



**NIST Grant/Contractor Report
NIST GCR 23-038**

**PSCR Impact Assessment:
2016-2022 Executive Summary**

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PSCR Impact Assessment: 2016–2022

Executive Summary



By Monika Bochert and Marc Leh



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ABOUT PSCR

The Public Safety Communications Research Division (PSCR) at the National Institute of Standards and Technology (NIST) is the primary federal laboratory for research and development (R&D) to advance public safety operational capabilities related to communications technology. PSCR's mission is to bring advanced capabilities to first responders and have a measurable impact on their ability to protect and save lives and property. The 2012 Middle Class Tax Relief and Job Creation Act allocated \$300 million to PSCR to establish an R&D program to support the development and deployment of the Nationwide Public Safety Broadband Network (NPSBN) from fiscal year 2016 through 2022. Now that the funds have been spent, PSCR seeks to outline accomplishments made possible by this mandate. This executive summary details the impacts of PSCR's intramural and extramural programs from 2016 to 2022 across its six research portfolios: User Interface/User Experience (UI/UX), Mission Critical Voice (MCV), Location-Based Services (LBS), Analytics, Security, and Resilient Systems.

Purpose

The purpose of this executive summary is to provide key stakeholders with relevant information about how PSCR spent Public Safety Trust Funds and the impacts of that funding. Furthermore, this report seeks to demonstrate the value and positive outcomes of a one-time injection of funds into a topic area and the extent to which this model can be repeated in other areas of significant impact, such as semiconductor supply or climate change. PSCR extensively tracked its impacts since 2016, aligning them across five leading indicators: research capacity, disruptive approaches and technology, standards, products, and public safety methods. Furthermore, data from extramural award recipients, prize challenge competitors, and accelerator program participants have been included to provide a more holistic view of programmatic impact. However, only preliminary data is included in this executive summary and a more complete and comprehensive report with additional analysis is scheduled to be published in spring 2023.*

LEADING INDICATOR DEFINITIONS:

Increase research capacity: Expand the community supporting public safety communications research (industry, academia, etc.) through PSCR's outreach and education efforts, and work towards developing new tools, platforms, and datasets for this community to use.

Advance disruptive approaches and technology: Create underlying new science, technology, and measurement approaches that demonstrate a fundamentally different and innovative technology capability or evaluation method is possible.

Contribute to standards: Educate standards bodies on public safety's communications needs, requirements, and reality; while making sure that communications technologies used in public safety field settings are built using industry-accepted, interoperable standards.

Develop products: Support the development of new communications prototypes, commercialization of these prototypes into products used in public safety operations, and enhancement of adopted products to meet evolving public safety user requirements.

Enhance public safety methods: Train and educate public safety users on the availability of new or enhanced products and how to best leverage new technologies in day-to-day operations.

* Exact counts are subject to change in the upcoming spring report.

NIST INVESTMENT

With limited time and a federal team beginning with only 31 full time employees in 2016, PSCR sought partnerships to join their mission. While PSCR was allocated \$300M, the following analysis is presented in 2022 dollars to effectively compare economic impact over time.

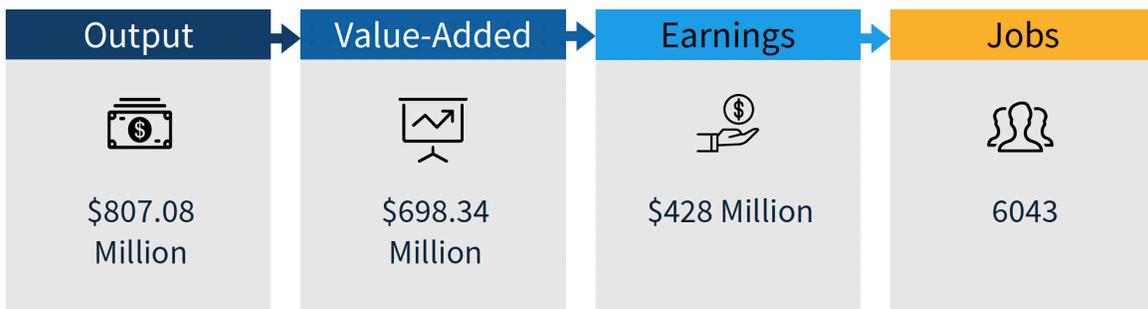
In 2022 dollars, PSCR invested **\$348.76M** between **internal research, external research, prize challenges, and commercialization**. With the funds' expiration, PSCR sought to better understand how their R&D investments resulted in economic impacts that rippled outward to state economies.

PSCR allocated **\$239.95M** to internal research, generating a total of **2,977 jobs** and fostering an ecosystem for technological developments detailed below.

Utilizing grants and cooperative agreements, PSCR supported a total of 83 funding opportunities, 77 of which were US-based and 6 of which were international. PSCR invested **\$108.76M** total in external awardees, with \$98.62M spent domestically and \$10.14M spent internationally. A total of **2,782 jobs** were added to the economy as a result of PSCR's support of domestic external research. However, the impact of international awards was not assessed in the economic report.

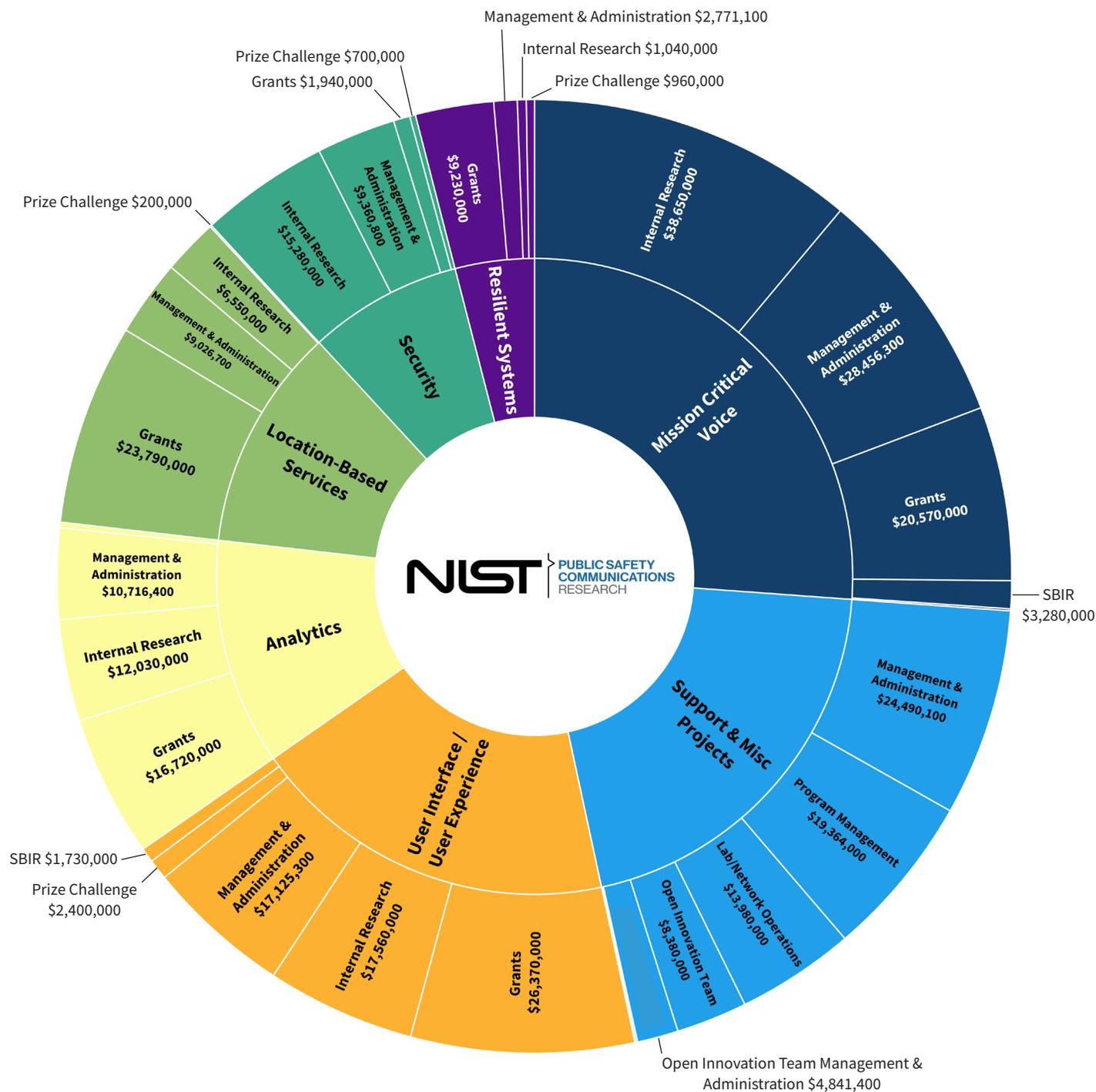
Employing prize challenges, PSCR invested **\$5.19M**, supporting the award of 184 teams and adding **233 jobs** to the U.S. economy. As with grants, while 5 international teams participated, their contributions to the economy were not formally assessed.

Finally, PSCR also supported **2 SBIR Phase 3 awards** at a total investment cost of **\$5.01M**, leading to **51 jobs**.



An independent analysis was conducted to demonstrate how PSCR's research investments translate into broader impacts to the United States, including jobs, earnings, value added, and total economic output. For more information about how these totals were calculated, please see the **NIST PSCR Economic Impact Analysis** found on PSCR's website.

NIST INVESTMENT



The visualization above illustrates PSCR's funding allocation per portfolio and project. Please note, these inputs are in 2022 dollars.

PSCR PROGRAM IMPACTS

PRODUCTS

Measurement Method Metrics



MCV Quality Of Experience



Public Safety Push-To Talk Modeling



XR Test Bed for Usability



Public Safety Analytics Open Framework



Indoor Localization Accuracy

Research Tools



21

Open Source Software



96

Publications

Standards

LTE

483 Contributions for Public Safety Service & Feature Requirements, Architecture, & Protocol Specifications

LMR to LTE

3GPP Standards Based LMR to LTE Interfaces for Public Safety

REACH

Hosted Events

More than
85

Stakeholder Engagements Since 2016

Lab visitors

More than
2200

On-site and Virtual Visitors Since 2016

STAFF

99

Staff Working on PSCR's Mission at Peak Operations

RESEARCH FACILITIES

Public Safety Innovation Lab



40-Gigabit Core LTE Network



P25 Phase 1 & 2 LMR System



2 RF Chambers for Testing Devices



Interoperability Lab Interconnecting LMR and LTE Systems



Virtual and Augmented Reality Lab



Mobile Research Vehicle for Field Measurements

Public Safety Immersive Test Center



A Modular Layout



A Motion Capture System with 62 High Speed Optical Tracking Cameras Capable of Centimeter Accuracy



A Variety of Augmented & Virtual Reality Headsets



A Mobile Staircase & Other Equipment for Z-Axis Motion



Physical Furniture and Gear to Add a Tactile Component to Simulations

PSCR PROGRAM IMPACTS

PSCR PROGRAM IMPACTS

Extramural Research

Grants and Cooperative Agreements



\$108.76M

In Grants
Awarded



247

Total Award Recipients,
Subcontractors,
and Public Safety
Practitioners



60*

Software
Resources



3

Patents
Granted



7

Additional Patent
Applications Submitted

Open Innovation



Winners
from
33 States
&
5 Countries



20

Challenges
Launched



246

Winning
Teams



\$5.3M+

In Prizes
Awarded



603

Prizes
Awarded



848

Total
Submissions

Federal Follow-On Funding

\$150,000 from Department of Homeland Security (DHS) SBIR Phase 1

\$150,000 from U.S. Department of Transportation (DOT) SBIR Phase 1

\$100,000 from the U.S. Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA)

\$50,000 from Phase 1 of AFWERX, a Technology Directorate of the Air Force Research Laboratory (AFRL) and the innovation arm of the Department Air Force

\$50,000 from Air Force SBIR Phase 1 and a pending award from National Science Foundation (NSF)

Commercialization Highlights

26* public safety organizations involved in commercialization efforts

20* funding opportunities with public safety demonstrations and pilot projects

PULSE Accelerator participant planned business expansion with the State of Colorado will create **372 new jobs** with an average salary of **\$143K annually**

\$17M in Series B funding secured by a UI/UX award recipient to support healthcare and public safety

Analytics awardee received **\$12.5M Series A funding** to support their work leveraging data-centric machine learning solutions

More than **\$3M** in follow-on funding secured by MCV award recipients

* Exact counts are subject to change in the upcoming spring report.

UNIQUE PORTFOLIO STATISTICS



User Interface/User Experience:

- **6*** testbeds developed
- **13*** VR scenarios developed and **35** unique AR prototypes across **4** incidents and **2** perspectives
- Usability evaluations and feedback gathered from more than **650*** first responders
- **600** first responders anticipated to use awardee NextGen Interactions' VR training products
- External awardees fostered formal partnerships with **49** public safety organizations
- **1** SBIR Phase 3 for TRAC Labs Inc.



Mission Critical Voice:

- **6*** prototype measurement systems developed
- **1** new software-defined radio company generated by awardee New York University
- Completed NR ProSe discovery and Layer 3 implementation for ns-3
- **4** Key Performance Indicators (KPIs) developed to support Public Safety MCV
- Enabled the interworking between LMR to LTE
- **1** SBIR Phase 3 for Catalyst Communications Technologies, Inc.



Location-Based Services:

- Over **4,461,000 square feet** of indoor space mapped
- Datasets from **28** mapped buildings published by external awardees
- **1,000+** views/downloads of the National Alliance for Public Safety GIS (NAPSG) Best Practices Guide to Indoor Mapping, Tracking, and Navigation
- **7*** academic, industry, or public safety trainings implemented on LBS capabilities
- **12*** students at a graduate level or higher trained on LBS capabilities as a result of federal funding
- **1500*** miles of roadways mapped



Analytics:

- **38*** software resources identified so far
- **2** studies developed
- Awardee Western Fire Chiefs Association developed a cross-department fire database and analysis sharing network used by more than **30** organizations
- Automated Streams Analytics for Public Safety (ASAPS) dataset published, featuring **8** continuous hours of activity with **150** actors, **42** synchronized data streams, **29** camera views, and data inclusive of 911/dispatch audio communications, social media streams, and gunshot sensor data



Security:

- **3** identity vendors adopted PSCR Mobile SSO standards and best practices
- Contactless fingerprinting success rates improved from 70% in 2019 to **over 90%** in 2022 through performance enhancements achieved through the mFIT prize challenge
- Fortify Edge developed a continuous authenticator on a Google WearOS smartwatch using Fast ID Online (FIDO) 2 and other SIM Challenge innovations
- NCCoE Lab completed four-way non-disclosure agreements (NDAs) between NIST, Axon, Datamaxx and CommSys



Resilient Systems:

- Resilient data sharing tool developed by awardee Michigan Technological University successfully transfers files up to **150MB** with no interruption at **100-yard** distance
- Emergency communications framework developed by awardee University of California Riverside delivers **81.93%** of all disaster-relevant social media posts to first responders
- UAS continuous flight time increased from 18 to **112 minutes** with a 10-lb payload, gas-electric or hydrogen cells
- UAS delivery of real-time data using machine learning for search and rescue operations

USER INTERFACE/USER EXPERIENCE

Definition of Success



Publish PSCR's UI/UX test environment with the Virtual Reality (VR) and Augmented Reality (AR) community for user interface (UI) providers to develop and test public safety products



Develop guidelines and metrics for evaluating the effectiveness of different UI capabilities that are adopted by the developer community



Deliver improved UI products to first responders through grants, cooperative agreements, and PSCR's Open Innovation program



Educate and form collaboration programs with the public safety community to enhance their knowledge and selection of products

Prior to 2018, the public safety augmented reality/virtual reality market essentially did not exist. However, today, PSCR's UI/UX portfolio team has supported more than 20 groups across industry and academia that now actively work in this space. A number of valuable tools and resources have been released for public use, including open-source VR builds, VR environments, and backend metrics, many of which came from prize challenges like the 2018 Heads Up Display Challenge and the 2019 Haptics Challenge. The Public Safety Immersive Test Center was established to serve as a testbed for measuring natural interactions with the environment, like crawling on the floor or picking up props such as fire nozzles or dummies. PSCR's AR Usability Evaluation Framework also supported the public safety community by providing an initial set of usability metrics and common terminology, facilitating comparability across AR R&D efforts and enabling sharing of usability evaluation results. Finally, the process of applying for and participating in prize challenges and funding opportunities enabled teams and applicants to

develop long-lasting relationships with the public safety communities across the U.S. as they iterated UI designs.

This portfolio **advanced disruptive approaches and technology** by supporting award recipients like Health Scholars and NextGen Interactions to develop VR trainings that have been integrated by partner public safety organizations across the country. Extramural award recipients **enhanced public safety methods** through cooperative agreements, including cognitive load studies on first responder wayfinding from the University of Florida, and VR-based intelligent UIs from North Carolina State University. PSCR's internal publications on AR usability **increased research capacity** by looking at time on task, task accuracy captured in AR/VR technologies, and other usability surveys. Additionally, the evaluation frameworks PSCR developed were leveraged in the CHARIoT Challenge to capture the accuracy of U/IUX technology and evaluate the usability of the interface based on Internet of Things (IoT) traffic.

IMPACTS AT A GLANCE:



* Exact counts are subject to change in the upcoming spring report.

MISSION CRITICAL VOICE

Definition of Success



Develop Mission Critical Push-to Talk (MCPTT) measurement systems to baseline existing and potential technology solutions



Enable Direct Mode Operations for LTE, 5G, and other future public safety networks through standards representation as well as modeling and simulation



Develop a framework and method for defining what Quality of Experience (QoE) of MCV means for public safety and use that framework to conduct measurements of QoE for stakeholders



Begin to identify a more affordable path for all existing Land-Mobile Radio (LMR) Systems to interface and integrate with LTE systems, as accomplished through funding the Nemergent IWF, Valid8 IWF tester, and Catalyst RoIP Solution

PSCR's MCV portfolio purchased and supported a number of measurement, certification, and modeling systems both internally through an SBIR with Catalyst Communications Technologies and externally through federally funded award recipients like the University of Basque, Keysight, Polaris, and Valid8. PSCR also supported the development of the Articulation Band Correlation Modified Rhyme Test (ABC-MRT) which estimates speech intelligibility to measure the effectiveness of narrowband MCV systems. Acquisition of the Project 25 (P25) Phase 1 and 2 LMR Radio System by PSCR in 2019 enabled more widespread interoperability based on updating QoE metrics, and it is currently in use for running all lab LMR tests. Finally, LMR and LTE interoperability capabilities within the PSCR Advanced Communications Lab have supported development testing and enabled access to newer technologies—such as 5G—for test and evaluation purposes. PSCR's efforts also fostered new methodologies and testing functions, enabling the MCV portfolio to serve as a broker for new products and evaluate such products to ensure they work as advertised.

PSCR **advanced disruptive approaches and technology** by developing QoE KPIs that provided new ways of measuring the effectiveness of public safety audio communications. The QoE KPIs include Mouth-to-Ear Latency, End-to-End Access Time, Voice Quality & Speech Intelligibility, and Probability of Successful Delivery. To support **contributing standards**, PSCR actively participated in 3rd Generation Partnership Project (3GPP) Radio Access Network Working Group 5 (RAN5) quarterly meetings, influencing the standards community to consider specifications for MCPTT, Mission Critical Video (MCVideo), and Mission Critical Data (MCData). Finally, the program helped create a community of more than 450 people who signed up to receive updates on the NIST List of Certified Devices. Prior to PSCR's efforts, this community with a desire to stay informed about NPSBN-compatible devices did not exist.

IMPACTS AT A GLANCE:



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LOCATION-BASED SERVICES

Definition of Success



Demonstrate to public safety a reliable indoor mapping, localization, and navigation capability



Show that indoor LBS products and capabilities are realistic and feasible for public safety agencies to leverage in the future



Make inroads towards the commercialization of such products

PSCR's LBS portfolio produced a pilot project with the Open Geospatial Consortium that demonstrated a process by which indoor lidar scans could be used to support public safety. This pilot project specifically addressed questions related to data formats and navigation capabilities. Extramural award recipients produced a wide array of contributions, ranging from University of California Irvine's SmartBoot that uses inertial navigation and 4G LTE signals for indoor localization, to Carnegie Mellon University's open-source software for ultra-wideband ranging components, and University of Oxford's cutting-edge use of thermal cameras for simultaneous localization and mapping (SLAM) algorithms. Additionally, among Carnegie Mellon University, Massachusetts Institute of Technology, Regents of the University of Michigan, and University of California Irvine, a total of nine patent applications have been submitted. These contributions have helped shine light on the public safety use case as a viable angle of development for technologies and innovators. PSCR helped define how indoor localization can be introduced and integrated into public safety operations and workflows, and has emphasized the need for infrastructure-free localization. Thanks to PSCR, innovators now have greater awareness

of public safety operational requirements, enabling the acceleration and update of indoor localization technology for first responders throughout the country.

The LBS portfolio **advanced disruptive approaches and technology** by focusing on obtaining one-meter accuracy with infrastructure-free localization technologies that were specific to public safety. The PSCR-funded First Responder Smart Tracking Challenge has already awarded over \$1.3M to participants competing to develop precise indoor localization systems. Additionally, internal work at PSCR supported the development of International Organization of Standards (ISO) 18305 to standardize localization measurement accuracy. The LBS portfolio also **enhanced public safety methods** through the NAPSG Foundation's Best Practices Guide, which describes indoor mapping, tracking, and navigation best practices assembled with input from public safety agencies from around the U.S. Finally, PSCR **increased research capacity** in LBS by making the Public Safety Immersive Test Center available to partner researchers to test products and ensure they meet public safety requirements to a specific degree of accuracy, providing a lasting resource to the community.

IMPACTS AT A GLANCE:



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ANALYTICS

Definition of Success



Empower public safety to take large amounts of data from various sources and transform it into actionable information in real-time



Build technology for the future to help first responders save lives, property, and critical infrastructure by helping public safety to be more fully data-informed and knowledge-enabled in responding to emergencies



Leverage artificial intelligence (AI) to ensure accuracy, timeliness, interoperability, security, integrity, and accountability of public safety analytics systems

As a result of increased computational, networking, and storage capacity, public safety real-time data analysis needs have sharply increased year by year. However, the vast amount of data public safety must monitor in real-time has already outgrown human capabilities. As a result, PSCR's Analytics portfolio looked at different forms of research domains, scalability, and real-time data usage to enable first responder workflow and ensure utility by closely incorporating end users as collaborators when considering public safety specific use cases. Specifically, PSCR's research was fueled by data-driven AI, as demonstrated by the implementation of machine learning, computer vision, multimedia analytics, differential privacy, data compression, stream optimization, and more throughout their intramural and extramural projects. Through these efforts, PSCR supported innovative development approaches, standards, R&D frameworks, tools, and research resources that foster interoperability and lower the bar for innovation to support a vibrant public safety analytics ecosystem.

Extramural award recipients **advanced disruptive approaches and technology** by developing their own evaluation and measurement approaches to assess the effectiveness of their analytical models. The University of Virginia developed an agent-based framework for emergency services interacting with patients. Southern Methodist University created an analytic model for optimizing resource deployment based on weather, traffic, and flooding conditions. Finally, the PSCR Analytics team developed resources that **increased research capacity** such as open-source AI analytics, R&D representative datasets, reusable test and evaluation R&D frameworks, performance-based data conditioning and compression tools, agile real-time multi-modal AI analytics, and fusion models for streaming data from video, audio, text, social media, sensor data, weather data, roadway data, patient data, and more.

IMPACTS AT A GLANCE:



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SECURITY

Definition of Success



Influence industry-developed security standards to the benefit of public safety



Educate industry partners on public safety-specific security learnings



Publish research findings to educate the public safety community and support more intelligent selection of products



Increase cybersecurity community awareness by enhancing public safety participation in cybersecurity efforts and sustaining outreach channels



Develop an Identity, Credential, and Access Management (ICAM) framework and collaboration capabilities

PSCR partnered with the National Cybersecurity Center of Excellence (NCCoE) to provide security policy expertise and collaboration opportunities to key stakeholders in the law enforcement community such as NLETS, FBI Criminal Justice Information Services (CJIS), Texas Department of Public Safety (DPS), and others. Publications on trust as a factor in identity, organizational trust, and single sign-on have enabled security capabilities to be scaled significantly across the nationwide public safety network. Beyond publications, extramural grants for trustmark enhancement resulted in ICAM demonstrations and pilots in Texas, increasing stakeholder education on process implementation and supporting likelihood of adoption. Additionally, these extramural security programs incorporated multiple new agencies and vendors into the National Identity Exchange Federation (NIEF) as part of the live ICAM pilot, allowing impacts to reach even further. While efforts are still underway to integrate ICAM into public safety operations, PSCR and its partners have laid an excellent foundation through education, coalitions, and pilot

programs to equip first responders with the awareness they need for tamper-resistant authentication.

PSCR's Security team **advanced disruptive approaches and technology** by leveraging prize challenges to expand the community supporting secure solutions for public safety communications technology. In the Mobile Fingerprinting Innovation Technology (mFIT) Challenge, participants' submissions resulted in improvements in mobile fingerprint imaging, such as eliminating the need for a contact peripheral and leveraging AI to capture prints and segment them into separate files. The challenge was so successful that a Contactless Fingerprint Pilot Program has been planned with the FBI for 2023. Furthermore, PSCR **contributed standards** through facilitating a widespread coalition between numerous law enforcement key stakeholders to implement NIST SP 800-53 for Security and Privacy Controls and SP 800-63-3 for Digital Identity Guidelines.

IMPACTS AT A GLANCE:



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RESILIENT SYSTEMS (INCLUDING DEPLOYABLES AND UNCREWED AIRCRAFT SYSTEMS)



Definition of Success



Clearly define what “resilient” means for public safety communications and what capabilities exist under disparate network circumstances so that public safety can more clearly articulate first responder needs to industry



Enable public safety to continue working in disconnected or degraded network conditions by using technology designed for data-transmissible applications



Define use cases and guidance to promote the adoption of Uncrewed Aircraft Systems (UAS) programs in first responder agencies and provide guidance to help first responders navigate Federal laws and regulations for UAS operation



Promote the development of new UAS technologies to address the unique needs of first responders and support domestic manufacturing and of U.S.-based UAS solutions

PSCR’s Resilient and Deployable Systems extramural program supports the expansion, reliability, and performance of broadband networks through numerous innovative solutions. For example, Michigan Technological University’s prototype for remote area data sharing on a portable Raspberry Pi helps ensure firefighters have access to accurate, up-to-date maps even when they are miles from the nearest available network connection. Spectronn’s patented “SiFi-200” prototype uses cognitive mobile edge computing to resiliently connect to a remote data center even if there is a complete loss of connectivity with the primary network. The University of Colorado identified a problem in the national emergency alerts system and was able to propose several defenses to address the threat in both the short and long term. In terms of prize challenges, PSCR supported the nascent drone industry and educated first responders about the potential impact UAS could have on situational awareness of public safety operations. Since the first UAS prize challenge in 2018, participants have moved the needle on numerous drone capabilities

by leveraging real-time actionable data and machine learning-driven sensor development to assist in search and rescue operations. PSCR’s spearheading of initial UAS prize challenges established a foundation for future research, resulting in a congressional requirement to continue investment and additional prize challenges in this area long after the expiration of the Public Safety Trust Funds.

PSCR supported **developing products** through funding extramural projects, like Texas A&M’s DistressNet-NG, which provided a scalable and resilient wireless interconnection fabric for first responder communications equipment. Additionally, PSCR grantee Regents of the University of California developed a resilient communications platform for efficient and widespread dissemination of information, enabling communication over congested channels. PSCR’s UAS program **advanced disruptive approaches and technologies** by improving safety requirements, focusing on stability, encouraging affordability, and influencing UAS industry standards to include public safety needs.

IMPACTS AT A GLANCE:



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