

NIST Special Publication 1248

**Public Safety Communications
Research Division Impact Report:
Fiscal Years 2017 – 2019**

Jeremy Glenn
Isabel Shaw
Marc Leh

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Public Safety Communications Research Division Impact Report: Fiscal Years 2017 – 2019

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Abstract

The Public Safety Communications Research Division (PSCR) at NIST plays a primary role in research and development to impact public safety operational capabilities. 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. This report details the impacts of PSCR's intramural and extramural programs across five leading indicators: Increasing Research Capacity, Disruptive Approaches and Technology, Standards, Products, and Public Safety Methods. As the PSCR program enters its final three years of allocated funding under the Middle Class Tax Relief and Job Creation Act of 2012, it aims to increase its dynamic impact on the development of standards, methodologies, and technologies that will make the next generation nationwide public safety broadband network a reality. PSCR will continue to document and report on the outcomes of its diverse research to ensure that technical advancements supported by the program are made available for all stakeholders to maximize the operational effectiveness of first responders.

Key words

communications; first responders; impact; public safety; research and development.

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List of Acronyms

3GPP	Third-Generation Partnership Project
5G	Fifth Generation
ACE	Analytics Container Environment
ADE	Application Domain Extension
API	Application Programming Interface
AS	Application Servers
BWC	Body-Worn Camera
CAD	Computer Aided Dispatch
CNCI	Category Normalized Citation Impact
D2D	Device To Device
ETA	Extensible Toolkit for Analytics, a Voxel51 product
FDL	Fire Data Lab
FirstNet	First Responder Network Authority
GIS	Geographic Information Science
IoT	Internet of Things
LBS	Location-Based Services
LMR	Land Mobile Radio
LTE	Long Term Evolution
MCOP	Mission Critical Open Platform
MCPTT	Mission Critical Push-to-Talk
MCS	Mission Critical Services
MCV	Mission Critical Voice
mmWave	Millimeter Wave
NFORS	National Fire Operations Reporting System
NIST	National Institute of Standards and Technology
NPSBN	Nationwide Public Safety Broadband Network
NTIA	National Telecommunications and Information Administration
ProSe	Proximity Services
PSCR	Public Safety Communications Research
PSIAP	Public Safety Innovation Accelerator Program
PSO	Public Safety Organization
QoE	Quality of Experience
RF	Radio Frequency
RMS	Records Management Service
R&D	Research and Development
UI/UX	User Interface / User Experience
VR	Virtual Reality

PUBLIC SAFETY COMMUNICATIONS RESEARCH DIVISION IMPACT REPORT: FISCAL YEARS 2017 – 2019

PUBLIC SAFETY INNOVATION ACCELERATOR PROGRAM: 3-YEAR RETROSPECTIVE

In the aftermath of the September 11th terrorist attacks, Congress and the nation wrestled with how to respond to the communications problems faced by our first responders: lack of interoperability, resilience, and cutting-edge technologies for over 60,000 state and local public safety organizations (PSOs) in the United States. Fast forward to the year 2005, when Hurricane Katrina exposed similar critical issues for public safety; it became clear that the nation needed a new, dedicated public safety network to empower local and state PSOs and to ensure that our first responders have the equipment and operational capabilities to do their jobs.

In response, Congress passed the Middle Class Tax Relief and Job Creation Act of 2012 (the “Act”) which allocated newly-available spectrum auction funds to create the Nationwide Public Safety Broadband Network (NPSBN). The Act established the First Responder Network Authority (FirstNet) to oversee the build-out of the NPSBN, which operates under a public-private partnership as “FirstNet built with AT&T.” The Act charged the National Institute of Standards and Technology (NIST) with developing and implementing a robust and impactful public safety communications research and development (R&D) plan to “conduct research and assist with the development of standards, technologies, and applications to advance wireless public safety communications.”

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 by the laboratory deliver positive operational impacts to responders in the field.

PSCR received funding from the spectrum auctions during a six-year period beginning in 2016, when funds first became available, and expiring in 2022. Prior to receiving the funds, PSCR executed a comprehensive roadmapping and portfolio planning process to identify the highest priority technology gaps and opportunities that deserved federal R&D investment. Through significant stakeholder engagement, PSCR developed six research portfolios and cross-cutting initiatives to maximize its impact: User Interface / User

PSCR IS THE PRIMARY FEDERAL RESEARCH LABORATORY FOR DELIVERING NEXT GENERATION BROADBAND COMMUNICATIONS TECHNOLOGIES TO THE NATION’S FIRST RESPONDERS

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

PSCR works closely with public safety, government, academic, and industry stakeholders through internal research projects, extramural research partnerships, grants, cooperative agreements, and prize challenge awards to produce workshops, publications, and training opportunities that directly impact public safety operational capabilities through innovation.

IMPACT SUMMARY: INFOGRAPHICS

PSIAP GRANT PROGRAM

167 TOTAL
AWARD RECIPIENTS
SUBCONTRACTORS &
PUBLIC SAFETY PRACTITIONERS

LOCATED IN
26  STATES

LOCATED IN
11  COUNTRIES
TOTAL
IN NORTH AMERICA & EUROPE

OPEN INNOVATION PROGRAM

OVER **\$1.3M**
IN PRIZES
AWARDED
TO DATE 

PARTICIPANTS
FROM **20**
STATES
& **7**
COUNTRIES

8 CHALLENGES 
LAUNCHED

OVER **300** TOTAL
SUBMISSIONS

WINNERS: 
88 TEAMS

STAKEHOLDER OUTREACH

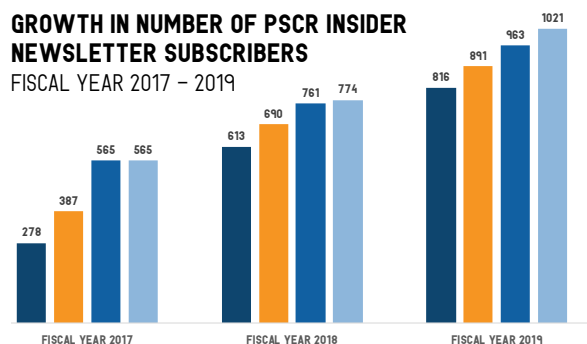
1,097 
NEWSLETTER
SUBSCRIBERS TO DATE

482  TOTAL
ATTENDEES
@ PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

SUBSCRIBERS IDENTIFY AS:

INDUSTRY	458
PUBLIC SAFETY	340
GOVERNMENT	343
ACADEMIA	169

GROWTH IN NUMBER OF PSQR INSIDER
NEWSLETTER SUBSCRIBERS
FISCAL YEAR 2017 – 2019



RESEARCH HIGHLIGHTS

123 PSQR PROFESSIONAL JOURNAL & CONFERENCE PUBLICATIONS 2013–2019

(This number reflects the number of publications that have been voluntarily reported to date, with final #'s (award "products") not due to be reported by PSIAP awardees until they submit final reports at the conclusion of their awards.)

INTRAMURAL

46 PSQR RESEARCH PUBLICATIONS

33 PROFESSIONAL JOURNAL/CONFERENCE PROCEEDINGS

13 OTHER PUBLICATIONS (INCLUDING NISTIR)

EXTRAMURAL

77 PSIAP AWARD RECIPIENT PUBLICATIONS

73 PROFESSIONAL JOURNAL/CONFERENCE PROCEEDINGS

4 OTHER PUBLICATIONS

OVER **20** 

PUBLICALLY AVAILABLE
OPEN SOURCE CODE
INCLUDING VR ENVIRONMENTS
& ANALYTICS FRAMEWORKS

1 PATENT GRANTED
FOR RESILIENT SYSTEMS
AWARD RECIPIENT

3 PATENT APPLICATIONS
SUBMITTED FOR
LOCATION-BASED SERVICES AWARD RECIPIENTS

DEFINING SUCCESS

In March 2018, PSCR's leadership developed the "PSCR 2022 Success Framework" to serve as the program's strategic "true north" - to guide an expanding research portfolio seeking to maximize impact before sunseting of allocated funding in 2022. The PSCR 2022 Success Framework provides researchers with a common framework for describing the program's ultimate goals, and ensures past and future projects align with the program's mission.

In partnership with industry, academia and state and local PSOs, PSCR's mission is to advance public safety communications by conducting research and developing new standards, technologies and applications in support of FirstNet's efforts to build an interoperable nationwide broadband network for first responders. PSCR focuses its funding allocation, staffing resources, and research attention to projects that align with the five leading indicators by which PSCR seeks to impact the public safety community: Increasing Research Capacity, Disruptive Approaches and Technology, Standards, Products, and Public Safety Methods (Figure 1). Following the Logic Model for Impacts Analysis¹ (Figure 2), the remainder of this report details how PSCR has directly impacted each leading indicator and, as a result, is positioned to impact public safety operational capabilities through intramural and extramural research activities.

PSCR 2022 SUCCESS FRAMEWORK

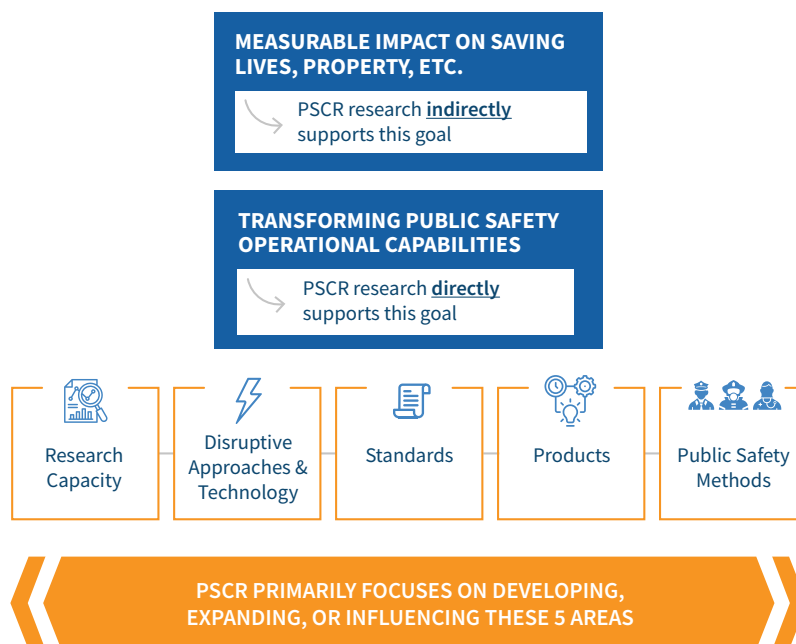


Figure 1. PSCR 2022 Success Framework

PSCR LOGIC MODEL FOR IMPACTS ANALYSIS

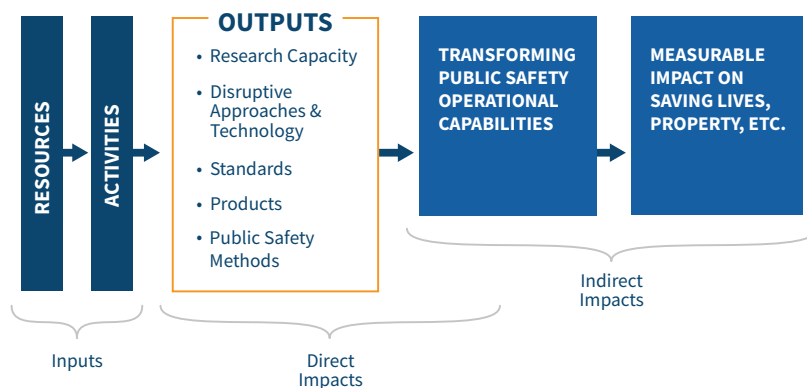
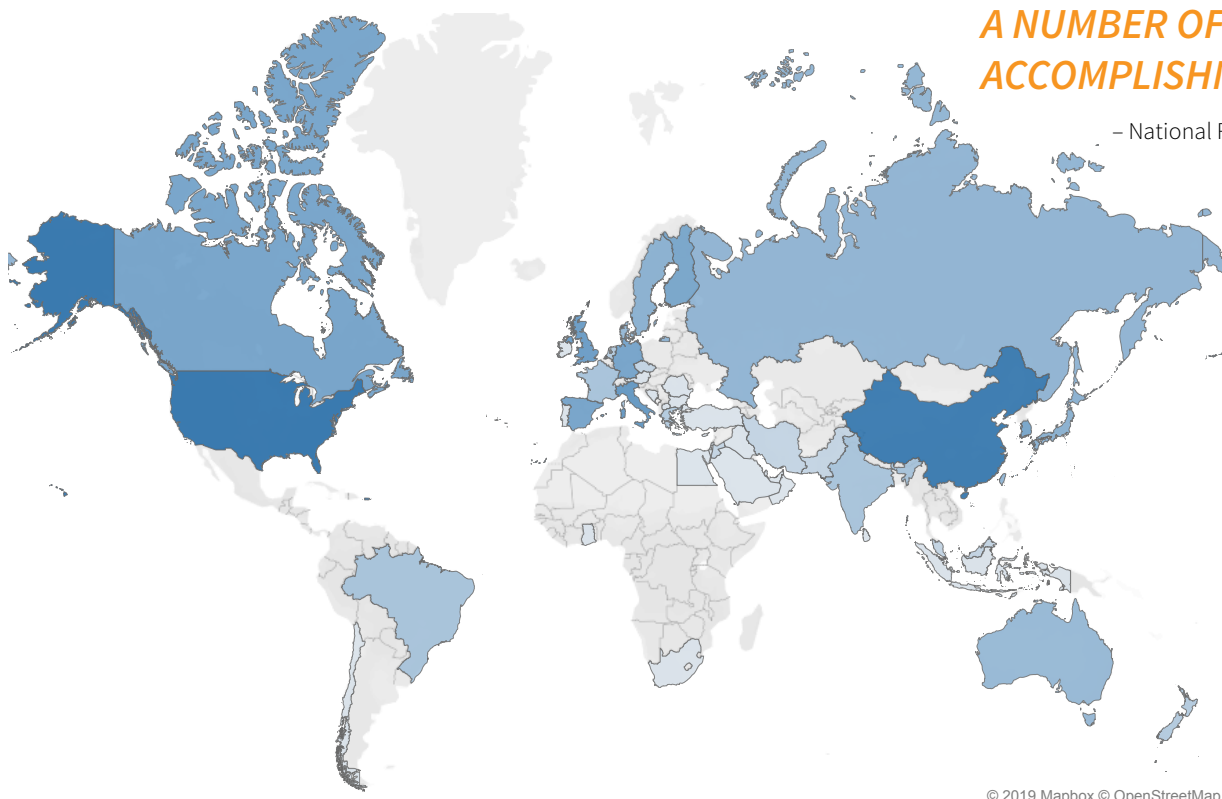


Figure 2. Logic Model for Impacts Analysis

¹ Logic models describe the theory and design of a program, how program activities and outputs influence program stakeholders, and how intended outcomes (short- and long-term) are achieved. PSCR's "Logic Model for Impacts Analysis" is adapted from: Jordan, Gretchen. "Generic R&D Logic Models Suggest Key Performance Indicators," Sandia National Laboratories. May 31, 2005. Slide 5.

*PSCR IS “A UNIQUE
NATIONAL RESOURCE”
THAT TO-DATE
“HAS PROVIDED
THE COMMUNITY
A NUMBER OF
ACCOMPLISHMENTS.”²*

– National Research Council



© 2019 Mapbox © OpenStreetMap

Figure 3. Country affiliations of authors citing PSCR publications, both intramural and extramural.

OVERVIEW

Within the first three years of spectrum auction funding, PSCR developed 45 intramural research projects and built the **Public Safety Innovation Accelerator Program (PSIAP)**. This unique federal financial award program is intended to modernize public safety communications and operations by supporting the migration from land mobile radio (LMR) to a nationwide public safety broadband network, accelerating critical technologies related to indoor location tracking, mission critical services and resilient systems, and improving public safety response efficiency, effectiveness, and decision making. To date, the PSIAP encompasses 167 extramural research partnerships

including award recipients, sub-awardees, and PSOs that service an estimated 28 million people across 26 states. PSCR partners are located in over 100 cities and 13 countries.

Collectively, PSCR’s award recipients produced one patent, three pending patent applications, and over two-dozen open-source software products to date. The eight prize challenges launched by PSCR’s Open Innovation team received over 300 submissions from industry, academia, and private citizens. In total, PSCR awarded over \$1.3 million to 88 winning teams between 2017 and 2019, with a planned offering of \$8 million in future prize purses.

² National Academies of Sciences, Engineering, and Medicine (2019). An Assessment of the Communications Technology Laboratory at the National Institute of Standards and Technology: Fiscal Year 2019. Washington, D.C.: The National Academies Press, p.14. <https://doi.org/10.17226/25602>. (Referred to in the remainder of this report as “NRC Assessment of NIST CTL (2019).”).

PUBLICATIONS

PSCR-funded projects produced over 123 professional journal and conference publications.³ To date, PSCR's intramural and extramural publications have garnered over 45,000 full page views with a combined 273 citations from authors affiliated with over 50 countries.⁴ (See Figure 3 on page 4)

PSCR's 33 intramural professional journal and conference publications⁵ achieved an overall Category Normalized Citation Impact (CNCI)⁶ of 2.10, over twice the average citation rate for professional publications (Figure 4). Among the highest categories for PSCR's papers are "Computer Science, Theory & Methods" (2.72), "Engineering, Electrical & Electronic" (2.50), and "Telecommunications" (1.66).

Likewise, PSCR's 77 extramural publications achieved an average CNCI over two and a half times the average citation rate (2.57), with the top performing categories being "Telecommunications" (2.95), "Computer Science, Theory & Methods" (2.85), and "Engineering, Electrical & Electronic" (2.82). In the "Telecommunications" category, PSCR's extramural publications have nearly three times the average citation rate compared to all publications in that category. Please note that the CNCI statistics only depict publication citations within topic areas of significant interest to PSCR and do not represent the entire PSCR publication library.

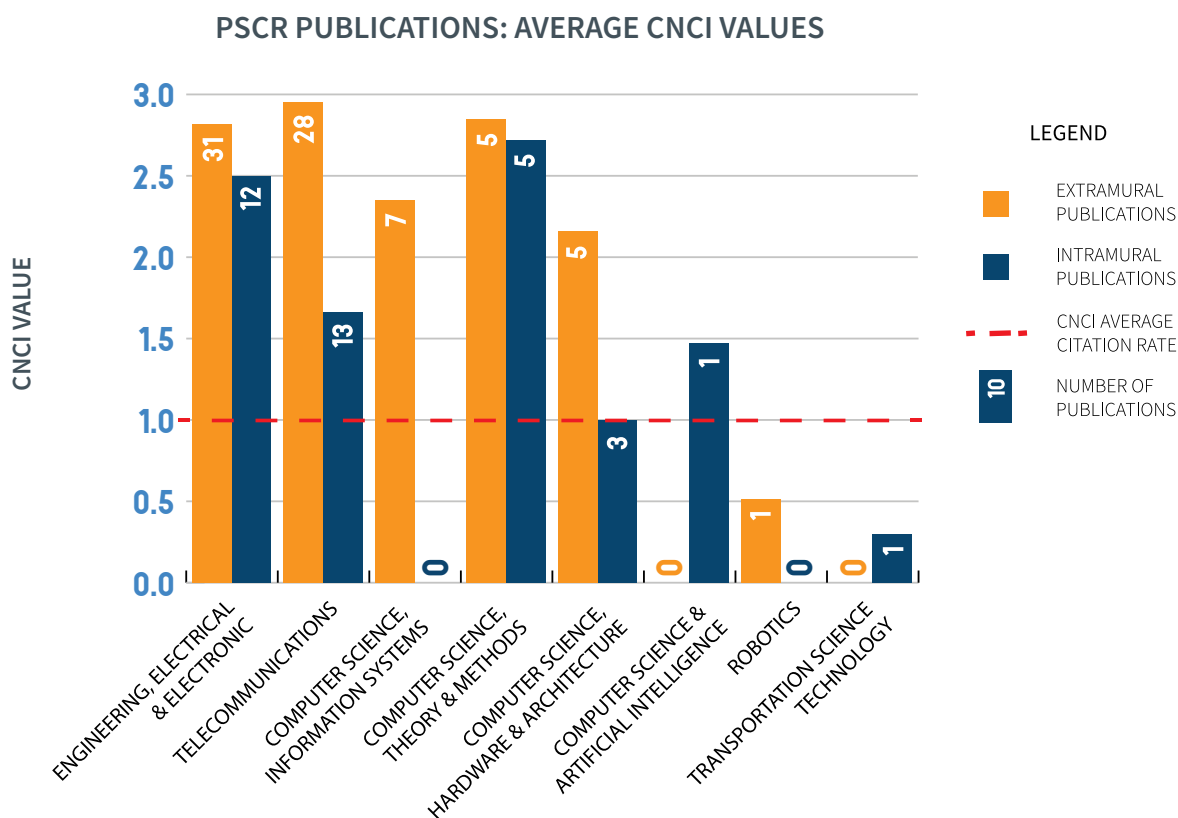


Figure 4. Average CNCI values for intramural and extramural publications by subject category.

³ PSIAP award recipients are required to report all research "products" - including publications - at the conclusion of the award period; therefore, current data reflects the known publications from PSCR-funded work.

⁴ Figures are based on analytic tools and bibliometrics from Web of Science (<https://www.webofknowledge.com>) and IEEE Xplore (<https://ieeexplore.ieee.org>).

⁵ PSCR produced a total of 46 intramural publications. Of these, 13 are NIST technical publications which are not included in the bibliometrics databases utilized for this report.

⁶ The Category Normalized Citation Impact (CNCI) is a generally accepted bibliometric that compares the impact of publications across subject categories. CNCI "is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication and subject area" (Clarivate Analytics, 2018). A CNCI value of 1 indicates a performance on par with the average expected citation rate in the given category; values higher than 1 are considered above average, while values below 1 are considered to be below the average citation rate.

LEADING INDICATORS OF PSCR IMPACT

PSCR considers the ultimate mission of its research activities as having a measurable impact on emergency responders' ability to save lives and property more effectively. PSCR supports this mission by advancing capabilities across five leading indicators that represent different components of the emergency communications research and development community. These areas include: 1) Increasing Research Capacity; 2) Disruptive Approaches and Technology; 3) Standards; 4) Products; and 5) Public Safety Methods. The remainder of this report details how, to date, PSCR has directly impacted each leading indicator through its intramural and extramural research activities. PSCR supports and furthers its work through the following projects.⁷ The icons below identify which PSCR portfolio each project falls under, and whether the project is intramural (performed internally by PSCR researchers) or extramural (performed externally by non-PSCR researchers).

■ = Intramural 👤 = LBS 📱 = UI/UX 📊 = Analytics 🚩 = Impact
■ = Extramural 📶 = MCV 🛡️ = Security 🤖 = Resilient Systems



INCREASING RESEARCH CAPACITY



The **NIST Analytics Container Environment (ACE)** project developed an open-source analytics reference framework to enable agile development and testing of public safety streaming data analytics in an accessible, scalable, and extensible software environment.

🚩 ACE will allow analytic algorithms, tools, and systems to function inside a virtual container. The container is modular and has secure connectivity to provide access to the larger reference environment and research data. ACE is currently used by researchers from the public and private sectors to test various analytics capabilities.



“PSCR HAS MADE A POINT OF REQUIRING DELIVERABLES SUCH AS DATA SETS, APPLICATION


PROGRAMMING INTERFACES AND OPEN-SOURCE TOOLS - ALL OF WHICH ENCOURAGE THE GROWTH OF THE PUBLIC SAFETY ECOSYSTEM AND CAN BE UTILIZED BY OTHERS AND BUILT UPON.”⁸


– National Research Council




PSCR explored the use of mobile mapping systems as a tool for public safety pre-incident planning of buildings. Despite the rapid advances in this field, significant R&D is still needed to make 3D mapping data more viable for widespread integration into navigation and tracking systems for public safety. Recognizing this need, PSCR created the **Point Cloud City** funding opportunity to develop an annotated dataset including data from 29 buildings in three cities with over 4.5 million square feet available.


🚩 This award program makes a significant contribution to the public safety and smart cities research communities by providing the first opportunities for researchers to use point cloud data in developing critical mapping and navigation tools for first responders.

 PSCR's **MCV Portfolio** positioned itself as a trusted leader of the public safety community by working to optimize the intelligibility, reliability, and quality with which first responders send and receive voice communications across broadband networks.

 From 2017 to 2019, the MCV Portfolio made the following contributions to the research community:


- Twenty-three professional publications that provide guidelines and performance tools on the topic of device-to-device (D2D) communications in long-term evolution (LTE);
- Multiple publications for off-network mission critical push-to-talk (MCPTT), including development of test cases;
- Extended open-source simulation software, published online at <https://github.com/usnistgov/psc-ns3>;
- Publications and tools for evaluating prioritization of public safety user traffic, published online at <https://github.com/usnistgov/qppsim>.


 PSCR's award to **TRX Systems** supports enhancement of TRX's NEON indoor location and mapping services. NEON already supports personnel tracking at major public events, active violence training events, and within critical infrastructure. NEON also provides signal and sensor mapping, which typically includes tracking a mix of law enforcement, EMTs, and other personnel working in large venues not necessarily under their complete control. With PSCR funding, TRX is expanding the use cases served by NEON to include law enforcement and fire personnel tracking in critical incidents.


 TRX conducted field testing and benchmarking activities with PSOs in Arlington County (VA) and Plain Township (OH). For Battalion Chief Matt Herbert of the Arlington County Fire Department, the project's impact on the public safety community is tangible:

With the support of NIST PSCR, the money that TRX got to do this research has really, really opened up the ability for them to


develop [indoor localization technology]. To be able to come to a building and have firefighters put this stuff on and put it into the hands of the people that will be using it... enables us to see what needs to be tweaked, what works well, and enables us to play out real life situations rather than just in a laboratory. Being able to work immediately with the first responders is imperative to any project like this.


 PSIAP award recipient **Sonim** along with sub-awardee Nemergent created an end-to-end mission critical system consisting of a device, app, and the various mission critical servers. Sonim and Nemergent performed end-to-end Quality of Experience (QoE) measurements and used the results to increase the efficiency of the system. During this project, Nemergent created one of the first commercially available MCPTT application servers (AS). Sonim created an application programming interface (API) for a physical push-to-talk button for MCPTT and also converted a channel selection module to select groups instead of channels. Additionally, Sonim developed a standards-compliant, commercially available device that can support multiple mission critical apps. Sonim leveraged multiple apps and APIs created by Sonim, Nemergent, and fellow PSIAP award recipient Universidad del País Vasco to demonstrate interoperability through standards compliance.


 Sonim's development of a 3GPP⁹ Release 13 compliant MCPTT platform - with both client and server-side elements - will accelerate adoption of MCV services without the need for proprietary software and hardware.


 First responders used the products produced by Sonim under this award in testing scenarios and provided feedback. Sonim accounted for the feedback and adjusted their products to meet public safety's needs.


 = Intramural  = LBS  = UI/UX  = Analytics  = Impact
 = Extramural  = MCV  = Security  = Resilient Systems


 PSiAP award recipient **Software Radio Systems (SRS)** created an open-source, end-to-end LTE network platform (srsLTE) as part of their OpenFirst project. The srsLTE platform allows innovators to prototype, test, and validate next-generation communications capabilities. This open source product is based on 3GPP standards and can be easily and affordably installed in any test lab. Additionally, the project aims to accelerate the commercialization path for public safety LTE products and services using proven business models.

 The OpenFirst project's outputs, namely srsLTE, enabled a robust, worldwide user/developer community to further advance telecommunications research. Researchers at Ruhr-Universität Bochum and New York University Abu Dhabi have used the product to test and demonstrate the practical feasibility of the [aLTEr attack](#). Researchers at KAIST national research university utilized srsLTE in an extensive investigation of the security aspects of control plane procedures based on dynamic testing of the control components in operational LTE networks, culminating in a [research paper](#). OpenFirst has been used in multiple other contexts to find security holes in LTE.

 Also under PSiAP's MCV Portfolio, PSiAP award recipient **New York University (NYU)** developed a powerful, integrated, end-to-end research platform for the design and evaluation of millimeter wave (mmWave) public safety communications networks. The research platform addresses core parts in the development cycle of a complex wireless system and will be invaluable for integrating mmWave frequency bands (28 GHz - 100 GHz) into public safety communications networks. These mmWave frequencies represent a critical enabler for high-bandwidth, ultra-reliable communications networks required for 5G and next-generation wireless applications such as autonomous driving, remote surgery, and internet-of-things (IoT) asset tracking.

 The NYU team is using mmWave technology to assist public safety and industry partners in the development of cutting edge 5G communications systems for first responders. NYU worked closely with the Austin Fire Department (TX) to develop use case scenarios in the mmWave spectrum. For example, the Austin Fire Department provided drone data to NYU related to flight trajectory, elevation, and speed, which NYU used to simulate drone performance using various mmWave frequencies. This allowed the Austin Fire Department to understand the performance tradeoffs in terms of range, latency, and line of sight between mmWave versus lower frequency bands.

 PSiAP's cooperative agreement with **New Jersey Department of Homeland Security and Preparedness (NJ DHS)** and **MIT Lincoln Laboratories** is creating a uniquely large-scale dataset and framework to evaluate video quality-as-a-service over first responder networks. Their datasets will support video analytics R&D in three public safety scenarios: traffic stop, lost backpacker, and foot pursuit. They collected 812GB of video data and are annotating the footage using crowdsourcing. This project engaged a broad range of PSOs across the country including New Hampshire State Forest and Wildlife Commission, New England Civil Air Patrol, Hawaii Civil Air Patrol, the National Telecommunications and Information Administration (NTIA), and FirstNet to understand their video needs and incorporate those features into their data collection framework.

 NJ DHS and MIT Lincoln Laboratories established a collaborative working relationship with FirstNet to demonstrate the dynamic adjustment of video streaming with bandwidth ability using the video data collected. They are building tools to perform diagnostics and demonstrate how data degrades as bandwidth degrades on the NPSBN, and to show how video can be pushed over the network.

 = Intramural  = LBS  = UI/UX  = Analytics  = Impact
 = Extramural  = MCV  = Security  = Resilient Systems

⚡ DISRUPTIVE APPROACHES AND TECHNOLOGY



Under their PSIAP award, **Universidad del País Vasco** developed a mission critical open platform (MCOP) that is usable by any developer seeking to build public safety LTE solutions. MCOP is a collaborative project that eliminates challenges and barriers to creating MCPTT applications based on 3GPP standards for the next-generation of voice communications for first responders. The platform enables researchers, developers, and other practitioners to test, evaluate, and validate their MCPTT applications.



⚑ This project is significant to public safety and telecommunications because it is the first to effectively address the challenge of entry barriers for developers seeking to create and standardize mission-critical solutions for public safety.

“NIST HAS TAKEN THE FIRE SERVICE TO ANOTHER LEVEL THROUGH REALISTIC, SUPPORTED STUDIES THAT ARE BACKED BY SCIENCE AND THE RIGORS OF ACADEMIA... WHILE IT MAY NOT BE VISIBLE TOMORROW, I AM MOST CERTAIN THAT IN A COUPLE OF YEARS WE WILL SEE THE BENEFITS.”

- Division Chief Dan Pfannenstiel, West Metro Fire Rescue Training Center (CO)



Under the Public Safety Analytics Portfolio, PSIAP award recipient **Voxel51** developed Extensible Toolkit for Analytics (ETA), an open software infrastructure that provides extensible tools for video analytics (Figure 5). ETA is an automated and affordable video analytics development system that supports custom insights from unique video data and environments in different jurisdictions and integrates these analytics into public safety operational decision making. This platform demonstrated the feasibility of integrating video object and pattern recognition within public safety operations. The system can be extended to agencies across the public safety community to provide first responders with potentially life-saving information, allowing for more efficient and effective operations.

⚑ In the years to come, Voxel51 and its collaborators expect to see ETA usher public safety analytics into a new level of capability not currently available. In the short-term, Voxel51 hopes to see ETA play a key role in shortening response time and improving public safety incident outcomes.

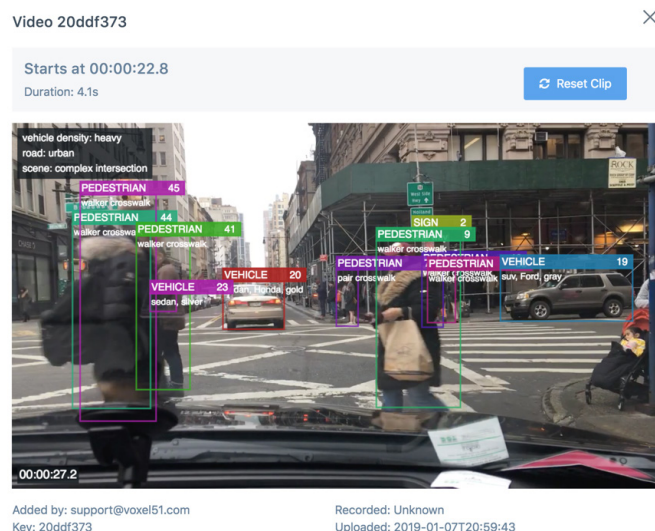





Figure 5. Screenshot of Voxel51's ETA software.


■ = Intramural 📍 = LBS 📱 = UI/UX 📊 = Analytics ⚑ = Impact
 ■ = Extramural 📶 = MCV 🔒 = Security 🔄 = Resilient Systems

 PSIAP award recipient **University of Michigan** is engaged in research to analyze the extremely high-motion video from body worn cameras (BWCs). The goal of this project is to spur novel research and catalyze the greater computer vision community to address the challenges of analyzing first person video. The University of Michigan team is developing unique and new analytic approaches for first person video that analyze both the scene and BWC wearer and relate that analysis to data from fixed surveillance cameras. The project developed open-source datasets and software tools that decrease the burden of entry for researchers.

 The analytics produced as a result of this project will enable PSOs to efficiently process, index, and store BWC data, search it via semantic queries, and use it in forensic analyses.

 Public safety officials perform tasks in a variety of environments that severely limit their senses and ability to communicate. The goal of PSCR's **Haptics Interfaces for Public Safety Challenge** was to investigate the relevance of haptic interfaces to assist first responder tasks. Additionally, the challenge aimed to assess the potential use of virtual reality (VR) environments as a development tool to prototype and iterate on designs for public safety technologies. The challenge resulted in six final contestants, four prototypes, and an assessment of the impact and effectiveness of the devices in real-world emergency response conditions.

 For the challenge, PSCR's **UI/UX Research Portfolio** team created three public safety VR environments - made publicly available on Github - that are safer and less expensive than using live training environments. Prototypes can be tested in PSCR's VR environments to allow for easier data collection and management, quicker design iteration, and shorter prototype lifecycles.

 Dan Pfannenstiel, Division Chief of Training at the West Metro Fire Rescue Training Center, gave opening remarks at the challenge's live final event:

The fire service has for a long time embraced experiential learning... but NIST has taken the fire service to another level through realistic, supported studies that are backed by science and the rigors of academia. What the fire service has already learned from NIST has made us rethink our strategies and debunk myths. I can only imagine that the information gained from the 2019 Haptics Challenge - while it may not be visible tomorrow, I am most certain that in a couple of years we will see the benefits.



Left: A proposed haptic solution. Right: A contestant assists a first responder during the Haptics Challenge live event.

**“[PSCR’S] ROLE AT 3GPP
HAS PROVIDED KEY
VALUE FOR FIRSTNET
IMPLEMENTATIONS
AND FUTURE CELLULAR
IMPLEMENTATIONS.”**

- National Research Council¹¹

STANDARDS

PSCR’s **MCV Portfolio** supports public safety as a member of 3GPP, the standards development organization responsible for 3G, 4G and 5G cellular standards. 3GPP’s RAN5 working group assigned PSCR’s Jason Kahn to develop public safety test specifications. Kahn managed the creation of the 3GPP TS 36.597 testing standards for Mission Critical Services (MCS). This family of standards is intended to be a necessary step as part of the overall certification process for adding a device to the List of Certified Devices for FirstNet.¹⁰

PSCR’s MCV team contributed **266 submissions** to 3GPP in Working Groups SA1, SA2, and CT1 resulting in **483 contributions** (after revision and to target each release where changes were needed) related to public safety service and feature requirements, architecture, and protocol specifications.

Through coordination and partnership with FirstNet, PSCR continues to support the introduction of public safety use cases and critical communications technologies to international standards bodies.

A team of researchers from **NIST Communications Technology Laboratory’s Wireless Networks Division** and **PSCR’s MCV Portfolio** (David Cypher, Wesley Garey, Jason Kahn, Richard Rouil, Yishen Sun, and Christopher Walton) were awarded the **2018 NIST Bronze Medal**, the highest annual award bestowed by NIST for outstanding technical achievement. The group is recognized for significantly advancing standards to enable MCV over broadband networks for public safety applications.

The group’s sustained efforts led to new products with MCV capabilities that will have significant impact on multi-agency coordination during severe network congestions and large disaster events by leveraging the broadband capabilities of FirstNet. These products will enable public safety communication across organizations on commercially available public safety devices — from smartphones to tablets to laptops.

PSCR’s **MCV Portfolio** researchers developed methods to measure the performance of voice communications systems by capturing the end-user’s QoE that enable operators to understand, monitor and predict MCV services over LMR, LTE, and future network technologies.

The MCV Portfolio team’s measurement systems have been used in follow-on research by the Universidad del País Vasco (Spain).¹² The MCV Portfolio’s research publications, test data, and source code are freely available via www.nist.gov.




Garey, Rouil, Sun, Walton, Kahn


■ = Intramural 📍 = LBS 📱 = UI/UX 📊 = Analytics 🚩 = Impact
■ = Extramural 📶 = MCV 🔒 = Security 🌐 = Resilient Systems


¹⁰ In the 2012 Act creating the NPSBN, Congress also called for the creation of a list of certified devices to keep track of which devices meet appropriate protocols and standards for access to the NPSBN. PSCR maintains the list that, to date, includes 165 devices that currently meet FirstNet standards.


¹¹ NRC Assessment of NIST CTL (2019).

¹² A. Sanchoyerto, R. Solozabal, B. Blanco and F. Liberal, “Analysis of the Impact of the Evolution Toward 5G Architectures on Mission Critical Push-to-Talk Services,” in IEEE Access, vol. 7, pp. 115052-115061, 2019.

 Jeff Cichonski of PSCR's **Security Systems Portfolio** provides input to 3GPP's working group for security, SA3, as the sole representative for NIST's public safety efforts. NIST garnered respect for its work to define cybersecurity and cryptology best practices to ensure private information transmitted and received over public safety networks is secured and protected. PSCR also supports FirstNet's priorities and objectives in the SA3 working group, and coordinates with their standards team on a weekly basis.

 PSCR's presence and input played a role in communications services critical to public safety use cases. "The mission critical stakeholders in SA3 know we have an interest in seeing public safety features specified and implemented in a secure way," stated Cichonski.

 PSCR's **Indoor Mapping and Navigation Pilot** program aims to create a prototype capability leveraging standardized, open GIS frameworks, data models, and data exchange formats to convert 3D point clouds to turn-by-turn navigation. The program demonstrated that point clouds could be transformed to IndoorGML networks for use in indoor navigation. This has never been done before and could transform indoor LBS far beyond public safety applications.

 Researchers on the Indoor Mapping and Navigation Pilot program also made several key contributions to geospatial standards, including: 1) creating a public safety application domain extension (ADE) for the CityGML standard, and 2) adding the concept of an ADE to the IndoorGML standard, along with a new public safety specific ADE. The new CityGML and IndoorGML Public Safety ADEs provide a mechanism to enrich 3D building models with new features and attributes required for public safety use cases.



Credit: NIST PSCR

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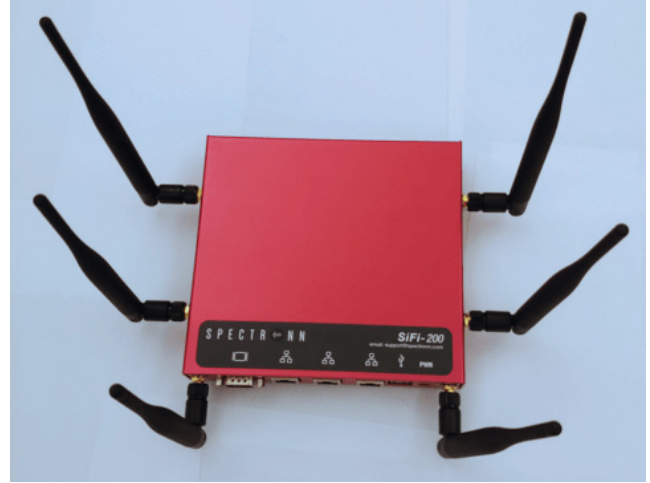
PRODUCTS



PSIAP award recipient **Spectronn** was granted a patent for their “SiFi-200” prototype, a hyper-converged, cognitive “mobile edge-computing-in-a-box” system. Spectronn’s technology combines cellular backhauls, a WiFi hotspot, local storage, and computing capability to allow public safety to resiliently connect to a remote data center or cloud even if there is a complete loss of connectivity with the primary network. Spectronn demonstrated the ability to store and analyze videos locally during degraded network conditions, providing first responders with session persistent seamless connection offload across different networks. This PSCR-funded, integrated networking and computing device is thought to be the first of its kind.



Spectronn deployed its SiFi-200 router with Brookline Police Department (MA) at the 2019 Boston Marathon, as well as at the Department of Homeland Security’s Shaken Fury OpEx exercise in partnership with the New Jersey Department of Homeland Security. These product demonstrations established the feasibility of Spectronn’s technology and connected the start-up edge networking and computing business with potential partners and significant follow-on funding.



Credit: Spectronn. One frame of the Boston Marathon live video stream that was transmitted using Spectronn’s technology.

“THE PSIAP AWARD WAS WHAT WE REALLY NEEDED. IT GAVE US EXPOSURE, CREDIBILITY... DEFINITELY HELPED US TO GET MORE AWARDS AND INVESTMENTS.”

- Spectronn co-founder R. Chandramouli



In partnership with PSCR, **Prominent Edge** developed StatEngine, a real-time, open-source data visualization platform specifically tailored to fire department data structures. This platform is built from “best of breed” open-source data analysis and visualization tools and enables wide scale utilization of powerful, real-time data analytics for PSOs. Key metrics provided by the analytics tool include turnout and response time for custom time periods, changes in average unit response duration over time, incident type and volume per day of week or year, and geospatial incident plotting that maps where jurisdictions’ most active and high demand areas are located.



Prominent Edge’s product is intended to significantly lower the cost and impediments of obtaining powerful, real-time analytics, which are currently only provided by proprietary solutions that may be too rigid and expensive to maintain for resource-limited public safety agencies. Through data sharing, the tool allows organizations across the country to discover potential trends and make improved predictions to optimize resource allocation.



Using StatEngine, PSOs of any size can exploit large volumes of complex, highly relevant, and impactful datasets in real time. StatEngine currently powers the National Fire Operations Reporting System (NFORS), the most comprehensive fire analytics system helping fire leaders to optimize resource allocation, reduce firefighter and civilian injury and death, and minimize loss of property. More than 39 fire departments were using the StatEngine software at the completion of the PSIAP award. StatEngine is freely available on [Github](https://github.com).



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 Through its PSIAP award, **Cornell University** produced an Emergency Edge Supercloud, a new hybrid cloud architecture for public safety smart devices that is able to conduct data transactions in on- and off-network response conditions. It includes a tamperproof log that sufficiently encrypts sensitive, personally identifiable information and operates locally on the device itself. The device can locally store a compact version of an entire database, continue updating multiple devices in the same area without an internet connection, and reconcile the centralized database when the device restores connectivity.


 The Emergency Edge Supercloud is intended to enable every first responder access to the same data as if they were carrying a computer and network router on the job. Providing essential computing, storage, networking, and management services could enable the secure and efficient use of resources during off-network emergency response scenarios.

 The **University of Southern California** created its own multi-layer three-dimensional channel sounder to collect channel measurement data in frequencies similar to Band 14 (under 1000 MHz).¹³ The goal of this sounder prototype is to characterize how public safety-specific spectrum bands behave in emergency response scenarios related to D2D and vehicle-to-vehicle communications with greater accuracy than previous sounder designs. Prior to this research project, the public safety channel frequency propagation characteristics received less attention from industry and academic stakeholders.

 The measurements collected by the sounder will be used to inform public safety broadband standards, radio hardware design, and antenna manufacturing processes. The goal is to ensure public safety devices and applications maintain sufficient levels of connectivity and performance when used in emergency scenarios.



 **Harris Corporation** built a radio frequency (RF) propagator to mimic proximity services (ProSe) and was able to provide real-world measurements, rather than simulations, on how ProSe behaves in relation to LMR. Importantly, this project resulted in the development of public safety-specific use cases that build upon existing commercial use cases in 3GPP standards. The new use cases address range requirements and management of ad hoc networks in degraded network conditions.

 This project could potentially enable responders to operate with greater confidence that their device will perform in direct mode in a wider than expected coverage radius without being constrained by increased network traffic or damage to existing networks. Harris plans to publish a summary of the results in an appropriate trade magazine so that new ProSe standard recommendations and range requirements are socialized among potential end users.

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¹³ Band 14 is defined in 3GPP TS 36.101, Table 5.5-1 E-UTRA operating bands.



PUBLIC SAFETY METHODS



Western Fire Chiefs Association (WFC), a Public Safety Analytics Portfolio PSIAP award recipient, partnered with sub-awardee Interra to build a functional model framework for a potential future data interoperability standard. WFC created a mapping from a variety of proprietary data storage formats to a common format to interface with a centralized data analysis system. This allows data sharing across systems and the application of analytics across departments. The PSIAP award enabled WFC to deploy the analytics technology to fire departments nationwide. This provided opportunities for fire departments to receive training, ongoing guidance, and technologies required to engage in data analytics, also facilitating collaboration across departments. These tools immediately provided each department with the capacity to conduct cross-domain performance analysis in a common framework. To date, this framework, called the Fire Data Lab (FDL), facilitates data storing, sharing, and analytics for **over 36 fire departments** serving a population of **over 20 million people**. FDL houses performance data from **over 4.4 million incidents** and counting.

This newly available dataset is anonymized and shared with the federated, cloud-based FDL warehouse. Subscribing fire departments can interact with the live, dynamic data pool of millions of calls from across the Western United States with tools for comparative call and response analysis, community metrics, regional trending, and predictive incident forecasting based on time and location. In addition to establishing a fire-specific data integration platform, WFC facilitated a series of workshops and summits held across the Western United States that created a motivated

network of fire departments engaged in data-driven decision making. The primary goal of the workshops was to define the types of information departments need, the most urgent analytic and shared response challenges they face, and which metrics would assist them in improving their use of resources and response to emerging needs.



WFC creates training opportunities for the fire departments it serves, and allows fire departments to collect and analyze incident performance data which was not previously possible without a common data sharing framework and central repository. Access to outcome data enables departments to identify deficiencies or unmet needs for services in their communities, highlight the positive impacts of alternative interventions provided by community partnerships, and ultimately improves their provision of care to vulnerable populations.




WFC educates fire PSOs on the potential use of analytics in improving response performance and began a discussion on how to work with potentially sensitive data both within and across fire departments. This research has inspired the PSOs to begin asking novel analysis questions about their data and identified data definition inconsistencies across records management systems (RMS) and computer aided dispatch (CAD) systems.




TO DATE,
36 DEPARTMENTS
SERVING **OVER 20 MILLION**
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HAVE JOINED THE
DATA SHARING PROJECT


THE **FIRE DATA LAB**
HOUSES PERFORMANCE DATA
FROM **4,453,781 INCIDENTS**
AND COUNTING




 In 2018, PSCR's LBS Portfolio team convened a workshop with first responders to receive input for designing what would become the **First Responder 3D Indoor Tracking (FR3D) Prize Challenge**. This challenge plans to award up to \$5 million to develop sensors and systems for locating and tracking responders within a building without the presence of a pre-deployed network infrastructure. In 2019, the **LBS Portfolio** team delivered a workshop conducting hands-on indoor mapping, tracking, and navigation capability training for firefighters at the Ohio Fire Chiefs Association.

 Jack Rupp, Assistant Fire Chief, Plain Township Fire Department (OH), reflected on the impact of working with PSCR from the perspective of a first responder:

I have often questioned in my mind if they and my firefighters would see [indoor tracking] during their careers. Now, I think they will, sooner than later.


 PSCR's **Public Safety Analytics Portfolio**, in collaboration with the **Baltimore Police Department**, the **University of Houston**, and the startup company **Voxel51**, built a deployable analytics-at-scale performance reference system for installation in Baltimore's CitiWatch, the real-time public safety video monitoring and alerting center within Baltimore. This video analytics platform scans privately-owned security cameras across the city to baseline normal ranges of city activity and trigger a tripwire alert to identify aberrations in activities recorded on video. Baltimore CitiWatch will test the system and display and give the developers feedback on the data presentation and other factors that relate to usability and efficiency based on the Baltimore Police Department's current operational environment.


 This partnership created tools to support agile generation and evaluation of custom video analytic algorithms derived from video data collected by Baltimore CitiWatch. This robust collaboration has not only helped to accelerate, ground, and evaluate the research within PSCR, it also is creating the basis for

“THE WORK BETWEEN [PSCR] AND BALTIMORE CITIWATCH LOOKS VERY PROMISING FOR SUPPLYING VALIDATION DATA FOR [PUBLIC SAFETY] METRICS... IT HAS THE POTENTIAL TO BE MAGNIFIED IN FUTURE RESEARCH EFFORTS.”¹⁴

~ National Research Council

best practices and future solutions to provide our cities with capabilities to generate and evaluate their own video analytics from their data.

 **Carnegie Mellon** leveraged its PSIAP award to develop a wearable headset that projects navigation information, thermal images, and available network assets onto a firefighter's view of an actual environment. In addition to assisting responders when network connectivity is not available and visibility is obscured, this project innovates pre-incident planning techniques used across the fire and emergency medical services. A hyper-reality helmet could automate many of these resource-intensive processes so responders can more quickly generate new site maps prior to or during an emergency event.

 Carnegie Mellon and PSCR envision that this headset offers the potential to produce more effective response training exercises and real-time situational awareness benefits.

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CONCLUSION

“[PSCR’S] SCIENTIFIC OUTPUT AND RESEARCH NEED TO

BE CONTINUED AND MADE BROADLY AVAILABLE IN ORDER TO ENSURE THE HIGHEST IMPACT OF THE WORK FOR THE FIRST RESPONDER COMMUNITY.”¹⁶

~ National Research Council



2019 PSCR staff.

PULLING THE FUTURE FORWARD

To build the scientific expertise necessary to execute the mission as mandated in the Act, PSCR established research, testing, and development abilities that align with the needs of the public safety stakeholder community. Through the efforts of its own internal staff, experts from other government organizations, 167 extramural research partners consisting of teams from academia, industry, and public safety, and by creating a series of eight prize challenges attracting over 300 submissions and 88 winning solutions from innovators around the world, PSCR successfully matured its R&D capabilities and achieved significant accomplishments in each of the research portfolios and cross-cutting initiatives.¹⁵

As PSCR enters the final three years of allocated spectrum auction funding, it aims to increase its dynamic impact on the development of standards, methodologies, and technologies that will make the next generation nationwide public safety broadband network a reality. PSCR will continue to document the outcomes of its diverse research to ensure that technical advancements supported by the program are made available for all PSCR stakeholders to maximize the operational effectiveness of first responders.

For more information on PSCR’s continuing work or to learn how you can get involved, sign up for the PSCR Newsletter at www.pscr.gov.

¹⁵ Adapted from NRC Assessment of NIST CTL (2019).

¹⁶ NRC Assessment of NIST CTL (2019).