthetic Data Challenge (DEiD 1.0)** (*Commenced 2018*), "tasked participants with creating new methods, or improving existing methods of data de-identification, while preserving the dataset's utility for analysis."[19]
- **First Responder Virtual Reality Heads-up Display Navigation Challenge (VR Heads-Up)** (*Commenced*: *2018*), created "a heads-up display (HUD) for navigation with unimpeded visual aids," supporting first responders and helping PSCR advance research for user interface (UI) technology.[20]

[15] https://www.nist.gov/ctl/pscr/psiap-first-responder-3d-indoor-tracking
[16] https://www.nist.gov/ctl/pscr/commercialization/psiap-taba-demonstration
[17] https://tongal.com/project/TheFutureofPublicSafetyTechnology/#tab-brief
[18] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/past-prize-challenges/2017-virtual-public-safety-test
[19] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/past-prize-challenges/2018-differential-privacy-synthetic
[20] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/past-prize-challenges/2018-virtual-reality-heads-display

- **The Unlinkable Data Challenge** (*Commenced*: 2018), a challenge to propose and implement a mechanism to enable the protection of personally identifiable information while maintaining a dataset's utility for analysis.[21]
- **Unmanned Aerial Systems Flight and Payload Challenge (UAS 1.0)** (*Commenced*: *2018*), a challenge to "help public safety operations by keeping a UAS and its payload airborne for the longest time possible with vertical and hovering accuracy."[22]
- **Expanding the SIM Card Use for Public Safety (SIM Card)** (*Commenced*: *2019*), raised "awareness of the need for convenient, standards-based, two-factor authentication for emergency responders, while demonstrating an innovative approach to authentication that could lead to future innovations."[23]
- **Haptic Interfaces for Public Safety Challenge (Haptics)** (*Commenced*: *2019*), a challenge focused on how haptic interfaces can assist first responders in both VR and real-world scenarios. Haptic interface prototypes were evaluated on how they "impact a first responder's performance in three virtual reality (VR) scenarios [law enforcement, emergency medical services (EMS), and fire service], and how, once embedded into firefighter personal protective equipment (PPE), the prototypes assist firefighters in a realistic scenario as they navigate and conduct a search and rescue task at a firefighter training facility."[24]
- **Tech to Protect** (*Commenced*: *2019*), "designed to engage entrepreneurs, technologists, students, programmers, designers and public safety experts to create solutions across critical technical areas of public safety communications, including secure communications, location-based services, public safety data analytics, mission-critical voice and user interface/user experience (UI/UX)." Proposed solutions support emergency responders' use of advanced communications technologies in their day-to-day activities.[25]
- **Automated Streams Analysis for Public Safety (ASAPS)** (*Commenced*: *2020*), an "(Artificial Intelligence) challenge to detect, analyze, and alert public safety to emergencies from streaming data. The vision of this challenge is to stimulate pioneering research that will provide public safety with advanced real-time emergency detection, situational awareness, and decision-making capabilities from many live unstructured data streams."[26]
- **CHARIoT Challenge** (*Commenced*: 2020), a two-pronged multi-phase competition "to develop solutions that can identify and transmit scenario-accurate city and personal network data streams or deliver first responders actionable and intuitive augmented reality interfaces."[27]
- **Differential Privacy Temporal Map Data Challenge (DEiD 2.0**) (*Commenced*: *2020*), extended the reach and utility of differential privacy algorithms through the development of temporal map data, utility metrics, de-identification algorithms, and open-source development of resulting software.[28]



[21] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/past-prize-challenges/2018-unlinkable-data-challenge
[22] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/past-prize-challenges/2018-unmanned-aerial-systems-flight
[23] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/past-prize-challenges/2019-expanding-sim-card-use-public
[24] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/past-prize-challenges/2019-haptic-interfaces-public-safety
[25] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/past-prize-challenges/2019-tech-protect-challenge
[26] https://www.asapschallenge.ai/
[27] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/current-and-upcoming-prize-challenges/2020-chariot
[28] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/current-and-upcoming-prize-challenges/2020-differential

- **Enhancing Computer Vision for Public Safety Challenge** (*Commenced: 2020*), "focused on advancing the capacity of no-reference (NR) metrics and computer vision algorithms to support public safety missions." Applicants created "image or video datasets that depict camera capture problems, such as grime on the lens or sun flare, that cause issues for computer vision applications."[29]
- **First Responder UAS Endurance Challenge (UAS 2.0)** (*Commenced: 2020*), aimed to create and build a powerful drone intended to support first responders on critical, life-saving missions by expanding drones' capabilities (i.e., vertical takeoff and landing, accuracy, stability, safety), payload management, and flight endurance).[30]

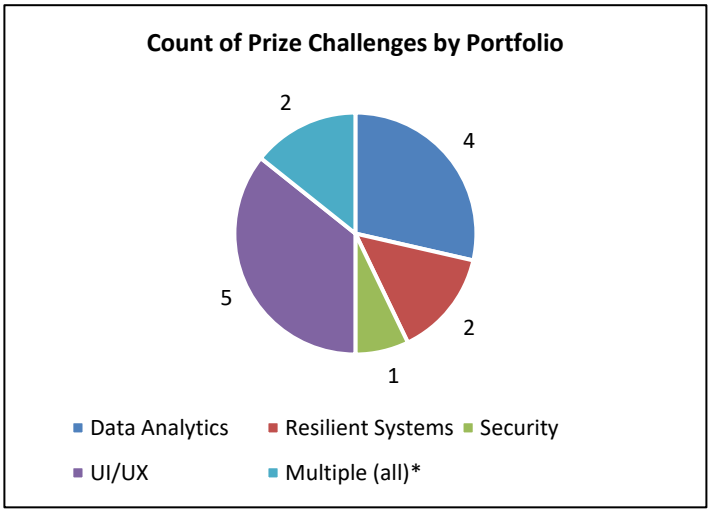


**Fig. 2.** Count of Prize Challenges by Portfolio.
*Two prize challenges were identified as contributing to all NIST PSCR portfolios and are listed separately in this graphic, as they do not represent an additional, unique prize challenge for each portfolio. These two challenges apply across portfolios, including the LBS and MCV portfolio not presented in the figure.

Figure 2 shows how these prize challenges correspond with the NIST PSCR research portfolios. As the figure indicates, the greatest number prize challenge competitions were associated with the UI/UX (5) and Data Analytics (4) portfolios. [31]

Across these challenges, there were 170 total winners (including those that received no cash prizes and 4 international awards), and 152 unique winners. Geographically, challenge winners were located in twenty-six states and four countries, with the majority of winners located in: California (43), Texas (12), and Indiana (11)).

### 2.4. Internal Research

Internal research is conducted by NIST PSCR staff on its Colorado and Maryland campuses to support specific research needs as well as the management and project support for a range of research mechanisms across NIST PSCR portfolios.



[29] https://www.nist.gov/ctl/pscr/open-innovation-prize-challenges/current-and-upcoming-prize-challenges/2020-enhancing
[30] https://www.firstresponderuaschallenge.org/index.php#about
[31] Two prize challenges were identified as contributing to all NIST portfolios in the data and are counted separately, as they do not represent an additional, unique prize challenge for each portfolio.

Figure 3 shows the count of internal research initiatives by PSCR portfolio. As the figure indicates, the largest number of internal research projects correspond with the MCV (40) and Security (32) portfolios[32].

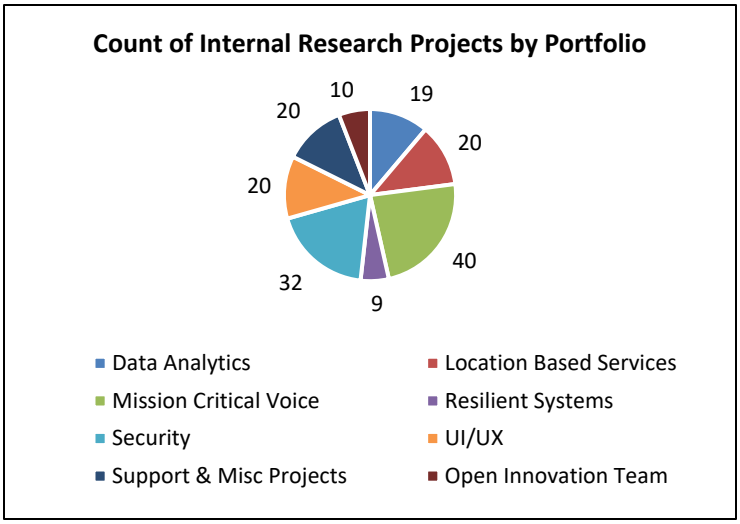


**Fig. 3.** Count of Internal Research Project by Portfolio.

## 3. Economic Impact Analysis

This section describes the economic impact analysis (EIA) conducted by ERG that demonstrates how the economic activity created through NIST PSCR's research mechanisms results in broader impacts to states, focusing on the creation of new jobs, earnings, value added, and total economic output. The economic impacts are estimated by applying standard economic input-output multipliers to the NIST PSCR research investment dollars, which does not account for the *ultimate* value to public safety generated by the research and development (R&D) conducted. Below, the methods used to conduct the analysis are presented, followed by the economic impact results.

### 3.1 Methods

Four key steps were used to conduct the economic impact analysis:

- First, we collected and compiled existing NIST PSCR data specific to each research mechanism on total dollars invested by NIST PSCR (e.g., total project dollars, total dollars awarded). Along the way, we converted the reported dollars to 2020 dollars to ensure the values were comparable with respect to inflation adjustments.
- Second, we assessed the focus of each research project, grant, SBIR Phase 3 contract, and prize challenge assigned an industry sector to each as defined by the North American Industry Classification System (NAICS). Assigning appropriate NAICS codes is key to performing EIA since the impact multipliers are specific to different industries.
- Third, we identified and obtained multipliers from the Bureau of Economic Analysis's (BEA's) Regional Input-Output Modeling System (RIMS II) model that we used to estimate how changes in demand, caused by NIST PSCR's investment, ripple through the economy of the states in which the activities occur.
- Finally, we calculated economic impacts by applying the state-specific BEA RIMS II multipliers to the NIST PSCR economic data. For prize challenges, an additional mark-up was applied to the NIST PSCR investment dollars prior to applying the state-specific multipliers in order to reflect that prize challenge winners likely spent more than the prize amount in resources to obtain the prize.

Each of these steps is described in additional detail below.

[32] These numbers count projects that span multiple years as separate initiatives for each year.

### 3.1.1. NIST PSCR Funding and Project Data

NIST PSCR provided ERG with funding data at the internal research project, grant, SBIR contract, and prize challenge award levels. This data included information on total project or award dollars and/or data that could be used to establish these values (e.g., other object and labor costs). In addition to the funding data, NIST PSCR also provided a range of data across research mechanisms that could be used to determine industry information for use in the analysis, as described further in the section that follows. In some instances, we supplemented NIST PSCR data through a search of publicly available information to obtain key information needed to conduct the analysis. The funding and project data collected and compiled for each research mechanism is described further below.

#### 3.1.1.1. Grants and SBIR contracts

NIST PSCR provided ERG with a Microsoft Excel spreadsheet containing PSCR-funded grants and SBIR contracts. The elements in the data contained:

- Funding amounts
- Year of award
- A brief description of the grant and SBIR work conducted
- Geographic location where grant and SBIR work occurred
- NIST PSCR research portfolio corresponding to each grant and SBIR

ERG supplemented NIST PSCR grant data by developing grant project descriptions from the program's "Past Funding Opportunities" webpage that could be used to determine relevant industry sectors when apply NAICS codes (See Sec. 3.1.2).[33]

#### 3.1.1.2. Prize Challenges

NIST PSCR provided ERG with a Microsoft Excel spreadsheet containing:

- A list of prize challenge competitions and the associated winners of each
- Dollars awarded
- PSCR research portfolio corresponding to each grant

ERG performed additional research on each prize challenge competition to identify a description of the prize challenge, year that the competition occurred, and challenge-winning projects and/or solutions that could be used to identify relevant industry information for the analysis. Lastly, ERG conducted an internet search of academic literature to identify possible studies that could inform methods for estimating the economic impact resulting from prize challenge competitions that considers impacts spurred by the initial product or solution developed for the competition.

ERG identified a study by Cason et al (2017) who posit that prize challenge winners are likely to incur effort in excess of the prize amount.[34] The study suggests that the effort expended potentially exceeds the prize amount by 45 percent. Thus, we applied a 45 percent mark-up based on the top

[33] https://www.nist.gov/ctl/pscr/funding-opportunities/past-funding-opportunities

[34] Cason, T.N., Masters, W.A. and Sheremeta, R.M., 2018. Winner-take-all and proportional-prize contests: theory and experimental results. Journal of Economic Behavior & Organization.

prize amount to each awardee.[35] This mark-up was applied in the economic impact calculation for prize challenges, as further described in Section 3.2.

#### 3.1.1.3. Internal Research

NIST PSCR provided ERG with the following data via several Microsoft Excel spreadsheets:

- Internal research projects by fiscal year
- A brief description of the project or research conducted
- PSCR research portfolio corresponding to each project
- Project cost information comprised of:
  - Total project costs (i.e., dollars invested by PSCR) where available
  - Labor and other object cost data that could be used to determine total project costs, where total project cost data was not available.
  - Overhead costs associated with internal research projects in the 'Support & Miscellaneous Portfolio' by fiscal year

ERG then supplemented, integrated, and reformatted NIST PSCR internal research data so that it could be easily integrated into the tool.

- ***Supplemented Project Descriptions***. ERG worked with NIST PSCR to supplement and better understand internal research project descriptions related to staff time, administration, lab operations, or management. For these projects, NIST PSCR further described whether the work was mainly managerial, administrative, or technical in nature to allow for industry code assignments (as described in the next section). For those projects that were identified as "technical" in nature, NIST PSCR further delineated the activities between early R&D technical work (taking place mostly at a desk), and advanced technical R&D work (taking place mostly in a lab).
- ***Allocated and Integrated Other Object Costs***. NIST PSCR provided other object cost (OOC) data to be integrated with labor dollar values to calculate total project cost in instances where the total project costs were not already available. For Mission Critical Voice and Location-Based Services portfolios, the other object data was provided for a set of projects for a given fiscal year, along with a description of how the OOCs should be allocated across those projects. ERG reformatted each set of projects associated with an OOC so that the tool listed individual projects in each row by fiscal year. We then allocated the OCC costs across those projects as directed by NIST PSCR. The OOCs for each project were then summed with the labor costs for that project to calculate total project costs.
- ***Allocated and Integrate Overhead Costs***. Overhead costs were provided for internal research projects from FY16-FY20. ERG divided the total overhead costs for each fiscal year equally among all projects in the "Support & Miscellaneous" portfolio for that year. The resulting overhead cost was then added to the corresponding project costs.

### 3.1.2. NAICS Industry Codes

As a first step toward determining the appropriate industry multipliers for use in the analysis, we assigned a six-digit North American Industry Classification System (NAICS) code to each internal

[35] For example, if three awards were provided (i.e., first, second and third place) and the first-place award was $10,000, we added $4,500 to each award winner to reflect the amount of effort expended to obtain the award.

research project, grant, SBIR contract, and prize challenge (hereafter referred to collectively as "projects"). We used the project descriptions included in the NIST PSCR data that indicate the type of work being conducted to identify corresponding industry descriptions.[36] ERG conducted a preliminary assignment of NAICS codes across projects and then obtained feedback from NIST PSCR on the relevance and appropriateness of codes selected prior to finalizing the code assignments.

For many of the projects, the scope of activities could not be fully described by only one NAICS code, so in these cases we assigned up two NAICS codes for each project that we termed "primary" and "secondary" NAICS codes, where the "primary" code was associated either 50 percent or 75 percent of the total funding value. Our default was to assume the work could be split equally (50 percent) between the two codes. In cases where ERG and NIST PSCR agreed, we assigned one code 75 percent reflecting the idea that the work was more concentrated in one area over another. We did not attempt to estimate more fine-tuned value (i.e., values different than 50 and 75 percent for the primary NAICS) since we did not have the time or resources available to make those determinations for all the projects. Table 1 provides an example of assigning one code 75 percent of a project's work to a primary NAICS code, while the remaining 25 percent is associated with the secondary NAICS code. Naturally, in instances where only one NAICS code was relevant, that code was attributed with 100 percent of the project activities.

**Table 1.** Example Showing Primary and Secondary NAICS Assignments and Corresponding Percentages.

| Grant Recipient | Project Description | Primary NAICS | Primary NAICS Description | Primary NAICS % | Secondary NAICS | Secondary NAICS Description | Secondary NAICS % |
|---|---|---|---|---|---|---|---|
| Name | Description of work conducted | 518210 | Data Processing, Hosting, and Related Services | 75.00% | 541512 | Computer Systems Design Services | 25.00% |

### 3.1.3. BEA RIMS II Industry Multipliers

The economic impact analysis uses the Bureau of Economic Analysis's (BEA's) Regional Input-Output Modeling System (RIMS II) model 6-digit, detailed industry code multipliers (hereafter referred to as "RIMS multipliers").[37] The RIMS II model shows how economic activity, such as that created through NIST PSCR's research mechanisms, results in other spending in the broader regional economy. BEA has compiled data for and linkages between industries that cover the U.S. economy,[38] and for each industry, the RIMS II model shows how much input (in dollars) is taken from other industries in the economy and, conversely, how much each industry contributes (in dollars) to other industries.[39] On top of this basic commodity flow structure, BEA also allocates the same values into "income" categories and "final demand" categories to allow for more detailed estimates of economic impact.[40] This structure forms what BEA refers to as the "make-use" tables, used to derive multipliers for estimating economic impacts. RIMS II multipliers are either regional or industry-level in nature, and for this analysis, we used state level multipliers to reflect the change in each indicator for states participating in PSCR research.

[36] NAICS search web page: https://www.census.gov/naics/?99967
[37] https://www.bea.gov/resources/methodologies/RIMSII-user-guide
[38] https://apps.bea.gov/regional/rims/rimsii/download/64IndustryListB.pdf
[39] BEA RIMS II multipliers are not designed to be applied to international entities, therefore the economic impacts of NIST investments in international-based project and entities are not estimated in this analysis.
[40] A final aspect accounts for "imports" into a region.

The types of multipliers of focus in the analysis include:

- **Output multipliers** reflect the change in the output of industries in a region for a one-dollar change in demand for a specific industry. That is, what is the total value of economic activity circulating through the states' economies generated by PSCR's R&D investments?
- **Value-added multipliers** reflect the change in regional value-added (gross domestic product, GDP) for a one-dollar change in demand for a specific industry. That is, value-added indicates how much the regional economies grew over a period of time due to PSCR's R&D investments.
- **Earnings multipliers** reflect the total change in household earnings in the region for a one-dollar change in demand for a specific industry. That is, what is the change in household earnings in the states' economies generated by PSCR's R&D investments?
- **Jobs multipliers** reflect the change in the total number of jobs (full- and part-time) per a one-million-dollar change in the demand for a specific industry. That is, what is the change in the number of full- and part-time jobs generated by each one-million-dollar change in the states' economic activity due to PSCR's R&D investments?

***Identifying Industry Multipliers***

We used our NAICS code assignments to identify the RIMS II codes needed for the analysis by applying a crosswalk between NAICS and RIMS codes made available by BEA.[41] This exercise resulted in 12 RIMS codes for use in the analysis, and Table 2 presents the counts of NIST PSCR project types by BEA industry category assigned by ERG. The left-hand column of the table provides the detailed industry codes used by BEA in the Regional Input-Output Modeling System (RIMS II).[42] The counts of each project type having a RIMS II code are presented on the righthand side if the table, with the final column presented the total projects having a given RIMS II code. As the table indicates, the largest number of NIST PSCR projects can be categorized as "Scientific research and development services" (137), followed by "Custom computer programming services" (94) and "Computer systems design services" (93).

**Table 2.** Count of NIST PSCR Projects by RIMS II Industry Codes.

| RIMS Code | Industry Represented by RIMS Code | Count of Projects with RIMS Code | | | | |
|---|---|---|---|---|---|---|
| | | Grants | SBIR | Prize Challenges | Internal Research | Total |
| 336411 | Aircraft manufacturing | 0 | 0 | 30 | 2 | 33 |
| 518200 | Data processing, hosting, and related services | 11 | 0 | 37 | 4 | 52 |
| 541300 | Architectural, engineering, and related services | 5 | 0 | 10 | 20 | 37 |
| 541511 | Custom computer programming services | 21 | 0 | 62 | 11 | 94 |
| 541512 | Computer systems design services | 28 | 2 | 58 | 5 | 93 |
| 541700 | Scientific research and development services | 46 | 2 | 60 | 27 | 137 |
| 561100 | Office administrative services | 0 | 0 | 0 | 18 | 18 |
| 517A00 | Satellite, telecommunications resellers, and all other telecommunications | 0 | 0 | 0 | 2 | 2 |
| 813B00 | Civic, social, professional, and similar organizations | 0 | 0 | 0 | 2 | 2 |

[41] Bureau of Economic Analysis. Industry List A. RIMS II 369 Detailed Industry Codes.
[42] These codes are used in developing the economic impact estimates in Section 3.3.

| | | | | | | |
|---|---|---|---|---|---|---|
| 512100 | Motion picture and video industries | 0 | 0 | 5 | 0 | 5 |
| 334511 | Search, detection, and navigation instruments manufacturing | 0 | 0 | 9 | 0 | 9 |
| 611B00 | Other educational services | 2 | 0 | 0 | 0 | 2 |

ERG purchased the state-specific RIMS multipliers for the detailed codes appearing in Table 2 below for the analysis. ERG used the "Type II" final demand output, value-added, earnings, and jobs multipliers for use in the benefits calculation tool.[43] The multipliers were added as separate tabs in the economic impact calculation tool spreadsheet and later compiled into a single tab for ease of use in the analysis.

### 3.2 Economic Impact Calculations

ERG developed a Microsoft Excel-based economic impact calculation tool to combine the multipliers and the NIST PSCR project investment data. Simplified versions of these calculation tools are depicted in Figure 4 (Grants, SBIR, and Internal Research) and Figure 5 (Prize Challenges). At a high level, these tools integrate the NIST PSCR economic data (see the green "Investment" a columns) and industry multipliers (see the teal "Multipliers - Final Demand (State-Specific)" columns) described in the previous sections to generate state-level economic impacts generated by each product/service. The economic impact on output, earnings, jobs, and value-added are calculated for each project-specific NIST PSCR investment, and the calculated economic impacts appear in the orange columns labeled "Economic Impacts (Final Demand) on Company's State."

***Calculation Steps***

Given that up to two industry codes were applied to each project, the actual economic impact calculations used in the analysis estimate impacts by calculating impacts twice: once for using the primary RIMS II multiplier and the percentage of project work attributed to that multiplier and again with the secondary RIMS multiplier and its associated the percentage of project work. Figure 6 shows how the economic impact calculations were set up to include primary and secondary RIM multiplier codes (columns C and E) and the percentage of each that might be attributed to the project work.

- First, we calculate the economic impacts associate with the primary RIMS industry code. The tool multiplies the NIST PSCR investment (column G) by the primary RIMS multipliers (shown in columns H-K) and the percentage of work attributed with that multiplier (column D). This results in the economic impacts associated with the primary RIMS industry multiplier shown in columns L-O.
- Second, we repeat this entire process using the secondary RIMS industry code and percentage (columns E-F) would be used.
- Third, we sum the economic impacts results calculated for the primary and secondary RIMS industry codes to estimate total economic impacts for that project.
- Lastly, we update the total economic impacts from 2018 to 2020 dollars using the Bureau of Labor Statistics (BLS) Consumer Price Index (CPI).[44]

[43] The Type II multipliers account for inter-industry and household-spending, while Type I only accounts for inter-industry.
[44] https://www.bls.gov/data/inflation_calculator.htm

Economic impacts were calculated for 60 grants, 2 SBIR awards, 166 prize challenges, and 170 funded internal research initiatives, comprised of 67 unique projects.[45] The results of this analysis are presented below.



[45] These figures do not include international projects, for which ERG did not calculate economic impacts.

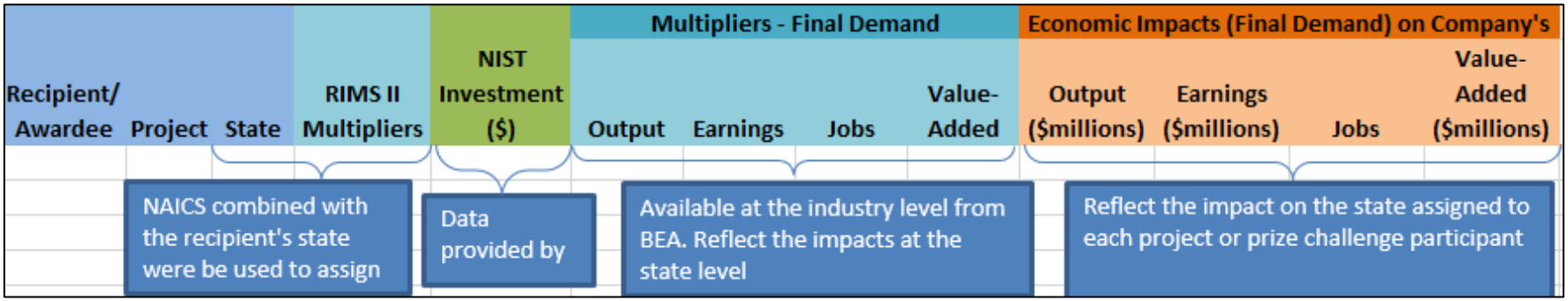


**Fig. 4.** Simplified Economic Impact Calculation Tool Used for Grants, SBIR, and Internal Research.

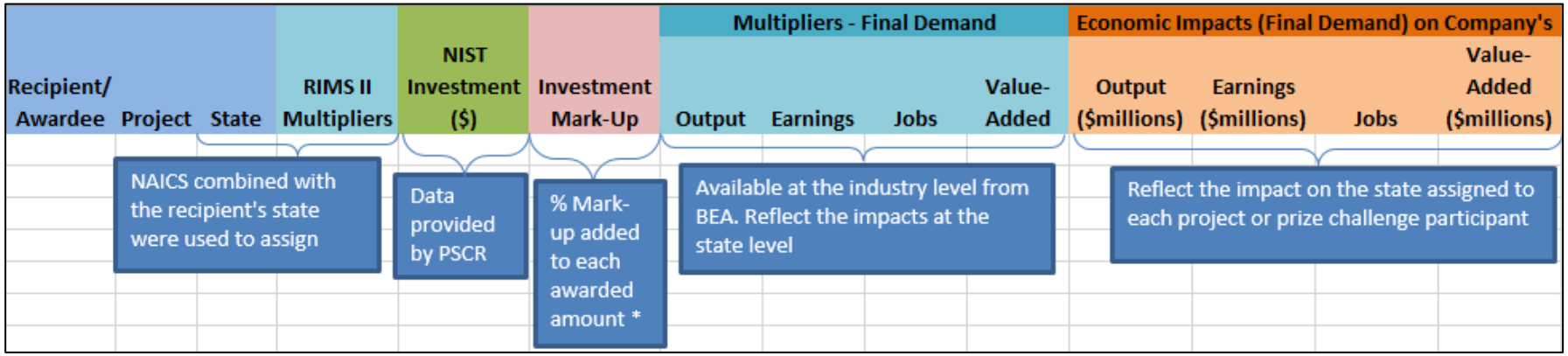


**Fig. 5.** Simplified Economic Impact Calculation Tool Used for Prize Challenge Competitions.

* A 45 percent mark-up of the top awarded dollar amount in a given challenge was calculated then added to each award for that challenge to account for the participant's re-investment of the awarded amount into further product or solution development.

| B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Industry Information | | | | | Primary RIMS Multipliers and Economic Impacts | | | | | | | |
| | | | | | | Final Demand Multipliers (State-Specific) | | | | Economic Impacts (Final Demand) on Awardee's State | | | |
| Project | Primary RIMS II Detailed Industry Code | Percent Activities Attributed to Primary RIMS | Secondary RIMS II Detailed Industry Code (If Applicable) | Percent Activities Attributed to Secondary RIMS | NIST Investment ($) | Output | Value-Added | Earnings | Jobs | Output ($2018 M) | Value-Added ($2018 M) | Earnings ($2018 M) | Jobs |
| Project X | 518200 | 75% | 541700 | 25% | $ 0.18 | 1.9174 | 1.0213 | 0.4357 | 8.2702 | $ 0.26 | $ 0.14 | $ 0.06 | 1 |

**Fig. 6.** Example of Calculation with Primary RIMS Multiplier.

### 3.3 Results

This section presents the estimated economic impacts of NIST PSCR's four research mechanisms covered in this project. We present the impacts across all research mechanisms and then transition to a breakdown of impacts by each research mechanism.

Table 3 shows the economic impacts calculated across each of the research mechanisms. Our analysis found that NIST PSCR's investment in the four in-scope research mechanisms resulted in a total of:

- $509.84 million in annual output ($2020)
- $431.19 million in annual value-added ($2020)
- $261.78 million in annual earnings and ($2020)
- 4,280 new jobs.

**Table 3**. Total Economic Impact by Research Mechanism (Based on Multipliers).

| | Grants | SBIR | Prize Challenges | Internal Research | Total |
|---|---|---|---|---|---|
| **Amount Invested ($FY M) [a]** | $73.94 | $4.48 | $3.50 | $142.67 | **$224.59** |
| **Amount Invested ($2020 M) [b]** | $68.07 | $4.48 | $3.44 | $145.71 | **$221.71** |
| **Total Output ($2020 M)** | $139.49 | $9.13 | $29.10 | $332.12 | **$509.84** |
| **Value-Added ($2020 M)** | $211.22 | $5.88 | $18.28 | $195.81 | **$431.19** |
| **Earnings ($2020 M)** | $123.36 | $3.42 | $10.65 | $124.35 | **$261.78** |
| **Jobs** | 1,967 | 53 | 169 | 2,091 | **4,280** |

[a] This sum reflects dollars invested by NIST PSCR for the original fiscal year of the investment and sums across fiscal years FY16-FY20 rather than putting all dollars in the same fiscal year.
[b] This amount invested excludes 9 international awards, totaling $7.98 M. For this project, we only included projects with domestic multipliers in the economic impact analysis.

Figure 7 shows how the funding provided through Public Safety Trust Fund (PSTF) allocations was applied by NIST PSCR to achieve direct and indirect impacts. Viewing from top to bottom, the figure shows how up to $300 million in PSTF allocations flow through NIST PSCR to internal and external research mechanisms. These research efforts generate direct economic impacts, like increased household earnings and jobs, in the states in which research occurs as well as improved public safety communications. The improved public safety communications then result in indirect impacts associated with improved support of public safety communities and the citizens they serve.

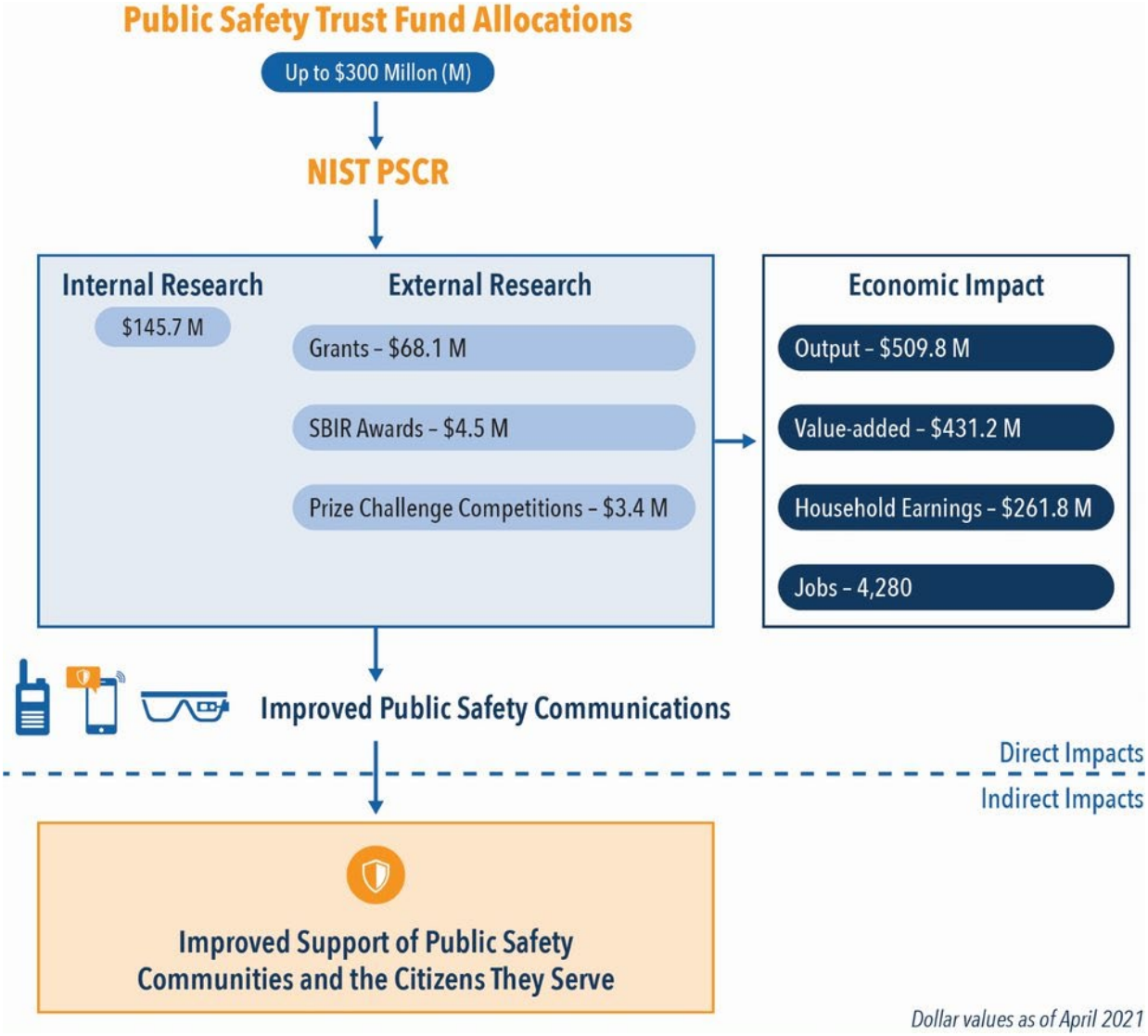


**Fig. 7.** NIST PSCR Investment in Research Generates Economic Impacts.

The breakdown of NIST PSCR investment and the resulting economic impacts across the six PSCR research portfolios is presented in Table 4. When comparing the NIST PSCR investment to economic impacts generated by that investment, the three portfolios that generated the largest economic output per dollar invested were Resilient Systems ($2.6 per $1 invested), Security ($2.5 per $1 invested), and UI/UX ($2.4 per $1 invested).[46]

[46] The difference in economic impact generated by each portfolio is due to the fact that each portfolio contains a mixture of different project-types associated with different industry sectors, and the work activities conducted for each portfolio occur in different geographies. This means that the PSCR dollars invested in each portfolio filter through economic impact multipliers that are both state- and sector-specific. Thus, the multipliers applied to each portfolio differ, and the application of these differing multipliers result in varying economic impacts for a $1 PSCR investment in a given portfolio.

**Table 4**. Impact by NIST PSCR Portfolio (Based on Multipliers).*

| | Number of Awards/ Projects [a] | NIST Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| Data Analytics | 63 | $16.35 | $37.50 | $48.72 | $27.10 | 450 |
| Location Based Services | 42 | $21.36 | $45.15 | $39.32 | $22.86 | 364 |
| Mission Critical Voice | 62 | $36.06 | $76.35 | $80.78 | $47.45 | 740 |
| Resilient Systems | 55 | $9.28 | $24.45 | $39.31 | $23.50 | 361 |
| Security | 47 | $8.18 | $20.26 | $12.06 | $7.22 | 117 |
| UI/UX | 101 | $22.76 | $54.96 | $64.11 | $38.99 | 626 |
| Support & Misc. Projects | 20 | $94.09 | $218.10 | $127.42 | $81.54 | 1,393 |
| Open Innovation Team | 10 | $13.62 | $33.09 | $19.47 | $13.13 | 228 |
| **Total** | **398** | **$221.7** | **$509.8** | **$431.2** | **$261.8** | **4,280** |

*In some instances, NIST PSCR Prize challenges were associated with all NIST PSCR portfolios rather than a single NIST PSCR portfolio. In these instances, the NIST PSCR investment for the award is divided evenly across each of the portfolios in order to evenly distribute the economic impacts of those awards.

[a] This excludes internationals awards/projects since they are not included in the analysis. Total awards/project including international projects is 407.

Table 5 shows the economic impacts by state across all research mechanisms. States with the greatest number of awards or projects include Colorado (CO), Maryland (MD), California, and Texas. NIST PSCR's internal research work is responsible for the high number of projects in CO and MD, as this research takes place at NIST campuses in both states.

**Table 5**. Economic Impacts by State Across Research Mechanisms.

| State | Number of Awards/Projects | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|
| AR | 1 | $0.13 | $0.09 | $0.06 | 1 |
| CA | 48 | $24.22 | $28.70 | $17.47 | 250 |
| CO | 110 | $304.25 | $183.34 | $117.40 | 1984 |
| CT | 1 | $0.26 | $0.47 | $0.22 | 4 |
| DC | 3 | $1.90 | $1.08 | $0.22 | 3 |
| FL | 12 | $3.02 | $3.94 | $2.45 | 44 |
| GA | 10 | $14.38 | $21.26 | $12.70 | 230 |
| IL | 4 | $1.42 | $0.93 | $0.57 | 8 |
| IN | 13 | $17.43 | $9.91 | $5.96 | 93 |
| IA | 1 | $0.10 | $0.06 | $0.04 | 1 |
| KS | 2 | $0.46 | $0.24 | $0.11 | 2 |
| KY | 1 | $0.22 | $0.11 | $0.05 | 1 |
| MD | 80 | $34.57 | $24.18 | $13.37 | 205 |
| MA | 6 | $6.00 | $7.74 | $4.56 | 64 |
| MI | 7 | $9.20 | $14.28 | $8.76 | 148 |
| MN | 1 | $0.06 | $0.03 | $0.01 | 0 |
| MS | 1 | $0.33 | $0.80 | $0.52 | 10 |
| MT | 1 | $0.19 | $0.09 | $0.05 | 1 |

| State | Number of Awards/Projects | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|
| NJ | 7 | $10.48 | $17.74 | $9.93 | 144 |
| NY | 9 | $12.12 | $14.56 | $7.91 | 112 |
| NC | 14 | $9.11 | $18.79 | $11.62 | 192 |
| ND | 1 | $0.05 | $0.01 | $0.01 | 0 |
| OH | 6 | $2.60 | $4.56 | $2.48 | 48 |
| OK | 1 | $0.13 | $0.08 | $0.05 | 1 |
| OR | 1 | $3.30 | $4.22 | $2.31 | 40 |
| PA | 11 | $10.21 | $15.03 | $8.97 | 139 |
| TN | 1 | $0.99 | $2.11 | $1.02 | 19 |
| TX | 23 | $24.75 | $38.17 | $22.33 | 375 |
| VA | 14 | $13.85 | $15.00 | $8.37 | 128 |
| WA | 8 | $4.13 | $3.67 | $2.28 | 32 |

### 3.3.1. Results by Research Mechanism

The estimates economic impacts generated by each of the four NIST PSCR research mechanisms are presented below. For each mechanism, we present the impacts by portfolio and state in tabular form.

#### 3.3.1.1 Grants

**Table 6**. Economic Impacts Generated by Grants by Portfolio.

| | Number of Awards | NIST PSCR Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| Data Analytics | 11 | $12.45 | $26.01 | $41.40 | $22.88 | 384 |
| Location Based Services | 13 | $16.92 | $33.42 | $32.22 | $18.50 | 294 |
| Mission Critical Voice | 12 | $16.85 | $33.85 | $55.12 | $32.04 | 496 |
| Resilient Systems | 8 | $8.00 | $17.01 | $35.06 | $21.13 | 324 |
| Security | 1 | $1.50 | $3.38 | $1.92 | $1.14 | 21 |
| UI/UX | 15 | $12.34 | $25.82 | $45.50 | $27.66 | 448 |
| **Total** | **60** | **$68.07** | **$139.49** | **$211.22** | **$123.36** | **1,967** |

**Table 7**. Economic Impacts Generated by Grants by State.

| State | Number of Awards | NIST PSCR Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| CA | 5 | $7.15 | $14.95 | $22.81 | $13.99 | 199 |
| CO | 2 | $2.20 | $4.81 | $7.52 | $4.68 | 72 |
| CT | 1 | $0.14 | $0.26 | $0.47 | $0.22 | 4 |
| DC | 2 | $1.33 | $1.87 | $1.06 | $0.21 | 3 |
| FL | 2 | $0.65 | $1.38 | $2.92 | $1.84 | 33 |
| GA | 3 | $5.72 | $12.55 | $20.09 | $12.00 | 218 |
| IN | 2 | $8.09 | $15.95 | $8.99 | $5.40 | 83 |
| MA | 3 | $2.81 | $5.63 | $7.51 | $4.44 | 62 |
| MD | 2 | $1.69 | $3.16 | $4.72 | $2.26 | 38 |
| MI | 6 | $4.56 | $9.13 | $14.24 | $8.74 | 148 |

| State | Number of Awards | NIST PSCR Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| MS | 1 | $0.18 | $0.33 | $0.80 | $0.52 | 10 |
| NC | 5 | $3.76 | $7.90 | $18.05 | $11.20 | 184 |
| NJ | 3 | $4.53 | $9.54 | $17.15 | $9.60 | 139 |
| NY | 3 | $6.10 | $11.59 | $14.21 | $7.72 | 109 |
| OH | 2 | $0.94 | $1.94 | $4.18 | $2.28 | 43 |
| OR | 1 | $1.75 | $3.30 | $4.22 | $2.31 | 40 |
| PA | 5 | $4.71 | $9.64 | $14.68 | $8.77 | 136 |
| TN | 1 | $0.46 | $0.99 | $2.11 | $1.02 | 19 |
| TX | 6 | $6.42 | $15.17 | $32.39 | $18.68 | 314 |
| VA | 3 | $3.31 | $6.37 | $10.13 | $5.64 | 87 |
| WA | 2 | $1.55 | $3.03 | $2.95 | $1.84 | 26 |
| **Total** | **60** | **$68.07** | **$139.49** | **$211.22** | **$123.36** | **1,967** |

#### 3.3.1.2 SBIR

**Table 8.** Economic Impacts Generated by SBIR Phase 3 Contract by Portfolio.

| | Number of Awards | NIST PSCR Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| Data Analytics | 0 | $0.00 | $0.00 | $0.00 | $0.00 | 0 |
| Location Based Services | 0 | $0.00 | $0.00 | $0.00 | $0.00 | 0 |
| Mission Critical Voice | 1 | $2.99 | $5.70 | $3.71 | $2.10 | 32 |
| Resilient Systems | 0 | $0.00 | $0.00 | $0.00 | $0.00 | 0 |
| Security | 0 | $0.00 | $0.00 | $0.00 | $0.00 | 0 |
| UI/UX | 1 | $1.49 | $3.43 | $2.17 | $1.33 | 21 |
| **Total** | **2** | **$4.48** | **$9.13** | **$5.88** | **$3.42** | **53** |

**Table 9.** Economic Impacts Generated by SBIR Phase 3 Contracts by State.

| State | Number of Awards | NIST PSCR Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| TX | 1 | $1.49 | $3.43 | $2.17 | $1.33 | 21 |
| VA | 1 | $2.99 | $5.70 | $3.71 | $2.10 | 32 |
| **Total** | **2** | **$4.48** | **$9.13** | **$5.88** | **$3.42** | **53** |

### 3.3.1.3 Prize Challenge Competitions

**Table 10.** Economic Impacts Generated by Prize Challenge Competitions by Portfolio.

| | Number of Awards | NIST PSCR Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| Data Analytics | 24 | $0.69 | $5.23 | $3.29 | $1.88 | 31 |
| Location Based Services | 0 | $0.28 | $2.56 | $1.70 | $1.02 | 16 |
| Mission Critical Voice | 0 | $0.28 | $2.56 | $1.70 | $1.02 | 16 |
| Resilient Systems | 29 | $0.75 | $6.23 | $3.55 | $1.92 | 30 |
| Security | 5 | $0.34 | $3.30 | $2.19 | $1.31 | 20 |
| UI/UX | 56 | $1.10 | $9.22 | $5.86 | $3.51 | 56 |
| Multiple (all) [a] | 52 | | | | | |
| **Total** | **166** | **$3.44** | **$29.10** | **$18.28** | **$10.65** | **169** |

[a] In some instances, NIST PSCR Prize challenges were associated with all PSCR portfolios rather than a single portfolio. In these instances, the NIST PSCR investment for the award is divided evenly across each of the portfolios in order to evenly distribute the economic impacts of those awards.

**Table 11.** Economic Impacts Generated by Prize Challenge Competitions by State.

| State | Number of Awards | NIST PSCR Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| AR | 1 | $0.00 | $0.13 | $0.09 | $0.06 | 1 |
| CA | 43 | $1.15 | $9.27 | $5.88 | $3.48 | 51 |
| CO | 10 | $0.29 | $2.10 | $1.35 | $0.82 | 13 |
| DC | 1 | $0.00 | $0.03 | $0.02 | $0.00 | 0 |
| FL | 10 | $0.21 | $1.64 | $1.02 | $0.61 | 11 |
| GA | 7 | $0.17 | $1.83 | $1.17 | $0.71 | 12 |
| IA | 1 | $0.01 | $0.10 | $0.06 | $0.04 | 1 |
| IL | 4 | $0.04 | $1.42 | $0.93 | $0.57 | 8 |
| IN | 11 | $0.27 | $1.48 | $0.93 | $0.56 | 10 |
| KS | 2 | $0.09 | $0.46 | $0.24 | $0.11 | 2 |
| KY | 1 | $0.02 | $0.22 | $0.11 | $0.05 | 1 |
| MA | 3 | $0.05 | $0.38 | $0.23 | $0.12 | 2 |
| MD | 10 | $0.17 | $1.12 | $0.72 | $0.40 | 6 |
| MI | 1 | $0.01 | $0.07 | $0.04 | $0.02 | 0 |
| MN | 1 | $0.00 | $0.06 | $0.03 | $0.01 | 0 |
| MT | 1 | $0.02 | $0.19 | $0.09 | $0.05 | 1 |
| NC | 9 | $0.13 | $1.20 | $0.74 | $0.42 | 8 |
| ND | 1 | $0.01 | $0.05 | $0.01 | $0.01 | 0 |
| NJ | 4 | $0.13 | $0.95 | $0.60 | $0.32 | 5 |
| NY | 6 | $0.06 | $0.53 | $0.34 | $0.18 | 3 |
| OH | 4 | $0.07 | $0.66 | $0.38 | $0.20 | 5 |
| OK | 1 | $0.02 | $0.13 | $0.08 | $0.05 | 1 |
| PA | 6 | $0.09 | $0.56 | $0.35 | $0.20 | 3 |
| TX | 12 | $0.15 | $1.66 | $1.00 | $0.58 | 9 |
| VA | 10 | $0.22 | $1.78 | $1.15 | $0.64 | 10 |
| WA | 6 | $0.07 | $1.10 | $0.72 | $0.44 | 6 |
| **Total** | **166** | **$3.44** | **$29.10** | **$18.28** | **$10.65** | **169** |

### 3.3.1.4 Internal Research

**Table 12.** Economic Impacts Generated by Internal NIST PSCR Research by Portfolio.

| | Number of Projects [a] | NIST PSCR Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| Data Analytics | 19 | $3.21 | $6.26 | $4.04 | $2.33 | 36 |
| Location Based Services | 20 | $4.16 | $9.16 | $5.41 | $3.34 | 54 |
| Mission Critical Voice | 40 | $15.94 | $34.23 | $20.25 | $12.29 | 196 |
| Resilient Systems | 9 | $0.54 | $1.21 | $0.70 | $0.45 | 8 |
| Security | 32 | $6.34 | $13.58 | $7.95 | $4.77 | 76 |
| UI/UX | 20 | $7.83 | $16.48 | $10.58 | $6.49 | 100 |
| Support & Misc. Projects | 20 | $94.09 | $218.10 | $127.42 | $81.54 | 1,393 |
| Open Innovation Team | 10 | $13.62 | $33.09 | $19.47 | $13.13 | 228 |
| **Total** | **170** | **$145.71** | **$332.12** | **$195.81** | **$124.35** | **2,091** |

[a] These are not unique projects. Number of awards may include multiple instances of a project over multiple fiscal years and locations.

**Table 13.** Economic Impacts Generated by Internal NIST PSCR Research by State.

| State | Number of Projects | NIST PSCR Investment ($2020 M) | Output ($2020 M) | Value-Added ($2020 M) | Earnings ($2020 M) | Jobs |
|---|---|---|---|---|---|---|
| CO | 98 | $128.57 | $297.34 | $174.47 | $111.90 | 1,899 |
| MD | 68 | $15.40 | $30.29 | $18.73 | $10.72 | 161 |
| TX | 4 | $1.74 | $4.50 | $2.61 | $1.74 | 31 |
| **Total** | **170** | **$145.71** | **$332.12** | **$195.81** | **$124.35** | **2,091** |

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