



NIST Grant/Contractor Report NIST GCR 23-044

PSCR Impact Assessment: 2016-2022

Monika Bochert

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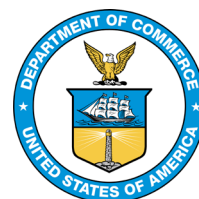
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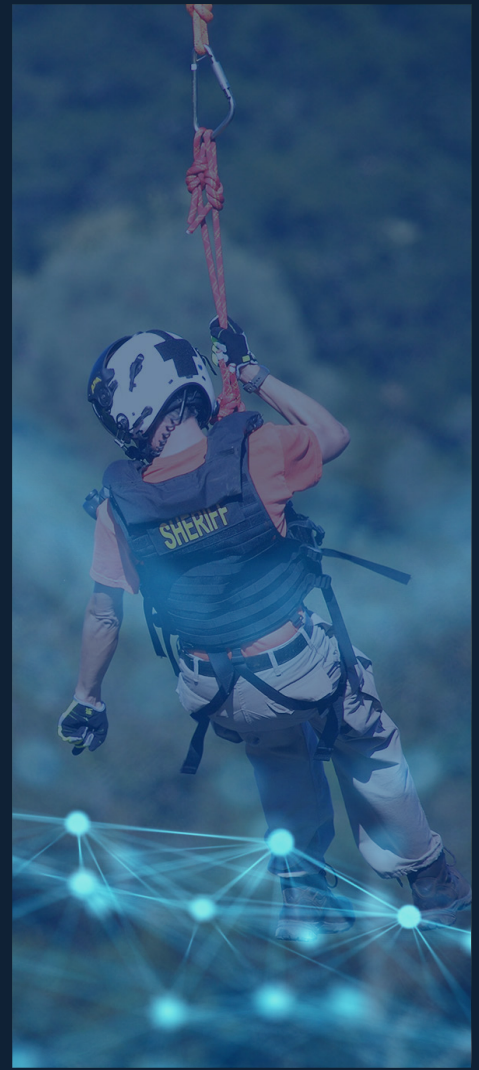
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PSCR Impact Assessment: 2016–2022

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Acronyms

Acronym	Expansion
3GPP	3rd Generation Partnership Project
ABCMRT	Articulation Band Correlation Modified Rhyme Test
ACE	Analytics Container Environment
AI	Artificial Intelligence
APCO	Association of Public Safety Communications Officers
APIs	Application Programming Interfaces
AR	Augmented Reality
ASAPS	Automated Streams Analytics for Public Safety
ATIS	Alliance for Telecommunications Solutions
BPA	Blanket Purchase Agreements
CCW	Critical Communications World
CES	Consumer Electronics Show
CJIS	Criminal Justice Information Services
CoECI	Center of Excellence for Collaborative Innovation
CRADA	Cooperative Research and Development Agreement
CTL	Communications Technology Laboratory
DHS	Department of Homeland Security
DOC	Department of Commerce
DPS	Department of Public Safety
EDA	Economic Development Administration
EL	Engineering Laboratory
eMBMS	Enhanced Multimedia Broadcast and Multicast Services
EMS	Emergency Medical Services
eNB	Evolved Node B
FAA	Federal Aviation Administration
FIDO	Fast ID Online
FRNA	First Responder Network Authority
FRST	First Responder Smart Tracking
GIS	Geographic Information Systems
GSMA	GSM Association
IEEE	Institute of Electrical and Electronics Engineers
IEEEVR	IEEE Conference on Virtual Reality
IoT	Internet of Things

Acronyms

Acronym	Expansion
IPCAN	Internet Protocol Connectivity Access Network
ISO	International Organization for Standardization
ITL	Information Technology Laboratory
ITS	Institute for Telecommunication Sciences
IWCE	International Wireless Communications Expo
KPIs	Key Performance Indicators
LBS	Location-Based Services
LMR	Land-Mobile Radio
LTE	Long-Term Evolution
MC	Mission Critical
MCDData	Mission Critical Data
MCOP	Mission Critical Open Platform
MCPTT	Mission Critical Push-to Talk
MCS	Mission Critical Services
MCS TaaSting	Mission Critical Services Testing-as-a-Service
MCV	Mission Critical Voice
MCVideo	Mission Critical Video
MCX	Mission Critical Services
mFIT	Mobile Fingerprinting Innovation Technology
ML	Machine Learning
MML	Material Measurement Laboratory
MOU	Memorandums of Understanding
NAPSG	National Alliance for Public Safety GIS
NCCoE	National Cybersecurity Center of Excellence
NIEF	National Identity Exchange Federation
NIFA	National Institute of Food and Agriculture
NIST	National Institute of Standards and Technology
NOFOs	Notices of Funding Opportunity
NPSBN	Nationwide Public Safety Broadband Network
NTIA	National Telecommunications and Information Administration
OMB	Office of Management and Budget
P25	Project 25
PETs	Privacy Enhancing Technologies
PML	Physical Measurement Laboratory

Acronyms

Acronym	Expansion
PSCIL	Public Safety Communications Innovation Lab
PSCR	Public Safety Communications Research Division
PSIAP	Public Safety Innovation Accelerator Program
PSITC	Public Safety Immersive Test Center
QoE	Quality of Experience
QoS	Quality of Service
R&D	Research and Development
R2	Response & Resiliency
RAN5	Radio Access Network Working Group 5
RF	Radio Frequency
RoIP	Radio over IP
SBIC	Small Business Investment Companies
SBIR	Small Business Innovation Research
SDOs	Standards Development Organizations
SLAM	Simultaneous Localization and Mapping
SPIE	Society of Photographic Instrumentation Engineers
STTR	Small Business Technology Transfer
TCCA	TETRA Critical Communications Association
TETRA	TErrestrial Trunked RAdio
UAS	Uncrewed Aircraft Systems
UAS 1.0	Unmanned Aerial Systems Flight and Payload Challenge
UAS 2.0	First Responder UAS Endurance Challenge
UAS 3.1	First Responder UAS Triple Challenge – FastFind: UAS Search Optimized
UAV	Uncrewed Aircraft Vehicle
UI	User Interface
UI/UX	User Interface/User Experience
USDA	U.S. Department of Agriculture
VR	Virtual Reality
WUI	Wildland Urban Interface
USDA	U.S. Department of Agriculture
VR	Virtual Reality

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About PSCR

The Public Safety Communications Research Division (PSCR) housed within the Communications Technology Laboratory (CTL) 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. The PSCR program'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 NIST 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. This impact assessment report details the results of PSCR's internal and external programs from 2016 to 2022 across its six research portfolios: User Interface/User Experience (UI/UX), Mission Critical Voice (MCV), Location-Based Services (LBS), Public Safety Data Analytics, Security, and Resilient Systems.

PURPOSE

The purpose of this impact assessment is to provide stakeholders with relevant information about how the PSCR program spent Public Safety Trust Funds and the results of that funding. 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 research and manufacturing programs or incentivizing research in the cause and effects of climate change. When the federal government is a good steward of taxpayer investment, agencies can efficiently and effectively carry out

their missions, achieving intended outcomes and making the best use of available resources. PSCR demonstrated that public investment in private industry can lead to tangible benefits for citizens, such as improved infrastructure, better public services, and enhanced public safety. To provide transparency and accountability to key stakeholders and taxpayers, PSCR extensively tracked its impacts since 2016, ensuring alignment across five leading indicators: research capacity, disruptive approaches and technology, standards, products, and public safety methods. Furthermore, the report includes data from external award recipients, prize challenge competitors, and accelerator program participants to provide a more holistic view of programmatic impact. This report will highlight success stories as they relate to the leading indicators. However, these cases represent only a small fraction of participants that have made an impact through this program. Statistics and examples in this report were collected from grantee closeout reports and publicly available information. PSCR analyzed and aligned data with a key performance indicators-based taxonomy to sort and categorize results. Due to the evolving nature of impacts, this analysis documents the lower bound estimate of what was reported with the understanding that some impacts are still unfolding and will be realized at a later time. At the time of this report's publication, only data up to September 1, 2022, is included. However, the PSCR program still oversees ongoing projects and awards, the effects of which will come to fruition in years to come. This report is the first phase of capturing and documenting these impacts. Have an update you would like to request? Email us at PSCR@NIST.gov and we can include them in the next version.

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

operational 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.

NIST Investment

PSCR contracted a team to conduct an independent analysis of PSCR's research investments and how they translated into broader impacts to the U.S. economy, 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](#).

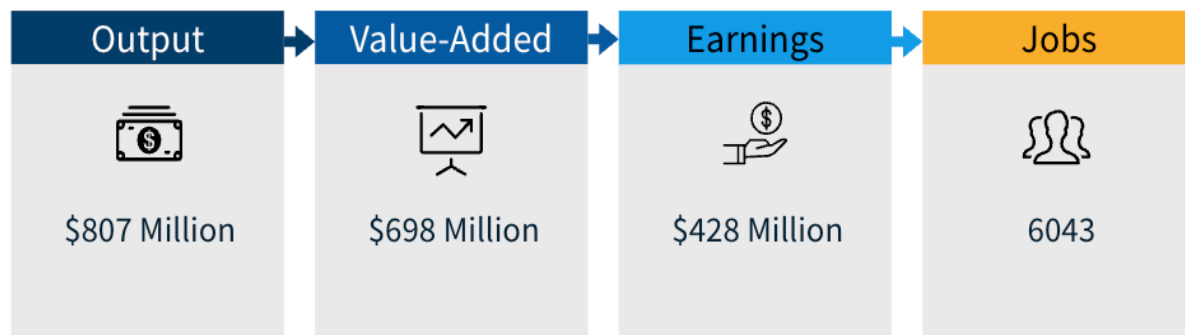


Figure 1 Nationwide totals in terms of output, value-added, earnings, and jobs

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.

According to the Economic Impact Analysis, PSCR allocated **\$239.95M** to internal research, generating an estimated **3,000 jobs** in the U.S. economy.

Utilizing grants and cooperative agreements, PSCR supported a total of 83 funding opportunities, 77 of which were U.S.-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. An estimated **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 an estimated **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 **two SBIR Phase 3 awards** at a total investment cost of **\$5.01M**, leading to an estimated **51 part time and/or full time jobs**.

NIST Investment

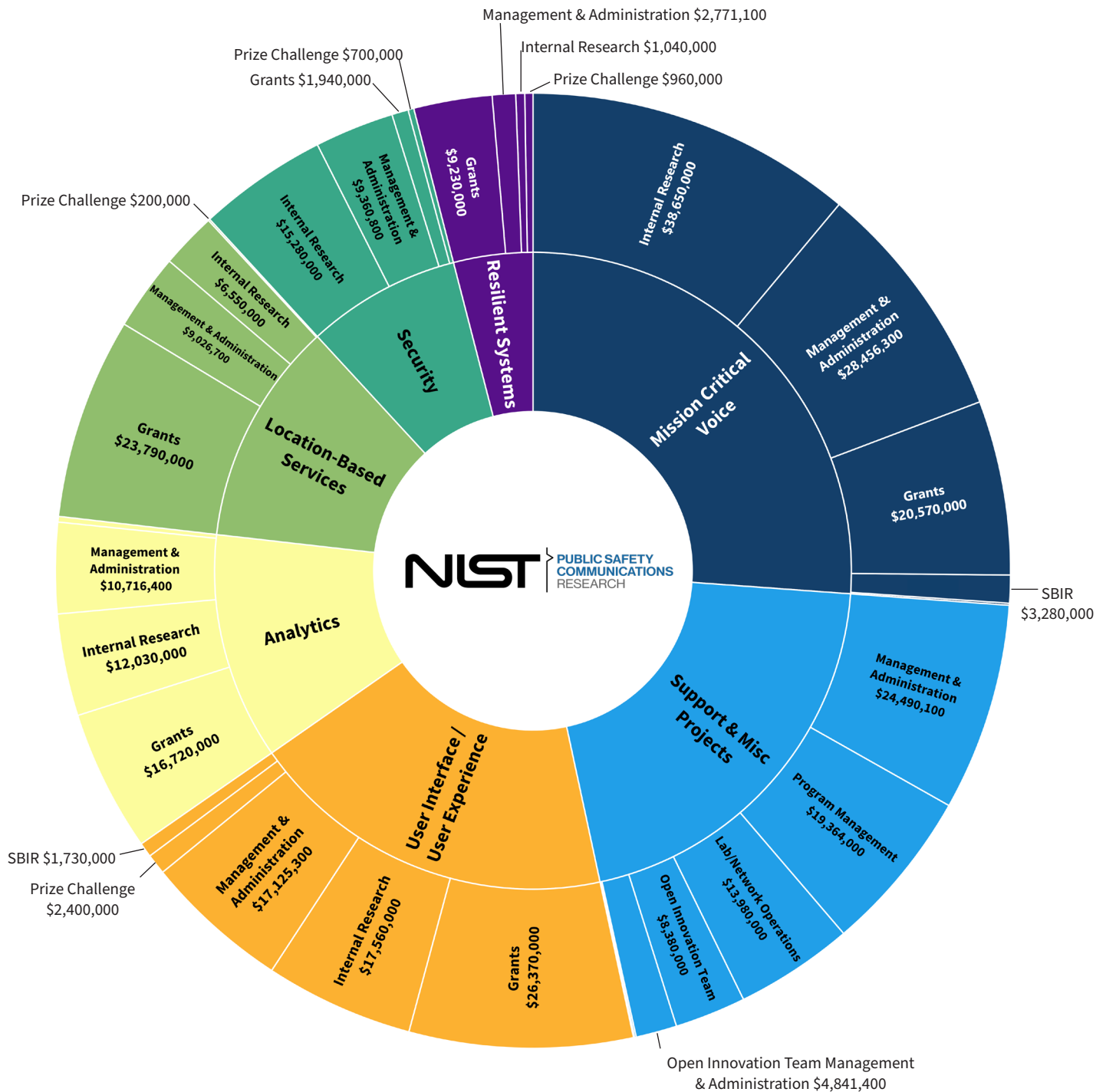


Figure 2 Illustration of PSCR's funding allocation in 2022 dollars per portfolio and project

PSCR Program Impacts

INTERNAL 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



23

Internal Open
Source Software



103

Internal
Publications

Standards

LTE

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

LMR
to LTE

Initiated many 3GPP
Standards-based LMR to LTE
Interfaces for Public Safety.

REACH

Hosted Events

More than
100

Stakeholder
Engagements
Since 2016

Lab visitors

More than
2600

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 (AR) 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 AR and
Virtual Reality (VR)
Headsets



A Mobile Staircase &
Other Equipment for
Z-Axis Motion



Physical Furniture
and Gear to Add a
Tactile Component to
Simulations

PSCR Program Impacts

External Research

Grants and Cooperative Agreements



\$108M

In Grants
Awarded



83

Total Award
Recipients



200+

External Software
Resources



7

Patents
Granted



300+

External Journal
and Conference
Publications

Open Innovation Prize Challenges



Winners
from
33 States
&
5 Countries



20

Challenges
Launched



246

Winning
Teams



\$5.3M+

In Prizes
Awarded



603

Prizes
Awarded



848

Total
Submissions

Commercialization Highlights

Entities that Provided SBIR Follow-on Funding to PSCR Commercialization Program Participants*

Air Force	9 awards
Department of Homeland Security	3 awards
Navy	3 awards
Army	2 awards
Defense Health Agency	2 awards
NASA	2 awards
National Science Foundation	2 awards
Department of Agriculture	1 award
Department of Commerce	1 award
Department of Transportation	1 award

26

Public safety organizations involved in PSCR-supported commercialization efforts

20

Funding opportunities with public safety demonstrations and pilot projects

\$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

* See the Appendix on page 76 for the full list of awards.



LESSONS LEARNED FROM A MAJOR FUNDING INJECTION

Lessons Learned from a Major Funding Injection

Lessons Learned from a Major Funding Injection

Since the PSCR program began using funds from the Public Safety Trust Fund in 2016, it has utilized the entire \$300 million while sharply focusing on enhancing essential public safety technology. With steadfast commitment, targeted focus, and well-planned execution, the PSCR program consistently prioritized the communication needs of first responders throughout each step of the process.

A significant one-time funding infusion to a federal agency allows for launching new initiatives, accelerating existing programs, and upgrading infrastructure and technology. However, this funding approach demands vigilant resource management. Agencies must plan meticulously, manage projects effectively, and ensure strict oversight to spend the funds wisely. Additionally, they need to consider how to sustain the initiatives when the one-time funding runs out. Transparency and accountability are essential when handling large funds to maintain public trust and make informed decisions. This funding approach can lead to remarkable outcomes when executed well, as demonstrated by other examples such as the National Aeronautics and Space Administration (NASA) Apollo Program,¹ the Coronavirus Aid, Relief, and Economic Security (CARES) Act (2020),² and the American Recovery and Reinvestment Act (2009).³ The same can be said of the PSCR program.

This section of the report explores the successes, strategic plans, and opportunities for future improvement of PSCR's approach to spending \$300 million from fiscal year 2016 through 2022. Moreover, this section serves as a repository of insights and can inform a roadmap for future large-scale one-time funding initiatives.

PROGRAM STRATEGY AND IMPLEMENTATION

The strategic planning of the PSCR program was underpinned by a clear vision and structured approach that maintained alignment with its core mission at every stage. PSCR defined its program by building out the required activities specified in the 2012 legislation, 47 U.S.C. §1443,⁴ and narrowing its focus from there. The program identified the desired future state by initiating the planning process with roadmaps and defined crucial requirements to meet the objectives. These roadmaps, in turn, informed the creation of summits, portfolios, and project plans, as illustrated in Figure 3. Each of these elements were closely tied to the overall mission and provided the foundation for the final deliverables. This approach was instrumental in avoiding scope creep and ensured that all activities remained anchored to the central goals. The program understood the need for accountability and used dashboards to assess risks, monitor progress, and make data-driven decisions.

This open environment allowed for calculated and swift decision-making, ensuring processes were well-documented.

Another strength of the PSCR program was the multi-faceted approach to engaging a diverse range of expertise. PSCR partnered with and funded other NIST operating units to secure specialty expertise. Collaborations with the Information

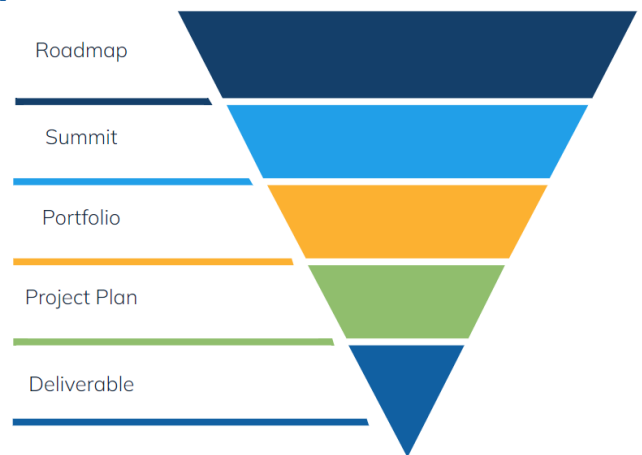


Figure 3 Planning process for program implementation

1 https://www.nasa.gov/mission_pages/apollo/missions/index.html

2 <https://home.treasury.gov/policy-issues/coronavirus/about-the-cares-act>

3 <https://www.fcc.gov/general/american-recovery-and-reinvestment-act-2009>

4 <https://www.law.cornell.edu/uscode/text/47/1443>

Technology Laboratory (ITL), the National Cybersecurity Center of Excellence (NCCoE), the Engineering Lab (EL), and the wider CTL provided PSCR with subject matter experts and recipient units with multi-year funding. Federal Term non-permanent hires, large-scale contracts such as Blanket Purchase Agreements (BPAs), and employing associates played an essential role in enhancing PSCR's capacities with a flexible and targeted workforce, especially in marketing communication, program management, engineering, and telecommunication expertise. Moreover, PSCR's strategy strongly emphasized external research, consisting of grants, cooperative agreements, and prize challenges. This blend of strategies fostered innovation and ensured a broad spectrum of insights and solutions for public safety challenges.

Importantly, PSCR recognized the value of engaging with public safety technology users early to ensure that the developed technologies effectively addressed real-world needs.

Lastly, the PSCR program's engagement beyond its internal operations added value to its strategic approach. Active participation in standards development organizations ensured that PSCR's research translated into real-world impacts, such as through the 3rd Generation Partnership Project (3GPP) and the Mission Critical Push-to-Talk (MCPTT) test case development and the integration of those test cases into the test equipment for MCPTT testing and conformance verification. The program's commitment to sharing knowledge through publications, website or newsletter updates, annual stakeholder meetings, bi-monthly webinar series, and frequent blogs, demonstrated a transparent and inclusive approach. PSCR also recognized that failure could be a stepping stone to success and, thus, incorporated learnings from its setbacks into future planning. This holistic approach of combining rigorous strategic planning, diverse collaboration, external engagement, and market research contributed to PSCR's successful advancement of public safety communications technologies by understanding the current state and the greatest impact possible.

Recommendations for future implementation

- **Establish Accelerator and Prize Challenge Program for Interagency Collaboration:** To facilitate more efficient funding disbursement and coordination, implement an accelerator program that fosters collaboration between federal agencies through grants and prize challenges.
- **Prioritize Detailed Project Planning With Stakeholder Input:** Emphasize the importance of comprehensive project planning, incorporating insights gathered from stakeholder summits and workshops, as a fundamental step in driving project outcomes.
- **Build a Diverse Workforce With Technical and Managerial Expertise:** Focus on developing a workforce that combines technical expertise with project management skills, ensuring a well-rounded team capable of addressing various aspects of the program.
- **Implement Strategies for Talent Retention:** Develop and implement strategies aimed at retaining skilled employees, particularly those with technical expertise, to ensure continuity and the effective execution of program objectives.

KEY PERFORMANCE INDICATORS

Key performance indicators (KPIs) are crucial for the success of federal programs due to their ability to provide clear, measurable goals that align with strategic objectives. This alignment allows for constant monitoring and adjustments, fostering accountability by establishing quantifiable outcomes. Additionally, KPIs enhance transparency in using funds, an essential factor in maintaining public trust. By providing a clear basis for evaluation, KPIs offer valuable insights that can inform future planning and support educated decision-making throughout the program. KPIs ensure that federal programs are purpose-driven, transparent, and accountable, maximizing their potential to use resources and yield positive impacts.

The PSCR program began its approach to spending the \$300 million by leveraging multiple strategic planning sessions to brainstorm and develop a set of unique KPIs that fit the program's objectives. Defining KPIs not only enabled PSCR to have metrics that quantified success at a portfolio level but also demonstrated to stakeholders such as Congress, the Office of Management and Budget (OMB), and Department of Commerce (DOC) executives that the program was achieving its goals. KPIs ensured the transparency and the clarity of progress for the awarded projects while also aiding the preparation for audits and the efficacy of deliverables. Starting from a foundation of KPIs also ensured stringent documentation that enabled the capture of key elements over time, such as external awardees' technology, their connection to public safety, and the impact on the community. Recognizing most impacts materialize after the funding period, the focus should also be placed on the communities built because of this initiative.

Recommendations for future implementation

- **Stakeholder-Informed KPIs:** Initiate program development with a comprehensive set of KPIs, ensuring they are formulated based on insights and inputs from relevant stakeholders.
- **Structured Outcome Reporting:** Establish a systematic process for communicating outcomes to stakeholders, centering discussions on predetermined objectives.
- **Incorporate Reflective Assessments:** Implement a reflective review at the conclusion of each cycle to critically evaluate the program's progress and outcomes, ensuring an understanding of achievements and areas for improvement.
- **Continuous Refinement of Evaluation Methods:** Utilize insights garnered from reflective assessments to fine-tune evaluation methodologies, facilitating ongoing improvement and ensuring alignment with program goals.

STAKEHOLDER ENGAGEMENT

Stakeholder engagement is a driving force behind the success and evolution of the PSCR program. Early involvement of stakeholders, including first responders, experts, academics, and industry representatives, promoted the development of cost-effective technologies that addressed the unique challenges in the public safety domain. Through networking, particularly via the annual stakeholder conference, PSCR built vital connections, promoted dialogue, and cultivated a user-centric approach where feedback was actively sought.

Continuous engagement with the public and collaboration with stakeholders was fundamental to achieving PSCR's mission of advancing public safety communications technology so public safety can more effectively protect lives and property. The program's leadership utilized an extensive network to maximize impact while balancing internal and external research, allowing for a diverse range of ideas and insights. The PSCR program expanded the public safety sphere by looking outside of the typical group of stakeholders and bringing in new groups through prize challenges and spreading awareness at various conferences and workshops. Through their regular engagement with stakeholders, PSCR created a sense of shared investment in the mission and ensured taxpayer resources were being spent on an initiative that genuinely mattered. This approach not only established sustainable initiatives but also created an entirely new community of researchers dedicated to public safety.

In summary, PSCR's emphasis on stakeholder engagement proved to be an invaluable strategy for innovation in the public safety sector. By fostering an inclusive and collaborative environment, PSCR was able to understand and address the communication needs of first responders more effectively. The engagement facilitated collective growth, created enduring partnerships, and ultimately contributed to the successful advancement of public safety communications technologies.

Recommendations for future implementation

- **Engage Stakeholders Early and Continuously:** Involve all relevant stakeholders, including first responders, experts, and industry representatives, from the beginning and maintain engagement through networking platforms such as conferences and meetings.
- **Cultivate a Unified Mission Among Partners:** Develop a clear, shared mission that aligns the varied goals of industry, academia, and government, to anchor all work moving forward around a central goal.
- **Adopt a User-Centric and Responsive Approach:** Continuously seek feedback from stakeholders and be agile in adapting the program based on their insights and suggestions, keeping the end-user's needs at the forefront.
- **Share Tangible Impacts:** Empower current stakeholders and partners to help share program impacts with their networks, the public, and key decision-makers.

FUNDING MECHANISMS

Grants and cooperative agreements

Grants and cooperative agreements are effective funding mechanisms for supporting technological development in areas that require less direct federal involvement and often have less defined problem statements and evaluation criteria. Notices of Funding Opportunities (NOFOs) for grants and cooperative agreements propose general goals, with applicants tailoring their submissions to achieve that goal. The most aligned applications are awarded funding. Once their projects begin, these external awardees act as a force multiplier, making progress on challenging technical problems while PSCR staff continue to pursue their internal research.

PSCR mandated grantee collaboration with public safety organizations for Public Safety Innovation Accelerator Program (PSIAP) participants, ensuring effective knowledge sharing and aligning research with real-world needs. Researchers could access frequent feedback about their products and prototypes and conduct user testing with their public safety partner agency. PSCR strategically spaced major NOFOs every two years, facilitating structured and ongoing engagement with the research community. This two-year NOFO cycle afforded PSCR strategic decision flexibility in obtaining R&D support tailored to the program's goals.

The PSCR program successfully integrated the outputs of grants into its internal research. One great example is utilizing the point cloud data files from the 2018 Point Cloud City cooperative agreement to support the CommanDING Tech Challenge, as well as to train and test machine learning algorithms to identify public safety objects of interest. Cooperative agreements allowed PSCR to incorporate external hardware, software, and expertise to enhance internal research capabilities, resulting in a synergistic innovation cycle. A notable result of this pattern was the integration of special interest communities into the realm of public safety applications, such as video game developers in public safety AR/VR simulations. This exemplified the program's ability to diversify and introduce innovative contributors that could apply their skills to the public safety use case. Through grants and cooperative agreements, the PSCR program succeeded in creating a vibrant research community that continues to contribute to public safety advancements today.

Recommendations for future implementation

- **Promote Collaboration and Diversity:** Mandate partnerships between grantees and primary stakeholders and involve diverse partners, including unconventional sectors, to spur innovation.
- **Integrate Outputs Into Internal Research:** Establish mechanisms to assimilate technologies resulting from

grants into internal research, fostering a mutually beneficial ecosystem that propels organizational objectives.

- **Adopt Meticulous Planning and Documentation:** Conduct thorough initial planning by consulting relevant legal and regulatory entities and keep detailed records for audit preparedness and impact assessment.
- **Innovate and Think Strategically:** Keep ahead of innovations and strategies adopted by stakeholders, think beyond immediate needs, and invest in foundational R&D to ensure sustainable growth and maximize taxpayer value.

Prize challenges

As an alternate funding mechanism to grants and cooperative agreements, prize challenges are most effective in supporting innovation in areas with known technological gaps and defined problem statements. A prize challenge is a competition where participants solve a specific problem or meet a set criterion, with the winner receiving a reward or recognition. PSCR prize challenges supplied financial incentives and provided market intelligence, data, and networking opportunities. Several prize challenges had culminating phases that encouraged contestants to develop a business or commercialization strategy for their prototypes. Some prize challenges took it one step further and provided additional awards to help finalists connect with commercialization resources and advance their early-phase innovations. Notably, the Uncrewed Aircraft Systems (UAS) industry experienced market success in which these challenges influenced the design trade-offs for affordable, feature-rich drones suitable for public safety applications.

These competitions have assisted researchers in innovating comparatively quicker than traditional grants, from two to three years versus one year for working prototypes. The shorter duration of prize challenges galvanized contestants to develop solutions more efficiently. The prize challenges attracted diverse external partners and talents by offering them insights into public safety needs, which fostered problem-solving technology geared toward the public safety community. The competitive environment further spurred innovation and diversified the technology landscape in public safety. Additionally, prize challenges played a pivotal role in the educational enrichment of stakeholders and the establishment of a cohesive community. A broad spectrum of contributors, including academia, small businesses, and first responders, were mobilized to work collaboratively.

Prize challenges allowed the PSCR program to have more control over the outcome of a competition than a grant or cooperative agreement because specific competition evaluation criteria aligned with the research objectives. Moreover, the expedited payout of resources proved to be a notable advantage. Data Privacy-focused prize challenges were particularly successful in engaging innovators to develop data sets, algorithms, and other tools for use in follow-on research. PSCR also strategically determined prize amounts by evaluating technology readiness, industry domain, and specific technological hurdles. This practical strategy, coupled with the rapid pace of innovation, educational outreach, community engagement, and market impact, highlights the sweeping effect that prize challenges have had on public safety communications enhancements.

Recommendations for future implementation

- **Tailor Prize Amounts:** Set prize amounts based on technology readiness, industry specifics, and participant incentives, employing phased rewards for complex challenges.
- **Set Clear Success Metrics:** Involve experts in creating evaluation criteria aligned with the prize challenge goals and employ KPIs to measure success.
- **Support Winners and Build Community:** Engage in outreach efforts and provide commercialization support to winners, fostering a community committed to advancing the mission.

- **Standardize and Collaborate:** Establish standard operating procedures for prize challenges and engage in knowledge-sharing through platforms such as the R2 network and the Challenge.gov community of interest.

Cooperative Research and Development Agreements and Memorandums of Understanding

The PSCR program notably benefited from employing Cooperative Research and Development Agreements (CRADAs) to foster collaboration and networking. Between 2010 and 2014, PSCR spearheaded a consortium using CRADAs to assess and enhance Long-Term Evolution (LTE) systems and communication technologies for public safety. This initiative culminated in 2015 with the creation of the Public Safety Communications Innovation Lab (PSCIL), involving over 50 companies that collaborated with PSCR to demonstrate and evaluate the behavior of public safety broadband technologies. This monumental initiative serves as a testament to the effectiveness of collaboration.

Through CRADAs, the PSCR program has partnered with various entities, including private industries, academia, and other government organizations. This has enabled PSCR to harness combined expertise, resources, and facilities and accelerate the transfer of technology from federal labs to the private sector. PSCR realized exponential success through these collaborations, as contributors originally targeting a specific application or industry discovered that their innovations could be tailored to also support public safety. Additionally, CRADAs offer a viable alternative to grants, prize challenges, contracts, and acquisitions, allowing for more flexibility and mutual engagement in research and development activities. Additionally, PSCR has actively leveraged Memorandums of Understanding (MOUs) to support the program mission and make resources go further with the program's trusted partners. While not legally binding, MOUs have been pivotal to the program, serving as agreements that clarify roles, responsibilities, and expectations for all involved parties.

PSCR used MOUs to solidify inter-agency relationships with organizations like the First Responder Network Authority (FirstNet Authority) to house the Public Safety Immersive Test Center (PSITC) on their campus, as well as the National Telecommunications and Information Administration (NTIA) and Institute for Telecommunication Sciences (ITS) for network support at the PSCIL. Furthermore, PSCR also had an MOU for the Tech to Protect Prize Challenge, which leveraged partnerships with the FirstNet Authority and FirstNet Built with AT&T to collaborate on ten prize challenge problem statements designed to develop new, creative technologies that address emergency responder needs. MOUs enabled the PSCR program to both be more flexible and work with more organizations to achieve a common goal. By fostering collaboration and pooling resources, MOUs have not only proven to enhance cost efficiency but also bolster the overall effectiveness of PSCR's initiatives.

Recommendations for future implementation

- **Identify Strategic Partners With Complementary Expertise:** It's crucial to select partners from industry, academia, or other governmental agencies that can contribute unique skills, technologies, or knowledge to the collaboration.
- **Clearly Define Objectives, Roles, and Intellectual Property Rights:** Ensuring that all parties have a clear understanding of what is expected of them and how intellectual property will be handled can help avoid misunderstandings and disputes later on. This, in turn, can result in a more productive and smooth collaboration.

Commercialization

The PSCR program has played an important role in accelerating the commercialization of vital technologies and products for public safety. By connecting innovators with business development resources and subject matter experts, PSCR has supported emerging companies into their next phase of market entry.

The Pulse Accelerator program played a crucial role in helping emerging communications technology companies accelerate growth and development of prototypes that support the public safety and first responder sectors. This program supported 28 business participants across three cohorts and offered entrepreneurial development and industry connections. This aided businesses in advancing public safety communications prototypes by working directly with specialists and experts to develop a commercialization plan for their technology innovation. The program fostered a collaborative environment for executive-level managers to engage with each other and public safety partners. Moreover, participants were connected with resources tailored to their Technology Readiness Levels, which enabled many to pursue additional government funding through programs like Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR). The Pulse Accelerator achieved notable results, with 11 businesses securing more than \$12 million in follow-on funding post-participation from agencies that range from the x Security (DHS) to the United States Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA)

Recommendations for future implementation

- **Establish Formal Programs to Foster Collaboration:** Programs to support emerging markets need to facilitate networking and collaboration among businesses, experts, and stakeholders. Providing technical and entrepreneurial development, as well as helping to validate technologies through industry partnerships, is crucial.
- **Facilitate Access to Funding and Tailored Resources:** To catalyze commercialization in emerging markets, agencies can connect businesses with resources that match their Technology Readiness Levels to support a structured pathway toward commercialization.

CONCLUSION

In conclusion, the PSCR program set a benchmark in successfully building out a cutting-edge R&D program through a well-orchestrated strategic planning and implementation process. The cornerstone of its success lies in alignment with its core mission, stakeholder engagement, and transparent decision-making. The application of KPIs was pivotal in ensuring accountability and optimizing resources. Furthermore, PSCR effectively harnessed grants, cooperative agreements, prize challenges, and CRADAs to foster a rich research ecosystem and catalyze innovation. By adopting a comprehensive and collaborative approach, PSCR delivered significant innovations and laid a solid foundation for future public safety initiatives. The program's success established a framework that can be utilized for future one-time funding injections, ensuring sustained progress and continuous advancements in the field of public safety communications.

Overall, the PSCR program's strategic planning, stakeholder engagement, transparent decision-making, and effective utilization of funding mechanisms have resulted in a program that is at the forefront of R&D in the public safety sector. Its accomplishments serve as a benchmark for excellence, paving the way for future advancements and improvements in public safety communications.



FIVE LEADING INDICATORS OF SUCCESS

Five Leading Indicators of Success

FIVE LEADING INDICATORS OF SUCCESS

Five Leading Indicators of Success

In addition to the lessons learned from administering a \$300 million program, the PSCR program also measured its impact against the five leading success indicators established in 2018. The ultimate goals for PSCR R&D activities were to transform public safety operational capabilities and contribute a measurable impact on public safety's ability to save lives and property. To achieve these end goals, PSCR focused funding allocation, staffing resources, and research attention on projects that aligned with these five leading indicators to deliver value to the public safety community through its Internal and external research activities.

INCREASING 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.

PSCR expanded research facilities

The PSCR program made significant strides in expanding its research facilities through strategic investments and innovations. Leveraging the Public Safety Trust Fund, PSCR expanded its Innovation Network, upgrading outdated equipment and ramping up networking capabilities. The upgrades support speeds to ten gigabytes per second, whereas previous network switches operated at 100 megabytes per second. This enhancement, among others, including server virtualization, ensures that PSCR's lab remains adaptable and able to support the increasing volume of data generated by research activities.

The PSITC is a standout achievement, equipped with a usability audio and visual (A/V) recording system, high-speed optical tracking cameras, modular environmental layouts, virtual simulation overlays, 3D scanning and modeling



Upgrading our lab capabilities to future-proof the design has enhanced our research because now, when our technical leads come to us with a problem, we have better resources to solve it.

– Wyatt Suess, PSCR



We had encouragement from leadership to think big and not be limited to how we traditionally ran projects. As a result, we made groundbreaking investments in [the PSITC] that could allow for huge progress.

– Scott Ledgerwood, PSCR

tools, the latest AR/VR headsets, and a Z-axis staircase. This unique facility enables researchers to place users into hyper-realistic simulations, which is invaluable for testing non-commercialized technology in relevant settings. This fosters innovation and ensures that emerging technologies meet public safety requirements. The PSITC also acts as a key engagement center with over 300 stakeholders across public safety, industry, and academia visiting since its launch in 2022.

Another notable research tool is the Mobile Measurement Research Vehicle, which has an

expandable tower specifically designed for remote testing of Mission Critical (MC) capabilities without causing any disruptions to commercial, public safety bands. Such testing is critical for developing and improving standards that align with public safety operations. In addition, the PSCR network supports Land-Mobile Radio (LMR) to LTE MC research by connecting to a fully functional LMR network at the Boulder campus. This research is critical to support the creation of MC quality and reliability metrics and testing for LMR to LTE communications. The PSCR program also acquired cutting-edge technology, including Interworking Function (IWF) equipment, testing functionality, and Radio over IP (RoIP) gateways. These upgrades have enabled researchers to conduct a wider array of experiments and analyze data pertinent to PSCR's priority projects.

The ability of the PSCR program to support remote networks like the PSITC and the Mobile Measurement Research Vehicle is possible by meticulous network management and cybersecurity protections. PSCR's network management allows for rapid adaptation and integration of state-of-the-art technologies and boosts scientific output for research portfolios.

PSCR and external partners recruited top talent

The PSCR program utilized available funds to attract a remarkable pool of internal and external talent, encompassing research experts from over 253 distinct organizations. This diverse cohort was instrumental in elevating the caliber of PSCR's research, leading to major advancements in domains such as identity, credential, and access management (ICAM) and MCV Quality of Experience (QoE).

Internally, PSCR prioritized the cultivation of expertise in key areas. Within LBS, researchers became subject matter experts related to indoor localization or lidar scanning. In the UI/UX portfolio, one staff member focused their Ph.D. dissertation on systems engineering in extended reality focusing on public safety. The incorporation of researchers with a background in the video game industry expanded the program's purview, further bringing together public safety with the commercial sector. PSCR's internal researchers also received recognition through the award of more than ten Gold, Silver, and Bronze Medals through the Department of Commerce (DOC), demonstrating their leadership in public safety communications. In 2021, the George A. Uriano Award was presented to the Open Innovation team, including Ellen Ryan, Terese Manley, Craig

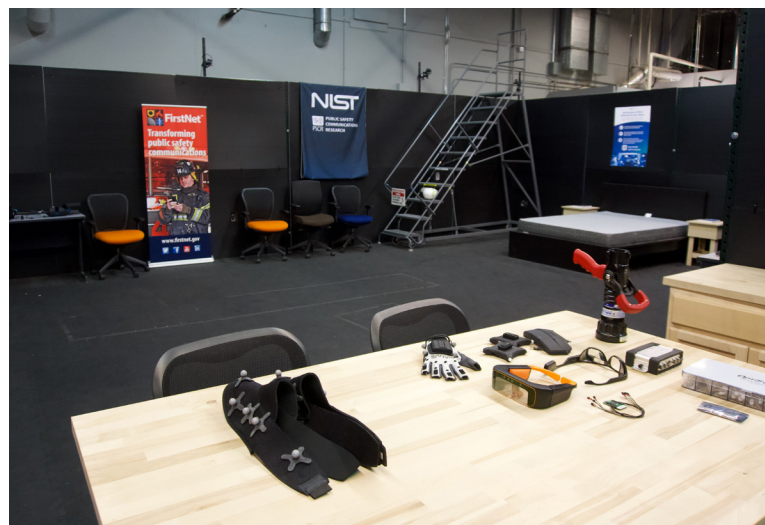


Figure 4 The PSITC provides opportunities to conduct immersive public safety standards and measurements testing

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PSCR's cutting-edge measurement labs have been instrumental in advancing telecommunications technologies. Our network has been built utilizing security best practices, enabling us to collaborate with other entities both internal and external to NIST. Sharing resources across collaborators is not only strategic but also cost-effective.

– Lisa Soucy, PSCR

Connelly, Gary Howarth, Joanne Krumel, Jeremy Glenn, and Sarah Hughes for outstanding leadership in creating a novel Open Innovation program at NIST. In 2022, Ellen Ryan was presented the Flemming Award for outstanding leadership in delivering public-private partnerships that drove the research and development of critical, life- saving communications capabilities for first responders. These are just a few examples of more than 20 awards presented to the PSCR program.

Cross-collaboration within the DOC emerged as an important strategy for the PSCR program, leveraging existing resources to bridge technical gaps and fostering inter-agency collaboration. Additionally, PSCR's ability to hire a substantial number of staff in a relatively short time frame played a crucial role in the expansion and success of the program. By enlisting specialists from various NIST units, including the ITL, NCCoE, EL, Physical Measurement Laboratory (PML), Material Measurement Laboratory (MML), the Wireless Networks Division (WND), along with NTIA's FirstNet Authority and ITS, PSCR significantly bolstered its problem-solving capabilities.

Additional partnerships outside the DOC include the NASA Center of Excellence for Collaborative Innovation (CoECI) and Department of Homeland Security (DHS). This partnership approach allowed PSCR to efficiently utilize the expertise within other divisions and agencies without duplicating efforts or undertaking the difficult task of building in-house programs. For instance, PSCR relied on existing fingerprint expertise within the NIST ITL for the 2021 Mobile Fingerprinting Innovation Technology Challenge (mFIT) prize challenge instead of hiring an external expert. PSCR collaborated with EL on aerial drone technology for the Uncrewed Aircraft Systems (UAS) prize challenge program. NCCoE, which now maintains a Public Safety research focus area, developed a network in their lab to facilitate initiatives such as mobile single sign-on and state-level public safety network architecture. Even as the PSCR program finished executing the Public Safety Trust Fund, the legacy of its collaborations ensured that these entities will continue to independently engage with public safety stakeholders.

PSCR used prize challenges to attract talent, resulting in over 240 participating teams. Simultaneously, PSCR strengthened research capabilities in public safety communications by engaging over 200 researchers through grants and cooperative agreements as principal investigators, key personnel, and support staff. Furthermore, PSCR's influence was not limited to the domestic landscape. The program's international outreach was evident in its engagement with participants from countries including Switzerland, Canada, Estonia, the United Kingdom, Spain, and Australia. This global impact expanded the talent pool and fostered cross-border collaboration, lending greater credibility and momentum to the innovative solutions developed.

PSCR grew the research community through publications, conferences, and networking opportunities

PSCR built up a research community that extended globally, owing to the resources allocated through the Public Safety Trust Fund. Through publishing papers, hosting and attending events, and providing additional connection opportunities, PSCR fostered a culture of knowledge sharing, collaboration, and innovation.

Publishing papers allows researchers to share their findings, methodologies, and insights with stakeholders and the wider research community. This not only promotes transparency and reproducibility but also advances collective knowledge by making the results of research projects widely accessible. Internally, PSCR published 103 publications, while external partners contributed an additional 415 publications, of which 331 were formal articles in journals or submitted for conferences. PSCR's internal publications have been cited a total of 460 times, averaging 5 citations per paper, and more than 230,000 downloads, averaging 2,900 downloads per paper. The volume of these publications indicates an expanding body of knowledge and signifies PSCR's role in enhancing research capacity within the public safety communications domain.



The capability of ramping up so quickly came from the notion of credibility. There was a sincere commitment to the PSCR mission from everyone that got involved. That was infectious. Partners believed it and wanted to become a part of it. When you see people excited about something, you want to be a part of that too.

– Brianna Huettel, PSCR

Besides publications, conferences played a key role in disseminating knowledge and building community. Every year since 2010, PSCR hosted its Annual Stakeholder meeting, gathering community members to connect around communications technology issues of first responders. In 2023, this event expanded to partner with FirstNet Authority, culminating in co-hosting 5x5: The Public Safety Innovation Summit. The inception and evolution of the Annual Stakeholder Meeting enables technologists and public safety users to continue building the future of responder communications technology.

In addition to convening its own stakeholders, PSCR also actively attended many external conferences. Participating in conferences served as a place for PSCR researchers to interact directly with their peers, learn about the latest developments in their field, and receive real-time feedback on their work. Conferences also offered the opportunity to discover interdisciplinary connections, inspiring novel approaches and collaborations. PSCR staff engaged in opportunities such as Critical Communications World⁵ (CCW), Comms Connect,⁶ Consumer Electronics Show⁷ (CES), South by Southwest⁸ (SXSW), Institute of Electrical and Electronics Engineers⁹ (IEEE), Society of Photographic Instrumentation Engineers¹⁰ (SPIE), IEEE Conference on Virtual Reality¹¹ (IEEEVR), Mountain Connect,¹² International Wireless Communications Expo¹³ (IWCE), and many more. These events served as a forum for discussing the latest advancements, technologies, and best practices in public safety communications and enabled PSCR staff to stay up-to-date with the current trends.

In addition to hosting and participating in events and conferences, PSCR fostered networking opportunities through other means. PSCR worked together with the Economic Development Administration (EDA) and FirstNet Authority to establish the Response and Resiliency (R2) Network,¹⁴ which serves as a bridge



Through a one-time injection of funding, PSCR succeeded in building a legacy. While the \$300M has been spent, the community still lives on.

– John Beltz, PSCR

- 5 <https://www.critical-communications-world.com/>
- 6 <https://www.comms-connect.com.au/>
- 7 <https://www.ces.tech/>
- 8 <https://www.sxsw.com/>
- 9 <https://www.ieee.org/conferences/index.html>
- 10 <https://spie.org/?SSO=1>
- 11 <https://ieeivr.org/>
- 12 <https://mountainconnect.org/>
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to connect first responders and technology innovators across the nation. This network facilitates collaboration and information sharing, providing a platform for testing and implementing cutting-edge technologies in real-world scenarios. Lastly, PSCR's efforts to increase research capacity and expand the community were supported by a strong marketing communications program that broadcasted the program's impacts through newsletters, emails, and website updates. Over its tenure, PSCR's newsletter subscriber list grew to over 2,400 stakeholders, with over 800 subscribers specifically dedicated to receiving the NIST List of Certified Devices. The PSCR program delivered over 26 newsletters containing news and updates ranging from funding opportunities to blog articles. The program had over 318 media mentions, lending credibility and trust in the research.

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If you engage with stakeholders up front, they are on the journey with you the whole rest of the way.

- Ellen Ryan, PSCR

ADVANCING DISRUPTIVE APPROACHES AND TECHNOLOGIES

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

PSCR accelerated R&D

The PSCR program is instrumental in accelerating R&D in public safety communications technology. By providing financial support and metrology guidance, PSCR enabled researchers and entrepreneurs to take on ambitious projects that might otherwise have been too risky or expensive to pursue.

PSCR's PSIAP grant program and Open Innovation program played a significant role in advancing research by directly stimulating and funding a diverse range of research projects. Since 2017, the PSIAP grant program announced and awarded more than ten competitive NOFOs across various portfolios, leading to 83 unique awards, and involving universities, startups, and corporations globally, totaling over \$90 million in external research. Through the Open Innovation program, NIST received over 800 submissions across 20 prize challenges, awarding over \$5.3 million to 246 teams. These substantial investments have turned concepts into prototypes and expedited the transition from basic R&D to commercialization, accelerating the delivery of innovative products to first responders.

One significant area of focus for PSCR and the Open Innovation team has been on UAS. Recognizing early the disruptive potential of UAS in public safety, PSCR invested in UAS prize competitions to promote awareness of the first responders' UAS use case and spur technology improvements to meet their needs. The series of UAS prize challenges motivated solvers to design, build, and test prototypes to meet the unique requirements for first responder missions, such as search and rescue. Innovators made design trade-offs on energy sources and frame types to achieve lower cost, longer flight times, and maximum size and weight limits required by public safety agencies.¹⁵

The PSCR program also increased momentum around exploring the first responders' quality of experience (QoE) in MCV communications. While the quality of service (QoS) is essential in determining the performance of a network, QoE looks at how effectively first responders can retrieve the necessary voice information. QoE is critical in ensuring that voice



“We talked to many people that are excited and passionate about the innovations, research, and outcomes produced by PSCR and our partner organizations. I have seen product proposals from various technology sectors interested in helping first responders and making a difference in emergency operations. Working with these entities makes me realize the difference that innovators can make in our research and improving people’s lives.”

- Don Harriss, PSCR

15 The Public Safety Trust Fund only contributed to UAS 1.0 and 2.0. However, follow-on challenges like UAS 3.0, 4.0, and 5.0, funded by other sources, would not have been possible if not for the progress achieved by earlier efforts.

communications convey accurate and concise audio quality in high-pressure environments. By focusing on these research areas, PSCR accelerated R&D by providing a more comprehensive perspective on the needs and experiences of first responders, allowing researchers to identify areas of need more accurately.

Engaging with stakeholders was a critical component of accelerating public safety communications R&D. Through workshops, summits, and conferences, PSCR continuously learned and adapted to the needs and incorporated feedback from the public safety community. Specifically, during the annual stakeholder meeting, innovators and first responders interacted and discussed questions or pain points, providing solvers the context they needed to take the next step in their development process. Stakeholder engagement sped up R&D by ensuring that public safety requirements were considered and addressed at every product development iteration without being overshadowed by general consumer demands.

PSCR encouraged experimentation and innovation

Due to the time-sensitive nature of the PSCR program's funding, experimentation and innovation were critical components of making breakthroughs in key priority areas. Also, innovators felt more secure in taking bigger jumps in their research, knowing that every explored path would be value added for the research program, regardless of the outcome. This liberty to innovate with fewer limits, compared to traditional contract funding, spurred researchers to think outside the box to develop cost-effective solutions for first responders. Internal researchers, prize challenge participants, and grant recipients all had a wide purview to explore paths that previously hadn't been considered for the public safety use case, leading to exemplary results.

One example of how PSCR encouraged experimentation is leveraging datasets developed from one prize challenge for use in a subsequent challenge. Specifically, the smart city disaster datasets developed for the 2020 CHARIoT Challenge proved useful for the 2022 PSIAP Artificial Intelligence for IoT Information (AI3) Prize Competition which aimed to develop software and hardware components that leverage Internet-of-Things (IoT) data to support situational awareness. Furthermore, the CHARIoT Challenge data were combined with other data sources in the 2022 CommandING Tech Challenge to improve the quality of incident command dashboards. This integration of varied data types, including location and IoT sensor data, led to further experimentation and provided PSCR collaborators with invaluable resources

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We were tackling these really distant technologies with a foundation in reality.

- Alison Kahn, PSCR

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We work with first responders continually as their operations change and the industry evolves. We need to understand the impact that technology brings to their daily missions and look for gaps in the tools they use. Whether it's helping them reduce the time it takes to reach a victim or consolidating the flood of data into actionable tasks, we are looking to disrupt the industry and help them save more lives and assets. We wouldn't be able to grasp their unique needs if we were working in a vacuum.

- Terese Manley, PSCR

to leverage. Similarly, by making resources like the Haptic Challenge environments open source, the PSCR program enabled other researchers to use them in their own work and see what other conclusions could be drawn from these valuable resources. Information about these resources, and many others, can be found in the Appendix of this report.

Additionally, internal researchers also incorporated innovative elements into their own projects. UI/UX researchers leveraged state-of-the-art VR/AR headsets, such as the HTC Vive, Magic Leap 2, Meta Quest, and Meta Quest Pro, in order to trial features and gauge usability within the PSITC. This integration of high-quality hardware enabled the creation of new testbeds and next-generation research environments for rapid prototyping and research specifically centered on conducting immersive public safety standards and measurements testing.

Finally, by convening diverse groups and individuals from the U.S. and beyond, the PSCR program created a dynamic ecosystem where stakeholders could collaboratively address common challenges, formulate solutions, establish partnerships, and exchange ideas toward a shared objective. This social aspect of PSCR's endeavors was instrumental in catalyzing a movement of innovation and shared commitment to enhancing public safety through technology.

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PSCR had a good habit of viewing failure as success. Sometimes, a research project wouldn't yield the results the program hoped for, and that was okay. The program couldn't spend the time to redo the project. Instead, they learned from the mistake and used that to plan for the next step.

- Brianna Huettel, PSCR

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For a program like this, you need to be open minded about the tools you have available. Just because you've used certain tools in the past doesn't mean you can't change how you use them in the future. It's important to think outside the box.

- Jason Kahn, PSCR

PSCR supported early-stage ventures

Understanding that the first few years of a startup's life cycle are often the most challenging, the PSCR program supported early-stage ventures through business assistance programs, demonstration project funding, and strategic prize challenge awards. This support was critical in helping startups overcome obstacles related to limited resources, market validation, team building, and investor attraction.



The Pulse Accelerator was designed to help emerging technology companies accelerate the growth and development of products supporting the public safety and first responder sectors. By offering three separate rounds of business assistance to interested companies, Pulse helped startups gain the tools, knowledge, and access needed to take the next step toward the public safety market. It incentivized organizations to pursue additional funding, ultimately creating highly tailored products and services, ranging from analytics toolkits to millimeter-wave communication platforms.

The PSCR program also ran the PSIAP Follow-on Funding for Technical and Business Assistance (TABA) and Demonstration Projects program to further support early-stage ventures. This program sought to close the gap between early-phase prototypes and publicly available products that can be purchased in the marketplace. TABA cooperative agreements were only awarded to entities with previous federal awards to advance their prototypes and accelerate improvements in communications technology for first responders. It focused specifically on either technical and business assistance or conducting a demonstration project with a partnering public safety agency in order to bring that prototype closer to market commercialization. One successful example from the TABA program is the University of California Irvine's uNavChip project, which developed a reliable indoor positioning system that fit on a microchip so small, it could be placed inside the sole of a shoe.

Another successful way to encourage emerging companies was through the Open Innovation program. Open Innovation allowed PSCR to engage early with the public and industry, thereby attracting talent from a broad range of fields. The program valued the delivery of outcomes that adhered to specific evaluation criteria, enabling problem solvers to apply their creativity within the established parameters. Perhaps most importantly, from a commercialization standpoint, some prize challenge purses awarded incremental seed funding, providing financial incentive for teams to continue competing as they developed their prototypes with the goal of winning the grand prize. Even those not winning the grand prize still walked away with highly developed prototypes.

The Tech to Protect Challenge addressed the lack of public safety-focused software applications and provided a significant Open Innovation success story related to early-phase ventures. The codeathon challenge took place in ten different cities across the country and provided a huge opportunity for small startup participation. Competitors decided which of ten

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Prize challenges provide an insider take of a market or business problem and provide clarity for technology use cases. Normally, innovators don't have access to public safety members, sample data, use cases, or environments. But with prize challenges, the problem we intend to innovate upon has already been articulated, saving us time and market research.

- Jad Meouchy, CTO, BadVR

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These prize challenges both drive and expedite innovation. It gives participants like us enough funding to incentivize us to operate quickly.

- Riley Dove, Hardware Engineer, RIIS

different problem statements they would compete for, with the possibility of providing submissions to multiple contests. The result was a varied ecosystem of early-phase solutions, with multiple participants continuing their product development after the conclusion of the prize challenge. Tech to Protect incentivized developers to engage with and implement real-life end-user feedback from the public safety community, supporting the creation of effective solutions and fostering an environment of adoption by first responders.

CONTRIBUTING 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

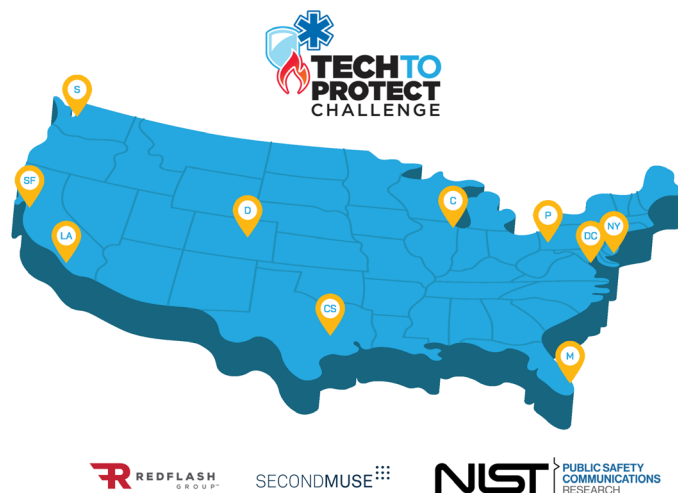


Figure 5 Graphic of the cities that hosted Tech to Protect codeathons

PSCR supported the development of public safety-specific standards

Since its inception in 2002, the PSCR program has been a cornerstone in the development of standards tailored to public safety communications. One of PSCR's pivotal roles is to ensure that the telecommunications industry considers unique requirements of public safety users. PSCR worked closely with various Standards Development Organizations (SDOs) such as the 3GPP, the Alliance for Telecommunications Solutions (ATIS), the GSM Association (GSMA), the Global Alliance of the Association of Public Safety Communications Officers (APCO), and TErrestrial Trunked Radio (TETRA) Critical Communications Association (TCCA). Through these collaborations, PSCR influenced the development of communication standards for voice, data, image, and video specific to public safety, promoting industry adoption of first responder LTE standards and task-based video quality standards.

PSCR award recipient University of the Basque Country was instrumental in standardizing public safety communications tools and creating paths for more developers to support public safety applications. Through the Mission Critical Open Platform (MCOP) initiative launched in 2017, the University of the Basque Country simplified the development process for MCPTT devices by providing an open-source platform with Application Programming Interfaces (APIs) that manage security and technical specifications. This enables developers to create public safety apps without needing extensive knowledge of the standards.

Additionally, the University of the Basque Country introduced the Mission Critical Services (MCS) Testing-as-a-Service (MCS TaaSting) project, a cloud-based platform for cost-effective certification of devices, ensuring their compatibility with both commercial and public safety networks. This service is particularly important for small organizations that cannot afford traditional certification labs. Other PSCR MCV award recipients, such as Polaris and Valid8, supported the certification environment by either leveraging open-source methods like Internet Protocol Connectivity Access Network (IPCAN) from 3GPP's Task Force 160 or creating their own code bases for verification using Word documents. For 3GPP MCS testing, test systems use an external radio frequency (RF) implementation which is integrated into the system simulator. Therefore, they can use an Evolved Node B (eNB) for the RF connection. This contrasts with the traditional method, which integrates the



NIST-supported initiatives have helped bridge the existing gaps in terms of availability of open interfaces and conformance testing tools, even when the difficult business case of such a niche market jeopardized the endeavor. The whole community worldwide will benefit from such an effort through a healthier and more innovative communications framework paving the way for the first responder of the future.

- Fidel Liberal, Professor, University of the Basque Country



Figure 6 Land mobile radios remain a primary mode of communication for first responders

RF implementation as part of the simulator, typically making testing more expensive. These awardee-developed methods make the test conformance environment more accessible to smaller equipment manufacturers.

Another significant contribution of the PSCR program is its involvement in the testing standards within 3GPP, specifically the MCS test cases under the 36.579 family of specifications. PSCR staff acted in the role of rapporteur in authoring these specifications. Within the 3GPP's RAN 5 group, responsible for creating test cases, PSCR staff proposed and developed

MCS cases by synthesizing multiple specifications into single test cases to ensure seamless functionality. This task was particularly challenging as it required harmonizing core specifications that often came from multiple authors. The efforts of the program's MCV grant awardees and sub-awardees, including the University of the Basque Country, TCCA, and

Nemergent, have been instrumental. They undertook the task of verifying the 3GPP code on their test equipment to ensure official certification. As a result of their work, over 75% of MCPTT on-network test cases are now verified.

Writing the MCS test cases was just the first step. The PSCR program effectively bridged the gap between research and practice by taking findings to SDOs. Through proactive participation and engagement with the appropriate SDOs, PSCR ensured that research insights translated into tangible, real-world standards that directly benefit public safety practices.

PSCR encouraged standards education and consortiums

The PSCR program played a vital role in fostering education standards and supporting consortiums, paving the way for a skilled workforce capable of adapting to emerging technologies in public safety. By collaborating with external partners, PSCR facilitated the development of programs that fostered a common understanding of industry standards. The consortium spearheaded by the University of the Basque Country focuses on supporting conformance testing of Mission Critical Services. Participants like GridGears and Enensys support hardware development, and partners like TCCA conduct

marketing to support getting equipment into test labs. Sonim Technologies provides devices, and Texas A&M University conducts additional proof of concept testing with equipment. Participants in the consortium work together, each fulfilling a necessary step in the conformance testing process to ensure official compliance. This consortium has been instrumental in promoting interoperability and fostering innovation in public safety communications systems. By disseminating this knowledge, PSCR empowered the public safety industry with the expertise necessary to effectively implement new technologies. The MCOP initiative mentioned above is a key outcome of this collaborative effort, demonstrating the impact of merging a diverse cohort of stakeholders from different technological areas, including industry leaders and academic institutions, to work toward the common goal of improving interoperability in mission-critical communications.



The public safety community demands at least the same level of interoperability, cost efficiency and flexibility all of us enjoy with our cell phones on a daily basis, as we land anywhere in the world and can seamlessly access added value apps and services. NIST funding has no doubt contributed towards healthy standards-based and open mission-critical communications ecosystems, the proven way to achieve this level of interoperability.

- Fidel Liberal, Professor, University of the Basque Country

Additionally, the program established the Broadband Consortium, engaging over 50 vendors who contributed equipment and support. This consortium enabled PSCR staff to undertake research projects critical to public safety, such as improving audio clarity in noisy environments and developing a database for communications in high-stress scenarios. It fostered research into key factors such as establishing MCPTT capabilities over broadband systems.

The PSCR program's initiatives in defining and developing standards had a tangible impact on their practical application in the industry. Major companies such as Nokia, Ericsson, Samsung, and Nemergent embraced the standards developed through PSCR's leadership, creating equipment and services grounded on these standards, signifying full compliance. This highlighted PSCR's vital role as a bridge between developing theoretical standards and their application in real-world scenarios, contributing to a more robust and efficient public safety communications ecosystem.

PSCR bolstered the overall first responder technological ecosystem

Regarding standards contributions, the PSCR program significantly bolstered the technological ecosystem for first responders in multiple ways. Primarily, PSCR played a crucial role as an intermediary between public safety and SDOs to enhance interoperability. Furthermore, PSCR made substantial contributions to the privacy field by developing benchmarks and advancing the national conversation on how to measure privacy through mathematical means. The profound impact of this progress is demonstrated through the heightened resilience of the privacy ecosystem.

To support the public safety technological ecosystem, PSCR combined the program's strong stakeholder engagement with efficiently facilitating collaboration between SDOs and innovators to promote public safety-related standards. Leveraging

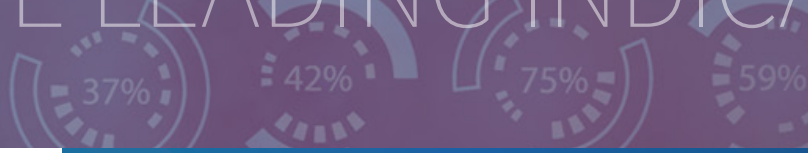
first responder requirements input, PSCR successfully acted as an intermediary and translated the operational needs of first responders into technical requirements. These requirements were then converted into standards, and integrated into commercial products, ensuring quality, reliability, and performance.

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PSCR bolstered this ecosystem in every direction, which is uncommon. It has been 360 degrees of evolution. It's not just reaching out to the research community, but also getting first responders involved, which is something PSCR does best. This community creation is a learning process for me as a researcher but helps me remember it's not just the new technologies I develop, but how my work can be applied to different areas in public safety.

– Jian Tao, Assistant Professor, Texas A&M University

Outside of the realm of SDOs, the program also played a prominent role in the field of privacy, particularly differential privacy and Privacy Enhancing Technologies (PETs). The Differential Privacy Challenge program cultivated NIST's technical expertise in PETs, inspiring the development of algorithms, many of which have been open-sourced and adopted by organizations such as the U.S. Census Bureau. This initiative also facilitated the development of fundamental metrology, which is crucial for evaluating synthetic data and privacy claims. In this context, metrology was a prerequisite for standards development, providing the mathematical framework needed for technical standards. PSCR's work laid the foundation for future privacy-related standards and offered the community benchmark tools for data quality and fidelity, further establishing NIST as a worldwide leader in differential privacy.



Having the opportunity to help participate in prize challenges, from the public safety view when these products go to market because of PSCR's lab, we know they have been ground-truthed and meet demanding standards. They were not something randomly built on the street, but rather they were developed through a challenge that had rigorous evaluation criteria for success. That level of effort builds a lot of trust in the technology built for public safety's use.

– Chief Sterling Folden, Deputy Chief of Operations,
Mountain View Fire Rescue

DEVELOPING 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.

PSCR accelerated time to market

The PSCR program has been instrumental in expediting the development and market entry of public safety communications technologies through its support programs and collaborations. The TABA program, for example, provided grants to small businesses to tackle technical challenges, helping them make well-informed decisions. A notable success story is Peak Response, a prize challenge awardee that developed an open-source software aimed at enhancing emergency response documentation and analysis during mass casualty incidents. With TABA funding, Peak Response actively engaged with first responders and industry experts to quickly transform their concept into a functional prototype.

The Pulse Accelerator program by PSCR is another landmark initiative that helped public safety communications-focused enterprises refine their prototypes and prepare them for commercialization. The program connected participants with experts, assisted in honing business pitches, and guided companies in financial planning and business growth strategies. The program's three cohorts included 28 businesses, with 11 receiving additional funding for continued development.



I don't think I would have been able to bring my app to market without PSCR. Public safety is not a big enough market for venture capitalists to care about, but I didn't want to dilute my focus. The grant opportunities, prize challenges, and Pulse Accelerator through PSCR were instrumental to moving my prototype to more than just a fun personal project.

– Francis Li, Co-Founder and CEO, Peak Response

An additional example of the PSCR program accelerating time to market for public safety communications prototypes can be seen through their early engagement with the burgeoning drone industry. The 2018 Unmanned Aerial Systems Flight and Payload Challenge (UAS 1.0) and the 2020 First Responder UAS Endurance Challenge (UAS 2.0) prize challenges drove innovations in flight time, payload, accuracy, and cost with the winning team surpassing 112 minutes of flight time for Federal Aviation Administration (FAA) Part 107 drone flights. PSCR's early involvement ensured that the specific requirements of first responders for search-and-rescue missions were addressed. As the industry evolved, PSCR's input helped shift the focus towards integrated solutions combining software and hardware, thus making drones versatile tools capable of incorporating technologies such as AR/VR, image detection, mapping, cameras, and sensors. This early engagement shaped the industry and established PSCR as a thought leader, speeding up the process of first responders having products available specifically for their use case.



Figure 7 The UAS 1.0 and 2.0 prize challenges had a significant impact on laying the groundwork for future public safety UAS innovation



Thanks to participating in the [2021 First Responder UAS Triple Challenge – FastFind: UAS Search Optimized (UAS 3.1)] challenge, we were able to take our R&D efforts out of the living room and into an actual office space. After this experience, we engaged in [2022 First Responder UAS Indoor Challenge (UAS 4.0)], and using funds from that prize purse, we were able to hire our first few employees and begin scaling our manufacturing.

- Duncan Mulgrew, CEO, Uniform Sierra¹⁶

PSCR improved quality

The PSCR program's strategic allocation of funds enabled researchers and companies to invest in R&D, spurring innovation and the creation of high-quality products. The funding fostered technological advancement and quality assurance, ensuring the development of safe and effective products. PSCR's testing facilities, including the Innovation Lab and Public Safety Immersive Test Center, played a crucial role by offering spaces for testing new technologies and providing valuable feedback to innovators.

¹⁶ The Public Safety Trust Fund only contributed to UAS 1.0 and 2.0. However, follow-on challenges like UAS 3.0, 4.0, and 5.0, funded by other sources, would not have been possible if not for the progress achieved by earlier efforts.



Funding from PSCR helped us build relevant prototypes in a development space that is hard to get into. At RTI, it has brought us together across domain areas to tackle diverse problems ranging from usability, education, and justice to crowdsource from within our institution. This major opportunity helped us take an implementation framework, integrate the first responder perspective, and leverage existing resources to connect to this sector.

– Laura Marcial, Senior Director, Center for Informatics, RTI International

PSCR also hosted prize challenges such as the Computer Vision Challenge and the CHARIoT Challenge, which generated datasets and integrated IoT data streams, respectively, driving forward improvements in image quality and efficient communication for public safety. For example, the Computer Vision Challenge enabled new research into no-reference (NR) metrics that make camera noise, jerky motion, and focus problems far less frequent in computer vision apps. Additionally, the Expanding the SIM Card Use for Public Safety Challenge proved the Universal Integrated Circuit Card (UICC), commonly known as the SIM card, can be used as a secure storage container for application credentials. The challenge demonstrated that the SIM card is a tamper-resistant hardware storage container and, if it was expanded for storing user credentials, could enable seamless, secure authentication to public safety applications. In addition to its strong security characteristics, the SIM card offers various potential usability benefits for public safety, such as a more user-friendly experience, enabling networks to provision credentials over-the-air via a secure channel, and enabling device sharing by storing sensitive data on the removable SIM card.



Prize competitions provide an avenue for innovators to understand the needs of first responders and challenge them to innovate to solve technological gaps. These gaps provide ample opportunities for businesses because they can focus on creating a product that doesn't exist on the market. In other cases, they may take an existing consumer technology and improve upon it to serve the unique needs of first responders.

- Don Harriss, PSCR



It's important to not make assumptions about the end state. Sometimes products and software are developed, but it feels like a solution looking for a problem. Through PSCR, you have innovators and researchers tied in at the beginning, which lead to better outcomes.

- Red Grasso, Director, First Responder Emerging Technologies (FirstTech) Program

Through its grant program, PSCR supported a range of projects that led to significant advancements. The 2018 Point Cloud City Award winners developed an annotated 3D point cloud data catalog. The University of Virginia produced a dataset of cardiac arrest reports, while Carnegie Mellon University explored crowd density identification and social media monitoring. The University of Houston worked on video analytics, object detection, and tracking. These projects and the many not listed projects have been instrumental in providing resources and tools that contribute immensely to public safety communications R&D.

PSCR enhanced the open-source environment for public safety

The PSCR program has been a driving force in bolstering the open-source environment for public safety, which is vital for organizations with budget limitations and a need for interoperability. Through PSCR's initiatives, 23 open-source software packages were developed internally, with over 60 additional open-source repositories contributed by external collaborators. Of PSCR's internal software, there have been a total of 1871 downloads. This open-source software not only provides cost-effective alternatives to proprietary systems but also allows customization to meet first responders' specific needs.



Public safety agencies have access to an overwhelming amount of data, and those data have huge potential to assist first responders. Analytics tools can play an important role to help agencies parse the information. PSCR shows leadership by supporting fundamental research and accelerating development of tools for public safety analytics.

- Gary Howarth, PSCR

One notable internal development was the Analytics Container Environment (ACE) Framework, made available on GitHub, which facilitated the design and functional testing of video analytics in public safety environments. Additionally, the Automated Streams Analytics for Public Safety (ASAPS) Challenge provided a simulated dataset consisting of lifelike emergency scenes. PSCR innovatively addressed privacy concerns, a common barrier in public safety, by constructing a mock city and utilizing actors for simulations, ensuring no exposure of private information.

Externally, Carnegie Mellon University contributed to Scalable UWB Ranging, an open-source firmware image focusing on Ultra-Wideband performance. The University of North Carolina at Greensboro developed a public safety resource library, and the University of Virginia made analytics algorithms and datasets available through GitHub for AR in emergency services. These technologies were showcased at stakeholder meetings, facilitating collaboration and innovation within the community. The PSCR program's commitment to open-source software has significantly enhanced the public safety landscape by fostering collaboration and innovation and providing access to cutting-edge, customizable technology solutions.



The fact that PSCR is a government agency and has put code on Github that any developer can use is great improvement. PSCR encourages private entities to interact with public safety, forge those relationships, and open-source the technology so other agencies and organizations can use it. That wouldn't happen without PSCR.

– Kishan Shetty, Principal Software Developer, JANUS Research Group

Finally, the Point Cloud City funding opportunity resulted in an extensive catalog of annotated 3D indoor point clouds that could be used to support indoor mapping, localization, and navigation for public safety. This initiative also demonstrated the potential value of ubiquitous indoor positioning and location-based information. This LBS cooperative agreement resulted in datasets from 28 mapped buildings published by the Enfield Fire Department in Enfield, Connecticut, the City of Memphis, Tennessee, and Hancock County, Mississippi. Over 4,461,000 square feet of indoor space were mapped by these PSIAP Point Cloud City awardees, and the datasets are available on their respective websites. Links to software resources can be found in the Appendix.

ENHANCING 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.

PSCR prioritized listening to public safety through extensive collaboration

The PSCR program realized how crucial it was to get first responder buy-in early and often for the technology they would be using. PSCR took an active approach to involve companies whose goal was to make an impact on public safety and to engage the end users for input and approval. Therefore, PSCR and its partners continuously tried to involve first responders in the research and development process. This led to over 160 direct collaborations with public safety organizations, showing the program's dedication to delivering technology that meets the real needs of first responders.

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This was the most focused and deliberate effort to bring innovators and small businesses together with public safety for the direct purpose of developing new technologies.

- Dereck Orr, PSCR

Through years' worth of technology roadmaps, summit reports, working groups, and annual conferences, the program collaborated with first responders to identify the specific challenges they face while carrying out their daily duties. This participatory approach was extended further by involving public safety professionals as prize challenge judges and subject matter experts in formal documentation reviews, such as with prize challenge rules and evaluation criteria. Another key strategy employed by PSCR required most grant awardees to partner with public safety agencies to ensure the innovators comprehended the unique first responder requirements and constraints that may not be immediately evident. Early engagement in the development process not only facilitated better design and alignment with public safety needs but also fostered trust and credibility for emerging technologies.

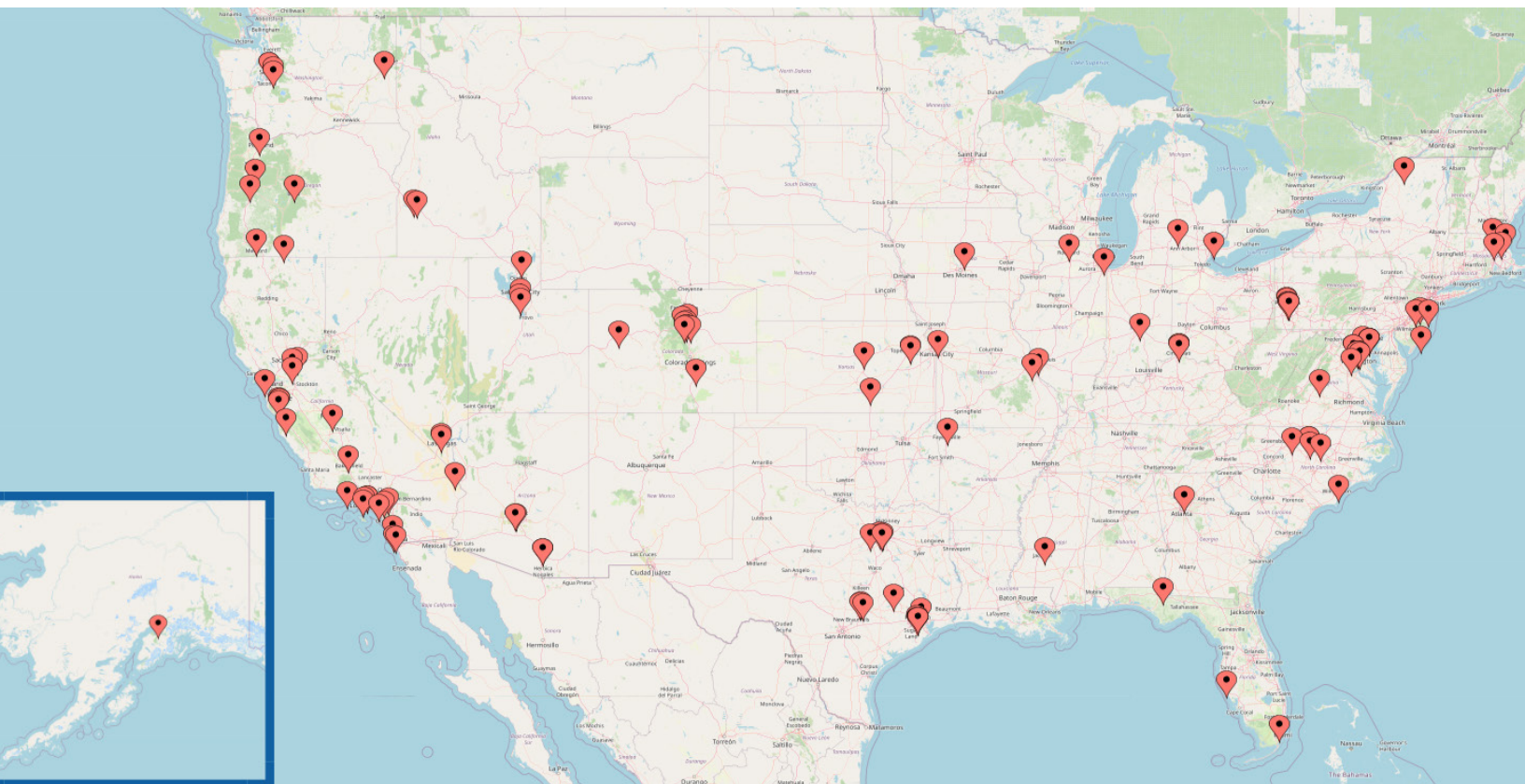


Figure 8 Map of engaged public safety partners throughout the U.S. See page 72 in the Appendix for the full list.



Working with first responders requires involvement through the entire lifecycle. In the beginning, you identify their problems and their needs. Once you understand user requirements, you perform a systematic user study before starting product development. Only once you really understand the problem can you begin designing the solution.

- Eric Jing Du, University of Florida

To support other researchers in this space, NIST researchers, through the PSCR UI/UX portfolio, conducted an exhaustive “Voices of First Responders” study involving interviews with 193 first responders and a nationwide survey of 7,182 first responders. The insights from this mixed-methods study, which combined qualitative and quantitative data, resulted in an extensive report documenting first responders’ experiences and needs concerning communications technology.

Finally, the PSCR program facilitated a participatory environment by hosting tours and meetings where feedback was actively sought. Interactions like these helped researchers realize the challenge of seeing technology displays in smoke-filled environments or trying to use small buttons while wearing protective gear. Through these diverse channels of collaboration, PSCR has effectively tailored its R&D problem statements to meet the real-world challenges faced by first responders and created a pathway for enhanced collaboration, facilitating the rapid implementation of innovative products in public safety.



It’s been great to see everyone get excited. It’s not just about the technology being good, people involved in PSCR projects focus on how it will get procured, what the legal ramifications are, and how to get something deployed in a department. At least half of these conversations are not technical. Bringing these holistic dynamics in gives technology the best chance at having an impact.

- David Van Ballegooijen, Chief Operating Officer, Western Fire Chiefs Association

PSCR’s program produced a range of training, demonstrations, and guidance documentation

The PSCR program is instrumental in enhancing public safety methods by increasing the access to and quality of technology training, demonstration, and guidance documentation. Each of these components are critical to facilitate the safe and informed adoption of innovative tools and bridge knowledge gaps that enhance the confidence of first responders in day-to-day operations.

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PSCR's efforts have started to build the trust with first responders that virtual reality is applicable to our use case. These efforts help us be early adopters of technology because we have a lot more faith in it, and we really trust in the technology early in the development phase.

– Chief Sterling Folden, Deputy Chief of Operations, Mountain View Fire Rescue

The PSCR UI/UX portfolio worked with collaborators in the PSIAP to research and develop simulation training for first responders in ways that could reduce costs and risks. Health Scholars, a PSIAP-User Interface (UI) awardee, employed voice-recognition and VR technologies to provide first responders with an immersive training experience for cardiopulmonary emergencies. Traditional training methods often pose logistical challenges and high costs, but this innovative VR approach mitigates these issues. First responders wearing VR headsets use voice commands to guide avatars through a cardiac arrest scenario, creating a realistic and engaging environment. This makes training more scalable and cost-effective and helps sharpen first responders' skills, particularly in rural areas where real-life experiences with certain emergencies might be infrequent. Through partnerships with public safety agencies such as Clear Creek EMS, Arvada Fire Protection District, and Thornton Police Department, Health Scholars has ensured the practical relevance and efficacy of its voice-driven VR training system.

NextGen Interactions, in collaboration with subject matter experts and firefighters, developed an innovative HazMat training tool utilizing VR to simulate environments mimicking real-world scenarios. This tool, known as HazVR, addresses the challenges faced by HazMat teams who cannot safely train with air monitors in the field due to the dangers involved. HazVR features virtual air monitors for testing various gasses, visualizations of simulated gasses, and performance tracking. By partnering with the Raleigh Fire Department and integrating feedback from over 100 first responders, NextGen Interactions refined HazVR, concentrating on learning objectives such as detecting readings, identifying gasses, and predicting gas behavior. The piloting of HazVR at the Raleigh Fire Department's training regimen was met with an overwhelmingly positive response, highlighting its effectiveness in enhancing the training experience and revealing unseen hazards. The 24/7 access to safe experiential training through HazVR holds great potential for better preparation, faster response to critical incidents, reduced injuries, and improved service in protecting both public safety members and the general population.

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Working with PSCR allowed us to focus on the most impactful use cases. Through this program, we got clear on not just what we can do, but what we should do.

- Jason Jerald, CEO, NextGen Interactions



As a researcher, it has been great having public safety partners on our project. Without their knowledge, experience, and feedback, we would not have the simulation we have developed today, which has been tailored specifically to police officers conducting traffic stops.

**- Jeronimo Grandi, Visiting Assistant Professor,
University of North Carolina Greensboro**

The University of North Carolina Greensboro developed a VR training and simulation tool to simulate various traffic stop scenarios, allowing end-users to customize different aspects of the simulation through a control panel. Users can modify the traffic stop's location, reason, vehicle, and driver history, as well as the driver's gender, race, and behavior. The system serves as both a training tool for traffic stops and a preview of what traffic stops could resemble with the widespread adoption of AR technology.

The PSCR program also funded work by the National Alliance for Public Safety GIS (NAPSG) and the LBS First Responders Working Group to address indoor LBS challenges. Through their collaborative efforts, they produced the Public Safety Location-Based Services Challenges Report, which identified critical issues in indoor mapping, tracking, and navigation. The report, informed by feedback from the public safety community, identified ongoing gaps and provided recommendations for future research. It also considered the need for interoperable data standards and the integration of new indoor technologies to enhance public safety operations. Additionally, the NAPSG Foundation developed the PSCR-funded i-Axis Best Practices Guide to Indoor Mapping, Tracking, and Navigation, which provides guidance for responders, academia, researchers, and manufacturers to work together to accelerate the adoption of these technologies. Collectively, these efforts by PSCR and its partners demonstrate a comprehensive approach to enriching public safety methods through technology-driven training, demonstrative collaborations, and insightful guidance documentation.



With PSCR's support, NAPSG Foundation was able to work with a diverse set of public safety stakeholders to identify best practices in indoor mapping, tracking, and navigation. This funding, additional support from PSCR staff, and opportunities to work with other PSCR-funded partners made it possible to conduct research and publish guides that will position public safety agencies to effectively adopt location-based services. With PSCR's support, these best practices will also influence the development of life-saving technologies and lead to interoperable, cost-effective, and operationally required solutions.

- Kevin Kay, Director, NAPSG Foundation

PSCR opened the door to operational capabilities once thought impossible

Through its innovative projects, the PSCR program is pushing the boundaries of modern communication technologies, showcasing proof of concepts for capabilities previously deemed public safety's greatest problem. For instance, the First Responder Smart Tracking (FRST) Challenge was created by the Indiana University Crisis Technologies Innovation Lab to address the problem of achieving accurate indoor localization and tracking of first responders down to one meter of accuracy. Through administering multiple phases, Indiana University fostered a community of experts to explore over 28 potential solutions to this problem. This can have significant implications for public safety if any solution meets the established challenge goal of demonstrating indoor localization and tracking of first responders within one-meter accuracy in a variety of buildings without any pre-deployed infrastructure.



Previously, students weren't aware this was a field. Not only are we getting the impact of the technologies involved, but we're benefiting from the network effect at a university level. We're creating a network that is hard to quantify, but we know it's spreading.

**- Sonny Kirkley, Director of User Experience,
Crisis Technologies Innovation Lab**

Additionally, PSCR supported streamlining the process of pre-incident planning by automating the creation of indoor maps through the Point Cloud City award. This initiative enabled the collection and annotation of detailed 3D data points and imagery from various building types to facilitate precise indoor mapping for emergency responses. Using lidar technology provided invaluable datasets to the research community for public safety applications. It demonstrated that paper maps may not always be necessary for first responders to have critical information about the environments they enter.



Rapid indoor mapping technologies will be a game-changer in public safety. They have the potential to fill the mapping gap and replace traditional maps with precise, digital 3D models, enhancing emergency response efficiency and situational awareness.

- Joe Grasso, PSCR

The PSCR program leveraged analytics to support emerging capabilities in public safety operations as well. The SAFE-NET project, developed by Southern Methodist University with funding from PSCR, is a specialized navigation platform for first responders. Utilizing machine learning (ML) and artificial intelligence (AI), SAFE-NET integrates data on traffic

patterns, weather conditions, and flooding risks to provide optimized routes for emergency vehicles. By considering the unique challenges and constraints of these vehicles, such as size and maneuverability, the platform enables faster and safer dispatch of personnel, which is critical in life-saving emergency responses. Additionally, SAFE-NET looks towards predicting where emergencies are likely to occur, facilitating proactive positioning of resources.



PSCR is very intentional about collecting input from stakeholders and using that input to identify, prioritize, and guide a wide range of innovative research and development efforts. This approach leads to communications advances that are well-aligned with stakeholders' needs, ultimately enabling more usable, efficient, and diverse communications systems that support the critical work of the public safety community.

- Stephen Voran, Electrical Engineer, Institute for Telecommunication Sciences

PSCR has also conducted extensive internal research on enhancing public safety methods by developing a low-cost computer system that integrates older public safety radios with modern wireless communication networks. This integration empowers first responders to leverage broadband technology for voice, text, instant messages, video, and data communication, thereby improving their operational efficiency and response capabilities. The prototype effectively combines analog LMR with LTE, retaining critical features such as MCPTT, high availability, and clear audio quality. The system's affordability and compatibility with existing technology offer public safety agencies a practical solution for upgrading their communication methods without incurring prohibitive costs. By bridging the technology gap, PSCR's initiative enables first responders to effectively harness the benefits of modern communication networks in their daily operations. These breakthroughs have generated excitement within the public safety community. First responders visiting PSCR labs see firsthand the transformative potential of these technologies, and how they can enhance their operational capabilities and safety. The collaborations and innovations pave the way for a safer and more effective future for first responders and the communities they serve.



This project provided a technology demonstration of how the flexibility of Software Defined Radios (SDRs) can be leveraged over the wide range of first responder communications technologies to provide interoperability on those systems. There are not many options commercially available to carry out this kind of interoperability. We hope that this proof of concept will serve to encourage other SDR-based commercial solutions to find their way to market.

- Jordan O'Dell, PSCR

SUPPORT THE ECONOMY AND COMMERCIALIZATION

In addition to how the PSCR program supported the five leading indicators above, PSCR also enabled significant economic growth and commercialization of public safety programs.

While not initially identified as a leading indicator, the program's impact on economic growth and commercialization of first responder technologies is undeniably significant. Through its PSIAP, Open Innovation, and commercialization efforts, PSCR has fueled the inception of new partnerships, businesses, and prototypes.

PSCR leveraged other industries to benefit the public safety user

With targeted involvement over the years, the PSCR program propelled innovation and industry focus towards public safety communications. PSCR's persistent efforts ensured that public safety needs and requirements were considered in the development of next-generation wireless technologies. If PSCR had not made efforts, including seeking funding from Congress to encourage the incorporation of these features, it is uncertain whether they would have been developed.

A critical aspect of PSCR's contribution has been its role as a connector between first responders and innovators. The Pulse Accelerator program, for example, provided participants access to first responders, facilitating user-centered design and development. The PSCR program also facilitated market intelligence through its prize challenges, providing seed funding that allowed businesses to receive technical business assistance and explore new public safety markets. Through initiatives like these, the program successfully leveraged advancements in other industries, such as military and space exploration, and found ways to augment them for public safety use.



Collaborating with PSCR has opened up a whole new world for us. Previously, we've primarily worked under NASA and DOD funding. PSCR offered a new set of problems, although still similar, like time-sensitive, life-critical, hazardous environments. We have been able to take our technology and adapt it to a new area.

- David Kortenkamp, Chief Technology Officer, TRAC Labs Inc.

Furthermore, the PSCR program provided platforms and funding for organizations to bring MCPTT and standards-based technology to first responders, a task the larger industry was not financially incentivized to undertake. Similarly, the program has influenced the global direction of public safety communications technologies, emphasizing the importance of international collaboration and adopting practices from countries further ahead in certain areas. Looking to the future, the emergence of enabling technologies like 5G and 6G will offer new opportunities for PSCR to continue leading and innovating in this critical area.



We did this work together and couldn't have done it without PSCR. Nemergent did not have access to an LMR system, but PSCR enabled us to leverage their Motorola Astro P25 system. PSCR provided a lot of support when we went through with the testing. MCS-LMR transcoding required a lot of back and forth and took a long time to achieve, but in the end we were able to complete our work thanks to partnership with PSCR.

- Pablo Rojas, Solution Architect, Nemergent Solutions

PSCR encouraged external investment

One major success of the PSCR program is the extent to which it laid the foundation for collaborators to pursue and receive additional external investment. The SBIR and STTR programs are key tools for boosting technological innovation, providing funding for small businesses to explore and commercialize their technological potential, and encouraging cooperation between businesses and research institutions. With funding from these programs, as well as others like the Small Business Investment Companies (SBIC) program, there is a much greater likelihood for companies to grow in size and continue developing their products. Other benefits of receiving SBIR and STTR funding include risk mitigation when developing products and services in nascent fields as well as companies having greater resources to acquire the talent needed to support their growing businesses.

While impacts are still in the making, in the first year since the conclusion of the Pulse Accelerator, more than \$12 million in follow-on funding was awarded to 11 program graduates through SBIR and STTR programs. To date, almost 40% of Pulse Accelerator participants have received some form of follow-on funding after the program's conclusion, in amounts ranging from \$150,000 to \$1.7 million. This demonstrates the market value of tools and prototypes developed out of the Public Safety Trust Fund and how they, while targeted at public safety audiences, can also have a broader appeal.

These results are a strong indicator that the Pulse Accelerator successfully provided tools for early ventures to take next steps in their business life cycles. As companies that found their beginning through PSCR continue to mature and evolve, they further validate the PSCR program's successful role as an enabler, fostering initial innovation and effectively fueling continued external investment, thus ensuring sustained development and progress in public safety communications.



If we can push the envelope that fits the public safety use case, it will most likely benefit a commercial use case as well.

- Dereck Orr, PSCR

PSCR increased the attractiveness of the public safety marketplace

Finally, the PSCR program has successfully galvanized a more diverse and inclusive innovation environment in the public safety marketplace. This has not only increased the sector's appeal to a broad spectrum of stakeholders but has also significantly influenced the development and adaptation of public safety communications technologies. Initially, the public safety marketplace was predominantly driven by existing industry and telecommunications players or former public safety officials. However, PSCR's proactive engagement has expanded this space, attracting a vibrant mix of start-ups, academics, and new innovators. This expansion has spurred a cycle of increased diversity of thought, varied skill sets, and novel problem-solving approaches, enhancing the effectiveness of R&D initiatives geared toward first responders.

The public safety landscape, marked by around 25,000 agencies in the U.S., faces significant budget constraints that make adopting new, often costly technologies challenging. The PSCR program, with support from the Middle Class Tax Act, has facilitated research to address the specific needs of these agencies. Their approach has been to diversify the contributors involved in R&D, inviting a multitude of disciplines to enrich the problem-solving process, and fully recognizing that success in this field demands a multidisciplinary approach.



When you come from the perspective of these topics that you can't expect one single actor to solve, you bring more people together.

- Sarah Hughes, PSCR

Prior to the PSCR program's efforts, the public safety sector lacked a central organization capable of fostering collaborations between different stakeholders such as academics, small companies, and first responders. Today, thanks to PSCR's outreach and advocacy, many university drone programs are now including a focus on public safety. Additionally, Indiana University's Crisis Technologies Innovation Lab (CTIL) focuses on accelerating research and practice on the use of next-generation technologies in the front lines of emergency and crisis response. PSCR's initiatives, from their earliest prize challenges to their latest grant opportunity, have connected thousands of external researchers and budding innovators to the public safety mission.

These efforts have not only had a positive influence on areas such as drone development but have also sown seeds of interest in younger demographics. This has led to the rise of a new generation of technically-inclined individuals passionate about contributing to their communities. PSCR's prize challenges have proven particularly effective in attracting new voices and ideas, leading to an array of innovative prototypes and, ultimately, creating jobs, capital funding, and economic impact. The PSCR program's major contribution lies in their understanding of the communications technology gaps experienced by first responders. By inviting innovators and businesses to adapt their products and services to meet these specific needs, PSCR has increased the attractiveness of the public safety marketplace while ensuring technological advancements align with the realities and requirements of public safety operations.



USER INTERFACE/
USER EXPERIENCE

User Interface/ User Experience

USER INTERFACE/USER EXPERIENCE

Definition of Success



Publish PSCR's UI/UX test environment with the VR and 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 AR/VR market essentially did not exist. However, today, due to their collaboration with PSCR, 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 PSITC 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 supports 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 partner public safety agencies across the country have adopted. External 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 UI/UX technology and evaluate the usability of the interface based on IoT traffic.

IMPACTS AT A GLANCE:

65

Cumulative
Publications

22

Cumulative
Software
Resources

10

Internal
Research
Projects

8

Prize
Challenges
Awarded \$2.4M
in Cash Prizes

24

Grants Awarded
for a Total of
\$26.37M



User Interface/User Experience Highlights

1. TESTBEDS

Six UI/UX testbeds were developed.

2. VR SCENARIOS

13 VR scenarios developed along with 35 unique AR prototypes across four incidents, and two perspectives.

3. FIRST RESPONDER FEEDBACK

Usability evaluations and feedback gathered from more than 730 first responders.

8. USER TESTING

In a user test with 14 firefighters, TABA awardee ARcortex received the following results about their PSCR-funded emergency response system:

- 85.7% agree system improves situational awareness
- 100% agree system improves visualization of interior spaces
- 100% agree system provides useful information
- 85.7% agree location tracking was useful
- 92.8 % agree building information displayed was useful
- 85.7% agree system provides new options for a MAYDAY call

7. PARTNERSHIPS

External awardees fostered formal partnerships with 49 public safety organizations.

6. INERTIAL MEASUREMENT UNIT & 1D-LIDAR-BASED CLASSIFIER

Awardee Carnegie Mellon University developed an inertial measurement unit and 1D-LiDAR-based classifier to predict seven different gesture and voice activities with an accuracy between 81.7% and 93.6%.

4. EMS PROTOCOL MODELING

Awardee University of Virginia developed EMS protocol modeling for action recognition based on a set of ten EMS protocols most commonly used during medical emergencies. They also developed methods for automated extraction of example reports from EMS datasets where these protocols were executed.

5. TRIAGE APP

Awardee Peak Response's Patient Triage Management Mobile App demonstrated a Technology Readiness Level Six with San Francisco Fire Department during a simulated mission critical incident training scenario.









MISSION CRITICAL VOICE

Mission Critical Voice

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 collaborated with NTIA ITS to support 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 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 (MCDData). 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:





Mission Critical Voice Highlights

1. PROTOTYPE

Six prototype measurement systems developed, including the PSCR QoE Measurement System, an NS-3 mmWave simulator developed by awardee New York University, and an LTE ProSe Simulator developed by awardee University of Southern California.

8. NIST LIST OF CERTIFIED DEVICES

Out of more than 2,400 subscribers to PSCR's email list, over **800** subscribe specifically to the NIST List of Certified Devices to learn about the devices that meet appropriate protocols and standards for access to, use of, or compatibility with the National Public Safety Broadband Network (NPSBN) that the FirstNet Authority and AT&T build and maintain.

7. LMR TO LTE

Enabled the **interworking** between LMR to LTE.

2. NEW COMPANY

One new company created, headed by awardees from New York University that sells mmWave front-ends for advanced software-defined radio platforms.

3. COMPLETED NS-3 TECH

Completed **NR ProSe discovery** and **Layer 3 implementation** for ns-3.

4. LTE SOFTWARE SUITE

Awardee Software Radio Systems Limited's LTE software suite was used by public safety organizations in Germany to uncover **security vulnerabilities at layer 2** of the LTE protocol stack, as well as uncover **51** security vulnerabilities across different target network components and device vendors in South Korea.

5. KPIS DEVELOPED

Four KPIs developed to support Public Safety MCV, including

- Mouth-to-Ear Latency
- Access Delay
- Probability of Successful Delivery
- Intelligibility

6. MCOP DEVELOPMENT

Awardee University of the Basque Country developed MCOP, an **open platform** that greatly reduces barriers for developers trying to innovate within the MCPTT ecosystem.





LOCATION-BASED SERVICES

Location-Based Services

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. External 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 specific to public safety. The PSCR-funded First Responder Smart Tracking Challenge has already awarded over \$1.3M of the \$5.6M prize purse to participants competing to develop precise indoor localization systems. Additionally, internal work at PSCR supported the development of International Organization for Standardization (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:

135

Cumulative
Publications

18

Cumulative
Software
Resources

14

Internal
Research
Projects

2

Prize
Challenges
Awarded \$200K
in Cash Prizes

18

Grants Awarded
for a Total of
\$23.79M



Location-Based Services Highlights

1. INDOOR SPACE

Over **4,461,000** square feet of indoor space were mapped alongside training procedures for creating 2D floor plans.

2. NAPSG BEST PRACTICES

1,000+ views/downloads of the NAPSG Best Practices Guide to Indoor Mapping, Tracking, and Navigation.

8. EMERGENCY RESPONSE TRAINING AND EDUCATION FOR STUDENTS

Indiana University's FRSTChallenge engaged the university student community, providing ongoing opportunities for emergency response training and education. The Indiana University-Purdue University Indianapolis School of Informatics and Computing's Human-Centered Computing Department is funding up to **14 positions** per semester to work **ten hours per week** with Crisis Technologies Innovation Lab staff on projects and develop skills in the field of crisis and emergency management.

3. MAPPED BUILDING DATASET

Datasets from **28** mapped buildings published by external awardees, including public schools, town halls, and other types of buildings.

4. LBS TRAININGS

Seven academic, industry or public safety trainings implemented on LBS capabilities, including lidar education and understanding for local government officials.

5. STUDENT TRAINING

More than 75 graduate-level students trained on LBS capabilities across all grants. LBS internal researchers provided lidar data for use in primary and secondary STEM classrooms.

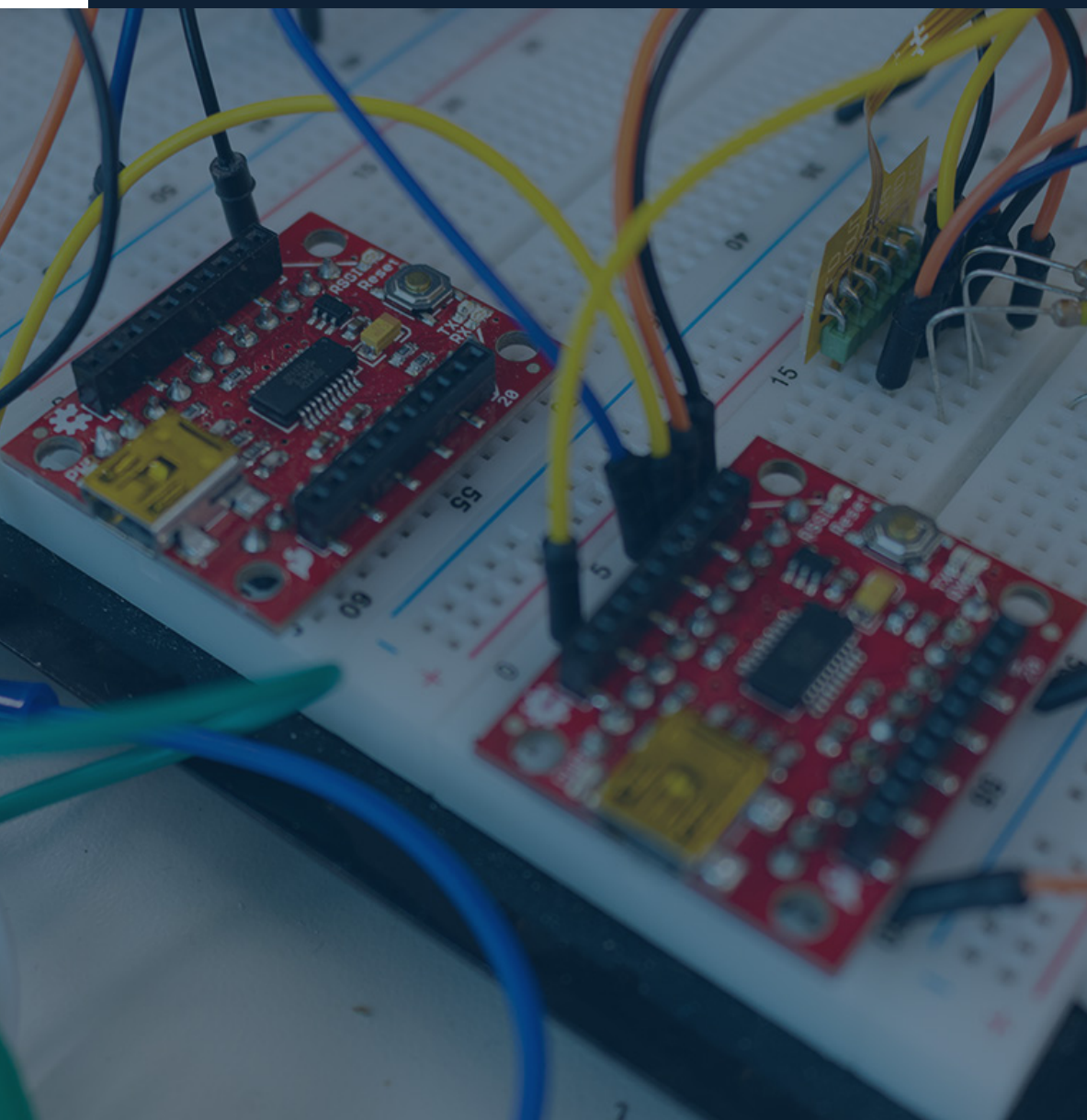
7. PERSONNEL TRACKER INNOVATION

Awardee TRX Systems' NEON Personnel Tracker **increased location accuracy** for first responders in GPS-denied environments with little or no infrastructure or pre-mapping required. The final field testing demonstrated the ability of NEON to track firefighters indoors and out with an average 2D accuracy error of **less than five meters** and an average 3D accuracy error of about **half a floor**.

6. INERTIAL NAVIGATION SYSTEM ACCURACY

Awardee UC Irvine's foot-mounted inertial navigation system known as the Sugar-Cube platform achieved a navigation accuracy of **1.2 meters** after navigating for **28 minutes** of testing. At a size of **0.3 cm × 2 cm × 5.5 cm**, the prototype is so small that it can be placed in the sole of a shoe.





ANALYTICS

Analytics

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 improve first responder workflow and ensure utility by closely collaborating with end users when considering public safety 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 internal and external 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.

External 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:

78

Cumulative
Publications

98

Cumulative
Software
Resources

8

Internal
Research
Projects

6

Prize
Challenges
awarded \$670K
in cash prizes

14

Grants Awarded
for a Total of
\$16.72M



Analytics Highlights

1. SOFTWARE RESOURCES

Analytics awardees developed **90+** software resources, including open-source software, proprietary software, datasets, environments, GUIs, SDKs, APIs, and others.

2. ANALYTICS STUDIES

Two analytics studies developed by PSCR researchers.

3. FIRE DATABASE AND NETWORK

Awardee Western Fire Chiefs Association developed the Fire Data Lab, a cross-department fire database and analysis-sharing network used by more than **34 organizations**. Workshops engaged over **100 first responders** to get their feedback on their data challenges, and the metrics they need most. More than **300 applications** from fire departments signified interest to be part of the Fire Data Lab.

8. PROTOTYPE FEEDBACK

One awardee received feedback from a working group facilitator: “The ability to determine behavioral information and individual characteristic tracking is **game-changing**. As a result of your work, executives at the conference better understood the power of open technology and the cultural application of open development approaches with agile development teams. You showed them technology models that functioned in a way that **actually got their attention**.”



4. ASAPS DATASET

PSCR published the Automated Streams Analytics for Public Safety (ASAPS) dataset, featuring eight 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.

6. ACCESSIBLE DATA

Prominent Edge’s StatEngine cloud environment processed **222,362** unique incidents in a single three-month period, enhancing data access for public safety decision-makers.

7. CARDIAC ARREST REPORTS

The University of Virginia created a dataset of **41,700** annotated de-identified cardiac arrest reports to build EMS protocol ontologies and annotate the data. These EMS ontologies related to use cases incorporating **2314** signs and symptoms, **86** medications, **110** procedures, **205** impressions, **123** complaints, and **38** call types. The team created a labeled dataset of **4484** de-identified pre-hospital care reports that pertained to **12** treatment protocols from the Old Dominion EMS Alliance.

5. LARGE-SCALE DATASET

Awardee University of Houston created a large-scale dataset, A Day on Campus (ADOC), with **25** event types, spanning over **721** instances and occurring over a period of 24 hours. This is the largest publicly available dataset with localized bounding box annotations that is available to perform anomaly detection.



SECURITY

Security

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 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, external 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 external 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 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 the FBI launched a Contactless Fingerprint Pilot Program in 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:

10

Cumulative
Publications

5

Cumulative
Software
Resources

18

Internal
Research
Projects

4

Prize
Challenges
Awarded \$700K
in Cash Prizes

2

Grants Awarded
for a Total of
\$1.94M



Security Highlights

1. MOBILE SINGLE SIGN-ON

Three identity vendors implemented Public Safety Mobile Single Sign-on (SSO) standards and best practices based on NIST SP 1800-13 from the PSCR Security Portfolio.

2. CONTACTLESS FINGERPRINTING

Contactless fingerprinting successful match rates improved from approximately 70% in 2019 to **over 90%** in 2022 through performance enhancements demonstrated through the mFIT prize challenge.

8. TESTBED RESOURCES

Georgia Tech Research Institute advanced the maturity level of their existing Trustmark Framework **testbed resources** into a robust implementer testbed for the public safety community.

7. TRUSTMARK FRAMEWORK

Georgia Tech Research Institute improved the public-facing **Trustmark Framework** web content, making it easier to navigate and consume for relevant stakeholders.

6. IDENTITY ASSURANCE PROFILES

Efforts from the PSCR-supported Georgia Tech Research Institute expanded the **NIEF** and developed Identity Assurance Profiles based on NIST SP 800-63-3 and ICAM Attribute Assurance Profiles.

5. CJIS SECURITY POLICY

FBI CJIS updated the CJIS Security Policy to synchronize with **NIST SP 800-53** and **SP 800-63** based on collaboration with NIST PSCR, the NIST NCCoE, and the NIST ITL.

3. SIM CHALLENGE OUTCOMES

Fortify Edge developed a continuous authenticator on a Google WearOS smartwatch using **Fast ID Online (FIDO) 2** and innovations achieved during the PSCR SIM Challenge. Their product initially provided frictionless and secure authentication but was later modified for continuous biometric on-device intelligence software for authentication and biobehavioral state.

4. FBI PILOT PROGRAM

The 2022 mFIT Challenge demonstrated dramatic improvements in quality digital fingerprint capture using common smartphones. Results are supporting the launch of an FBI-led pilot program which will further this research by testing emerging contactless fingerprint technology using the FBI Repository for Individuals of Special Concern (RISC) program.





RESILIENT SYSTEMS (INCLUDING DEPLOYABLES AND UNCREWED AIRCRAFT SYSTEMS)

Resilient Systems (Including Deployables and Uncrewed Aircraft Systems)

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 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 program supported 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 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 external 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:





Resilient Systems Highlights

1. INCREASE AWARENESS IN SECURITY VULNERABILITIES

The 2021 First Responder UAS Triple Challenge – Shields Up! Securing UAS Navigation & Control (UAS 3.3) increased awareness of **security vulnerabilities** in software and video transmission for both public safety end users and some manufacturers.

8. PROTOTYPE

Awardee Spectronn's SiFi-200 prototype holds up to **four SIM cards** for different providers that can load share for **increased bandwidth** and redundancy.

7. LEVERAGING BLOCKCHAIN

Awardee Cornell University developed an Android application that created an ad-hoc wireless network between mobile devices, leveraging **blockchain** to provide non-repudiation on messages and database updates.

2. 2021 UAS 3.1 ENHANCEMENTS

The 2021 UAS 3.1 enhanced UAS **image detection** and delivery of real-time data using **machine learning** for search and rescue operations.¹⁷

3. UAS 1.0 & 2.0 INNOVATIONS

Both the 2018 UAS 1.0 Challenge and the 2020 UAS 2.0 Challenge examined flight time versus payload and demonstrated an increase in UAS continuous flight time from **18 to 112 minutes** with a **10-lb payload** by using gas-electric or hydrogen fuel cell energy sources with both multirotor and fixed-wing frames.

4. UAS PIVOTAL IMPACTS

The UAS Prize Challenge series has had pivotal impacts, including **defining use cases** to promote the adoption of UAS programs in first responder agencies, **providing guidance** to help first responders navigate federal laws and regulations for UAS operation, and utilizing UAS technology to provide real-time and actionable data.

5. INCREASED BROADBAND DATA CONNECTIONS

The First Responder UAS Triple Challenge – LifeLink: UAS Data Relay (UAS 3.2) increased broadband data connections to first responders in a cellular-denied environment by developing a **mesh network** to transmit voice communications, images, and video at a distance of **800 feet**, improving directional antennas and using protocols such as Wi-Fi to offer continuous connectivity.

6. DATA SHARING TOOL

Resilient data sharing tool developed by awardee Michigan Technological University successfully transfers files up to **150MB** with no interruption at a **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.



17. The Public Safety Trust Fund only contributed to UAS 1.0 and 2.0. However, follow-on challenges like UAS 3.0, 4.0, and 5.0, funded by other sources, would not have been possible if not for the progress achieved by earlier efforts.



WHAT'S NEXT FOR PSCR

What's Next for PSCR

What's Next for PSCR

This report underscores the significant achievements and progress of the PSCR program. However, the task of improving public safety communications is far from complete and many questions still lie ahead. Following the conclusion of the Public Safety Trust Fund, PSCR refined its focus to better address the gaps that remained. PSCR transitioned the Resilient Systems portfolio to the UAS portfolio, focused on drone technologies, and also integrated elements of the Analytics portfolio into the remaining portfolio projects as applicable. The revised core portfolios, UI/UX, MCV, LBS, Security, and UAS, drove strategic road-mapping sessions during 5x5: The Public Safety Innovation Summit, held in June 2023, where portfolio leads discussed with stakeholders where the PSCR program should focus its attention next.

As a result of 5x5's road-mapping sessions, PSCR walked away with a short list of priority gaps that still require attention from solvers and innovators. Moving forward, the UI/UX portfolio is considering exploring human-machine teaming, integrating natural language processing as well as large language and multimodal models, focusing on the trust, accuracy, and reliability of these systems. The MCV portfolio aims to explore Mission Critical Device-to-Device (D2D), and Vehicle-to-Everything (V2X) communications for public safety, as well as continuing to research how LTE systems can offer quality and user experience on par with, if not superior to, LMR systems. For the LBS Portfolio, research continues to center around methods to achieve a one-meter level of indoor mapping accuracy as well as thinking through the best steps to collect location data in a way that is broadly usable by agencies. The Security portfolio will investigate the challenges and benefits of multi-factor authentication and single sign-on usage and continue to find ways to share lessons learned within the public safety community. For the UAS portfolio, areas of exploration include Beyond Visual Line of Sight (BVLOS), indoor capabilities, swarm technology, and leveraging AI on drones, while still seeking ways to ensure prototypes are budget-friendly for public safety agencies.

Perhaps the biggest step forward for the PSCR program is its formalized partnership with the FirstNet Authority. Both entities, driven by the goal to enhance first responder communications, share a unified vision for the future of public safety communications technology. This collaboration will guide their respective research and ensure alignment with standards bodies and industry advancements. While the Public Safety Trust Fund has concluded, PSCR will maintain its momentum through this enhanced collaboration with the FirstNet Authority, opening avenues for increased stakeholder engagements and commercialization opportunities. Finally, the impact of PSCR's work is just starting to ripple through the public safety community and marketplace. The full effect of PSCR's efforts will not be fully visible until years to come; until then, the program and their partners look forward to continuing to shape the abundant opportunities for innovation and advancement in this critical field.





APPENDIX

Appendix

Public Safety Collaborators

State	Organization Name
Alaska	Anchorage Fire Department
Arizona	Northwest Fire District
	Phoenix Police Department
	Tucson Fire Department
Arkansas	Rogers Fire Department
California	Los Angeles City Fire Department's Unmanned Aerial Systems
	Los Angeles Police Department
	Chula Vista Fire Department
	Clovis Fire Department
	Corona Fire Department
	Cosumnes Fire Department
	Culver City Fire Department
	El Segundo Fire Department
	Folsom Fire Department
	Kern County Fire Department
	North County Dispatch Joint Powers Authority
	Orange County Fire Authority
	Riverside Office of Emergency Management
	Sacramento Metro Fire Department
	Salinas Fire Department
	San Bernardino County Fire Department
	San Diego Fire-Rescue Department
	San Jose Fire Department
	San Rafael Fire Department
	Santa Clara City
	Santa Clara County Fire Department
	Southern Marin Fire Protection District
	Ventura County Fire Department
Colorado	Arvada Fire Department Protection District
	Aurora Police Department
	Colorado Center of Excellence for Advanced Technology

State	Organization Name
	Dacono Police Department
	Denver Department of Public Safety
	Denver Police Department
	Mountain View Fire Department Rescue
	Pueblo Fire Department
	Thornton Police Department
	West Metro Fire Department Rescue
District of Columbia	DC Homeland Security and Emergency Management Agency
Florida	Jackson County Fire Department
	Miami-Dade Police Department
Georgia	Southern Manatee Fire Department & Rescue
	Roswell-Alpharetta Public Safety Training Center
Idaho	Boise Fire Department
Illinois	National Interagency Fire Department Center
	Chicago Police
	Rockford Fire Department Department
Indiana	Indianapolis Fire Department
Iowa	Story County Sheriff's Office
Kansas	Kansas Bureau of Investigation
	Salina Police Department
	Sedgwick County Emergency Medical Services
Maryland	Topeka Fire Department
	Baltimore City Information Technology
	Baltimore City Police CitiWatch team
	Baltimore Mayor's Office of Criminal Justice
	Baltimore Police Department
	Civil Air Patrol
	Dale City Fire Department & Rescue
	Department of Justice
	Montgomery County Fire Department and Rescue Service
	Montgomery County Police
	National Law Enforcement Telecommunications System
	Washington Area Transit Authority
Massachusetts	Brookline Police Department
	Massachusetts Emergency Management Agency

State	Organization Name
	Massachusetts State Police USAR Task Force 1
Michigan	Detroit Police Department
	Michigan State Police
Mississippi	Mississippi Emergency Management Agency
Missouri	Southern Platte Fire Department Protection District
	St. Louis County Police
	Eureka Fire Department District
Nevada	Clark County Fire Department
	Las Vegas Police Department
New Hampshire	Nashua Office of Emergency Management
New Jersey	Atlantic City Police Department
	Monroe Township Fire Department District
	New Jersey Office of Homeland Security and Preparedness
	New Jersey State Police USAR Task Force 1
North Carolina	First Responder Emerging Technologies of the North Carolina Department of Information Technology
	Greensboro Police Department
	Hillsborough Police Department
	Hillsborough Police Department
	Pender County Emergency Medical Services and Fire Department
	University of North Carolina Police Department
Ohio	Cincinnati Police Department
	University of Cincinnati Law Enforcement
	University of Cincinnati Parking Services
Oregon	Deschutes County
	Eugene-Springfield Fire Department
	Jackson County Fire District No.3
	Klamath County Fire District No. 1
	Lebanon Fire Department
	Tualatin Valley Fire Department & Rescue
Pennsylvania	Allegheny County Fire Department Academy
	Bureau of Emergency Medical Services, City of Pittsburgh
	Canton Fire Department
	Carnegie Mellon University Police Department
	Carnegie Mellon University, Facilities Management Department
	Department of Public Safety-Bureau of Fire Department, City of Pittsburgh

State	Organization Name
Texas	Office of the Fire Department Marshal, Town of McCandless
	Pittsburgh Fire Department
	University of Pittsburgh Medical Center Emergency Medical Services
	Austin Fire Department
	City of Fort Worth
	City Of Irving
	Clear Creek Emergency Medical Services
	Dallas City Hall Emergency Management Division
	Dallas Fire Department Rescue Department
	Houston Fire Department
	Houston Information Technology Services
	Houston Mayor's Office of Public Safety and Homeland Security
	Houston Office of Emergency Management
	Houston Police Department
	Houston Public Works Emergency Management
	Porter Fire Department
	Texas A&M University Emergency Medical Services
	Texas Department of Public Safety
	Texas Military Department
Utah	Logan City Fire Department
	South Davis Metro Fire Department
	Unified Fire Department Authority
Virginia	Utah Deputy State Fire Department Marshall
	Arlington County Emergency Comm Center
	Arlington County Fire Department
Washington	North Garden Volunteer Fire Department Company
	194th Air Support Operations Group
	City of Seattle
	King County Emergency Management
	Puget Sound Regional Fire Department Authority
	Seattle Fire Department

SBIR Follow-on Funding Received by Pulse Accelerator Participants

Pulse Accelerator Companies	Funding Amount	SBIR Phase	Funding Entity	Project
Advanced Aircraft Company (AAC), LLC	\$49,999.00	Phase 1	Air Force	HAMR (Hybrid Advanced Multi-Rotor) UAS for Advanced Integrated Base Security
Advanced Aircraft Company (AAC), LLC	\$749,999.00	Phase 2	Air Force	HAMR (Hybrid Advanced Multi-Rotor) UAS for Resilient Integrated Base Security
Bio1 Systems Inc.	\$100,000.00	Phase 1	Army	Expeditionary Technology Search (xTechSearch) Dual-Use Technologies to solve challenging Army problems
Bio1 Systems Inc.	\$550,000.00	Phase 2	Defense Health Agency	Improved Human Machine Interface Usability for Clinical Healthcare Providers to Enter Data into Electronic Health Records
Diamond Age Technology	\$49,818.00	Phase 1	Air Force	Virtual Reality Training for Aircraft Shutdown Procedures with VALOR
Diamond Age Technology	\$749,543.00	Phase 2	Air Force	F-16 Digital-Twin & Simulation Platform for Planning, Training, & Testing in Virtual Reality
Diamond Age Technology	\$256,000.00	Phase 1	National Science Foundation	SBIR Phase I: Scan-to-Simulation: Digital Twin Infrastructure
Diamond Age Technology	\$156,464.00	Phase 1	NASA	Hyper-realistic Elastically Computed Topologies in Adaptive Reality Environments (HECTARE)
Spectronn (Misram LLC)	\$149,556.60	Phase 1	Department of Homeland Security	AI Platform to Enable 911 Multimedia Telecommunicator Function
Venti LLC	\$98,746.00	Phase 1	Department of Agriculture	Remote environmental sensor system for wildfire detection and response
Andro Computational Solutions, LLC	\$1,249,984.00	Phase 2	Air Force	Peer-based Information Distribution in Contested Environments
Andro Computational Solutions, LLC	\$140,000.00	Phase 1	Navy	Robust Autonomy for NeGation of Enemy Radar (RANGER)
Andro Computational Solutions, LLC	\$1,699,996.02	Phase 2	Army	Waveform Agile System Palette (WASP)
Andro Computational Solutions, LLC	\$749,998.00	Phase 2	Air Force	Adaptive and Dynamic Jammer nUlling System with multi-resolution Transform domains (ADJUST)
Andro Computational Solutions, LLC	\$149,999.56	Phase 1	Department of Homeland Security	Project Wi5G: Methodology for Secure Coexistence of 5G and Wi-Fi 6/6E for Federal Networks
Andro Computational Solutions, LLC	\$799,998.00	Phase 2	Navy	Deep reinforcement learning based unManned ARiel VEHicLes (D-MARVEL)
Innovative AI Technologies (iAI Tech)	\$149,994.27	Phase 1	Department of Transportation	Innovative AI Video Analysis of Dilemma Zone Conflicts at Signal-controlled Intersections using Edge Computing and 5G
Onclave Networks	\$974,306.10	Phase 2	Air Force	Onclave Quantum-Resistant Encrypted Communications

Pulse Accelerator Companies	Funding Amount	SBIR Phase	Funding Entity	Project
Onclave Networks	\$255,663.00	Phase 1	National Science Foundation	SBIR Phase I: Blockchain architecture for improved, cost-effective, secure transactions
Black Swift Technologies	\$149,969.00	Phase 1	NASA	All Weather UAS for Long Term Unattended Environmental Observations
Caliola Engineering	\$1,249,880.00	Phase 2	Air Force	EdgeSync: Evolving Syncthing for the Tactical Edge
Caliola Engineering	\$1,249,377.00	Phase 2	Air Force	OverKey Swarm: Low-Cost Secure Communications for Autonomous Collaboration
Caliola Engineering	\$246,481.00	Phase 1	Navy	Automated High Frequency Communications Planner
Tiami Networks LLC	\$98,681.00	Phase 2	Department of Commerce	Digital TV-based Positioning for First Responder Tracking in GPS-Denied Environments
Tiami Networks LLC	\$147,142.36	Phase 1	Department of Homeland Security	Interworking between Mission-Critical and Non-Network-Based Push-to-Talk Services

Company Name	Country	Status
Catalyst Communications Technologies, Inc.	United States - (U.S.)	Active - (A)
Catalyst Communications Technologies, Inc.	United States - (U.S.)	Active - (A)
Columbia University	United States - (U.S.)	Active - (A)
Georgia Tech Research Institute	United States - (U.S.)	Active - (A)
Hughes Network Systems, LLC	United States - (U.S.)	Active - (A)
Nvidia Corp	United States - (U.S.)	Active - (A)
Sonim Technologies	United Kingdom - (UNIK)	Active - (A)
Texas A&M Engineering Experiment Station (TEES)	United States - (U.S.)	Active - (A)
University of Colorado Boulder	United States - (U.S.)	Closed (C)
Aeroflex Incorporated	United States - (U.S.)	Closed (C)
Airbus DS Communications	United States - (U.S.)	Closed (C)
Alcatel-Lucent USA Inc.	United States - (U.S.)	Closed (C)
Anritsu Corporation	Japan - (JP)	Closed (C)
AT&T Services, Inc	United States - (U.S.)	Closed (C)
AT4 Wireless, Inc	United States - (U.S.)	Closed (C)
Aviat Networks, Inc.	United States - (U.S.)	Closed (C)
CalAmp Wireless Networks Corp	United States - (U.S.)	Closed (C)
Cisco System Inc.	United States - (U.S.)	Closed (C)
CoCo Communication Corporation	United States - (U.S.)	Closed (C)
CommScope Technologies, LLC (formerly Andrew Solutions, a CommScope Company)	United States - (U.S.)	Closed (C)
Dragonwave Corporation	United States - (U.S.)	Closed (C)
EDX Wireless, Inc.	United States - (U.S.)	Closed (C)
Elektrobit, Inc.	United States - (U.S.)	Closed (C)
Ercom Inc	United States - (U.S.)	Closed (C)
Ericsson Inc.	United States - (U.S.)	Closed (C)
Fujitsu Network Communications	United States - (U.S.)	Closed (C)
General Dynamics C4 Systems, Inc. (fka IP Wireless, Inc)	United States - (U.S.)	Closed (C)
Global Wireless Technologies	United States - (U.S.)	Closed (C)
Harris Corporation	United States - (U.S.)	Closed (C)
Hughes Network Systems, LLC	United States - (U.S.)	Closed (C)
iBwave Solutions Inc.	Canada - (CN)	Closed (C)
Invisitrack, Inc.	United States - (U.S.)	Closed (C)
JDS Uniphase Corporation	United States - (U.S.)	Closed (C)
Juniper Networks, Inc	United States - (U.S.)	Closed (C)
Kyocera Communications, Inc.	United States - (U.S.)	Closed (C)
Lemko Corporation	United States - (U.S.)	Closed (C)

Company Name	Country	Status
LG Electronics Mobile Research	United States - (U.S.)	Closed (C)
Motorola Solutions	United States - (U.S.)	Closed (C)
NEC Corporation of America	United States - (U.S.)	Closed (C)
Neustar, Inc.	United States - (U.S.)	Closed (C)
Newfield Wireless, Inc.	United States - (U.S.)	Closed (C)
Nokia Solutions and Networks U.S. LLC	United States - (U.S.)	Closed (C)
Northrop Grumman Systems Corporation	United States - (U.S.)	Closed (C)
Oceus Networks, Inc.	United States - (U.S.)	Closed (C)
Oracle	United States - (U.S.)	Closed (C)
Parallel Wireless	United States - (U.S.)	Closed (C)
Polaris Networks Inc.	United States - (U.S.)	Closed (C)
Raytheon JPS Communications Inc	United States - (U.S.)	Closed (C)
Rohde & Schwarz, Inc.	United States - (U.S.)	Closed (C)
Samsung Telecommunications America	United States - (U.S.)	Closed (C)
SIGOS LLC (formerly Keynote Systems)	United States - (U.S.)	Closed (C)
Solutelia, LLC	United States - (U.S.)	Closed (C)
Sonim Technologies	United States - (U.S.)	Closed (C)
Sprint Nextel Corporation	United States - (U.S.)	Closed (C)
Star Solutions International, Inc.	Canada - (CN)	Closed (C)
Tait Limited	New Zealand - (NZ)	Closed (C)
TeleCommunication Systems, Inc.	United States - (U.S.)	Closed (C)
Texas A&M University Internet2 Technology Evaluation Center (TAMU/ITEC)	United States - (U.S.)	Closed (C)
Traffix Systems, Inc. (a wholly owned subsidiary of F5 Networks, Inc.)	United States - (U.S.)	Closed (C)
ViaSat, Inc.	United States - (U.S.)	Closed (C)
Xceed Technologies	United States - (U.S.)	Closed (C)

Patents

Portfolio	Patent Application
Analytics	S. Shah and P. Mantini, "Methods and Systems for Customized Image and Video Analysis," US11532158B2. Dec. 20, 2022 Available: https://patents.google.com/patent/US11532158B2
LBS	M. Z. Win, H. ElSawy, W. Dai, and M.-S. Alouini, "Base station ordering for localization," US11019592B2, May 25, 2021 Available: https://patents.google.com/patent/US11019592B2
LBS	L.X. Chuo, H.S. Kim, D. T. Blaauw, D. Sylvester, M. Yang, "Low-power, long-range RF localization system and method," US10746844B2, August 18, 2020 Available: https://patents.google.com/patent/US10746844B2/en
LBS	Z. Kassas, and A. Abdallah, "Indoor localization with LTE carrier phase measurements and synthetic aperture antenna array," US11454726B2, September 27, 2022 Available: https://patents.google.com/patent/US11454726B2
Resilient Systems	V. Sagar, R. Chandramouli, and K. P. Subbalakshmi, "Systems and methods for wireless spectrum access in heterogeneous networks," US10548021B2, January 28, 2020 Available: https://patents.google.com/patent/US10548021B2
Resilient Systems	Z. Shen, R. Van Renesse, and H. Weatherspoon, "Method and system for improving software container performance and isolation," US20210109775A1, April 15, 2021 Available: https://patents.google.com/patent/US20210109775A1
Resilient Systems	L.-X. Chuo, H.-S. Kim, D. Blaauw, D. Sylvester, and M. Yang, "Low-power, long-range RF localization system and method," US10746844B2, Aug. 18, 2020 Available: https://patents.google.com/patent/US10746844B2

Open Innovation Winning Teams

Prize Challenge Name	Portfolio	Team Name	Prizes Won
Automated Streams Analysis for Public Safety (ASAPS) Output: concept paper on their proposed data analytics approach	Analytics	Madhukar Karmacharya	\$30,000.00
		Systems Engineering, INC	\$30,000.00
		The University of South Florida	\$30,000.00
		University of Central Florida	\$30,000.00
		University of Michigan	\$30,000.00
		Vidrov, INC	\$30,000.00
Automated Streams Analysis for Public Safety (ASAPS) Total			\$180,000.00
CHARIoT Challenge Outputs: augmented reality interfaces and IoT data transmitters	UI/UX	ARCortex	\$39,500.00
		Augmented 1st Responders (A1R)	\$9,500.00
		BadVR Inc	\$53,250.00
		CMU Helmet	\$27,000.00
		ENGR Dynamics	\$27,000.00
		FRITES	\$52,500.00
		Hydroinformatics Lab	\$12,500.00
		iMixedReality	\$12,500.00
		Inhance Digital	\$12,500.00
		JANUS Research Group	\$72,000.00
		LifeSavar - HCI IUPUI	\$27,000.00
		NextGen Interactions	\$47,250.00
		North Star Simulations (NSS)	\$57,000.00
		Reality Garage	\$32,000.00
		Research Triangle Institute (RTI International)	\$12,500.00
		SafeStream	\$9,000.00
		ScenARio	\$12,500.00
		Screen Door Laboratories	\$32,000.00
		SHOCKOE	\$27,000.00
		Smart IoT	\$40,500.00
		Team Onclave (Onclave Networks, Inc. and Mutualink, Inc.)	\$9,000.00
		U. Group XR Lab	\$12,500.00
		Venti	\$9,000.00
		Zenext IOT	\$9,000.00
CHARIoT Challenge			\$654,500.00

Prize Challenge Name	Portfolio	Team Name	Prizes Won
CommanDING Tech Challenge Output: incident command dashboard	UI/UX	3AM Innovations	\$5,000.00
		Apollo A.I.	\$5,000.00
		BadVR, Inc.	\$196,000.00
		Cloud Responder	\$47,500.00
		Emergency Ventures, Inc.	\$10,000.00
		Engineering Dynamics	\$154,625.00
		Headwall	\$202,625.00
		JANUS Research Group	\$10,000.00
		Red Volta, LLC	\$45,000.00
		Smart Firefighting	\$12,500.00
		Smart Response Technologies, Inc.	\$10,000.00
		Televerse Robot, LLC	\$35,000.00
		Three Firefighters, LLC	\$10,000.00
		Thrusight	\$2,500.00
		TurnRock Labs	\$200,250.00
		Valoarus	\$30,000.00
CommanDING Tech Challenge Total			\$976,000.00
Differential Privacy Synthetic Data Challenge (DeID 1.2) Output: algorithms	Analytics	PrivBayes	\$17,000.00
		Team DP-D	\$1,000.00
		Team DPSyn	\$38,000.00
		Team Epsilon-delta	\$1,000.00
		Team John Gardner	\$13,000.00
		Team pfr	\$27,000.00
		Team Ryan McKenna	\$40,000.00
		Team UCLANESL (UCLA & IBM Research	\$9,000.00
Differential Privacy Synthetic Data Challenge (DeID 1.2) Total			\$146,000.00

Prize Challenge Name	Portfolio	Team Name	Prizes Won
Differential Privacy Temporal Map Data Challenge (DEiD 2.0) Outputs: concept papers and algorithms	Analytics	3401 Walnut	\$1,000.00
		Bounding Utility Loss via Classifier	\$2,000.00
		Confusion Matrix	\$4,000.00
		DPSyn_S	\$38,000.00
		Duke DP Team	\$12,000.00
		Goose DP	\$9,000.00
		Jimking100	\$24,000.00
		MGD, Team DPSyn_S	\$5,000.00
		Minutemen	\$48,000.00
		N - CRiPT	\$44,000.00
		Practical DP Metrics, Team N-CRiPT	\$3,000.00
		SyrDP	\$5,000.00
Differential Privacy Temporal Map Data Challenge (DEiD 2.0) Total			\$195,000.00
Enhancing Computer Vision for Public Safety Challenge Output: image or video datasets that depict camera capture problems and no-reference metrics	UI/UX	CalAster	\$28,000.00
		Ozer	\$11,000.00
		Team iAI Tech-NJIT (Innovative AI Technologies and New Jersey Institute of Technology	\$28,000.00
		Team IUPUI	\$23,000.00
		Trueface	\$5,000.00
		University of Texas at Austin, Laboratory for Image & Video Engineering	\$23,000.00
Enhancing Computer Vision for Public Safety Challenge Total			\$118,000.00
Expanding the SIM Card Use for Public Safety (SIM Card) Outputs: concept papers, software code, mobile applications, and credentials on SIM	Security	B.EST Solutions	\$18,000.00
		ENGR Dynamics	\$3,000.00
		Fortifyedge, Inc.	\$10,500.00
		Fractal Technologies	\$1,000.00
		Rivetz	\$3,000.00
		SoloSIM	\$40,500.00
Expanding the SIM Card Use for Public Safety (SIM Card) Total			\$76,000.00

Prize Challenge Name	Portfolio	Team Name	Prizes Won
First Responder UAS Endurance Challenge (UAS 2.0) Output: drone	Resilient Systems	Advanced Aircraft Company	\$135,000.00
		Alfred Gessow Rotorcraft Center Team (AGRC)	\$15,000.00
		Autonomous Robotics Competition Club (ARCC of Pennsylvania State University)	\$55,000.00
		Endure Air	\$45,000.00
		Intelligent Energy	\$50,000.00
		MarutSpace	\$10,000.00
		Mobile Recon Systems	\$10,000.00
		Pharos	\$15,000.00
		RMD Systems	\$10,000.00
		SPIN	\$10,000.00
		SummitView	\$20,000.00
		Team GB40	\$20,000.00
		Team Maverick (Minnesota State University)	\$5,000.00
		Team Tempus	\$20,000.00
		Team UAV Master Lab (formerly Rapunzel)	\$15,000.00
		Therecraft	\$10,000.00
		UAS@UCLA	\$10,000.00
First Responder UAS Endurance Challenge (UAS 2.0) Total			\$455,000.00
First Responder Virtual Reality Heads-up Display Navigation Challenge (VR Heads-Up) Output: virtual reality heads-up display interface	UI/UX	Engineering Dynamics, LLC	\$25,000.00
		FactualVR, Inc	\$5,000.00
		Guardian Airwaves	\$7,500.00
		LookOnVRTU	\$25,000.00
		NextGen Interactions	\$15,000.00
		Screen Door Labs	\$10,000.00
First Responder Virtual Reality Heads-up Display Navigation Challenge (VR Heads-Up) Total			\$87,500.00

Prize Challenge Name	Portfolio	Team Name	Prizes Won
Haptic Interfaces for Public Safety Challenge (Haptics) Outputs: provided haptic hardware and interfaces	UI/UX	Brilliant Sole	\$7,500.00
		Contact Control Interfaces, LLC	\$20,000.00
		Engineering Acoustics, Inc.	\$43,500.00
		Engineering Dynamics, LLC	\$32,500.00
		IFTech Investing Future Technology, Inc.	\$7,500.00
		Janus Research Group, Inc.	\$45,000.00
		Team ASA-VR	\$7,500.00
		Team DSGN	\$22,500.00
		Team Haply	\$32,500.00
		Team Helmet from Carnegie Mellon University	\$43,500.00
		WEAR Lab	\$7,500.00
Haptic Interfaces for Public Safety Challenge (Haptics) Total			\$269,500.00
Tech to Protect Outputs: software concept and application prototypes	Multiple (all)	ALIKE Fire Safety Cloud Service	\$11,000.00
		Apollo A.I.	\$27,000.00
		AR Extrication Assist	\$105,000.00
		ATOMIC: Assisted Triage Online for MCI Incident Commander	\$6,000.00
		Authim	\$69,500.00
		Beam Reach	\$10,000.00
		Bio1 Systems’ PhysioCap: clinical data capture and transfer system for mass casualty incidents.	\$115,000.00
		Corroborator	\$89,500.00
		Critical Access	\$10,000.00
		CritSit Care	\$50,000.00
		Dream Team Maps	\$6,000.00
		Effective Media	\$3,500.00
		ESafe	\$18,500.00
		Fire Saftey in 3D	\$6,000.00
		FireHUD: Biometric IoT System for First Responders	\$15,000.00
		FirePrepKit	\$11,000.00
		First Responder Jarvis	\$1,000.00
		Front-Ranger	\$21,000.00
		Guardian	\$1,000.00
		Harris County Proactive Image Protection	\$58,000.00
		Heart in Hand	\$10,000.00
		HeartLink - Realtime Emergency Response Database	\$6,000.00

Prize Challenge Name	Portfolio	Team Name	Prizes Won	
		Home Pro-Tech	\$109,500.00	
		Insitue Observer	\$3,500.00	
		Map my LTE (LTE Coverage tool extension)	\$94,000.00	
		MCPTT Application	\$10,000.00	
		Mobile Device Security Dashboard	\$1,000.00	
		Modern Triage Management by QuantaSTAT	\$126,000.00	
		NAVI	\$6,000.00	
		Next-Gen MCPTT	\$131,000.00	
		Peak Response	\$130,000.00	
		Planning and fire safety with virtual environments	\$1,000.00	
		Safe Cam	\$8,500.00	
		Secure Matrix	\$8,500.00	
		SIMBA	\$10,000.00	
		Simba	\$6,000.00	
		t2p.Contest10	\$1,000.00	
		Team Talk	\$19,500.00	
		Trailblazer	\$11,000.00	
		Triage Track	\$3,500.00	
		TTPTriage	\$3,500.00	
		Virtual Patient Tagging using Face Detection in Mass Casualty	\$8,500.00	
		Voice Assistant	\$2,500.00	
		vTriage	\$97,500.00	
		Who Knows LTE Signal Strength	\$3,500.00	
		Who's Who - an RFID & AR approach to Organize Chaos	\$6,000.00	
		Zenext	\$136,000.00	
Tech to Protect Total			\$1,587,500.00	
The Future of Public Safety Technology 100k Video Series	Multiple (all)	"No Name"	\$500.00	
		Hitmakers Media	\$500.00	
		Output: marketing video	Levinson Brothers LLC	\$500.00
		STEMedia Incorporated	\$500.00	
		The Norman Invasion	\$98,000.00	
The Future of Public Safety Technology 100k Video Series Total			\$100,000.00	

Prize Challenge Name	Portfolio	Team Name	Prizes Won
The Mobile Fingerprinting Innovation Technology Challenge (mFIT) Outputs: prototypes and mobile device apps	Security	BlueBible	\$12,500.00
		ENGR Dynamics	\$12,500.00
		IDEMIA	\$115,750.00
		Identy	\$32,500.00
		T3K & TeelTech	\$24,000.00
		Tech 5	\$4,000.00
		Telos	\$115,750.00
		The Slapshot SDK Team	\$32,500.00
The Mobile Fingerprinting Innovation Technology Challenge (mFIT) Total			\$349,500.00
The Unlinkable Data Challenge (DeID 1.1) Output: concept paper	Analytics	Team DPGans from Georgia Tech University	\$20,000.00
		Team DPSyn from Purdue University	\$15,000.00
		TeamWestTeam from WestTat	\$5,000.00
The Unlinkable Data Challenge (DeID 1.1) Output: concept paper Total			\$40,000.00
Unmanned Aerial Systems Flight and Payload Challenge (UAS 1.0) Output: drone	Resilient Systems	ACRG - Applied Cybernetics Research Group	\$20,000.00
		AmeriSky	\$20,000.00
		ARS - Aerial Robotic Systems LLC	\$20,000.00
		DV8 Tech LLC	\$70,000.00
		Endure Air Inc	\$20,000.00
		escAerospace Inc	\$20,000.00
		IRISS - Integrated Remote & In Situ Sensing Program, CU Boulder	\$20,000.00
		MaxPran LLC	\$20,000.00
		PFA_William Gleason	\$20,000.00
		SOAPdrones	\$20,000.00
Unmanned Aerial Systems Flight and Payload Challenge (UAS 1.0) Total			\$250,000.00
Virtual Public Safety Test Environment Challenge Output: concept paper	UI/UX	Cosumnes Community Services District	\$5,000.00
		Design Interactive, Inc	\$12,000.00
		NextGen Interactions, LLC	\$20,000.00
		UNSN	\$8,000.00
		Variable Labs	\$5,000.00
Virtual Public Safety Test Environment Challenge Total			\$50,000.00

PSIAP AWARD RECIPIENTS

PSIAP Award Recipients

Grant Program Name	Portfolio	Participant Name	Project Title	Federal Budgeted
Measurement Science and Engineering (MSE 2017)	Analytics	Carnegie Mellon University	Educating and Training the Public Safety Community in Advanced Video Analytics Capabilities and Tools	\$50,000.00
	MCV	CENTRE TECNOLÓGIC DE TELECOMUNICACIONS DE CATALUNYA	Modeling, Simulation and Performance Evaluation of NR V2X	\$215,776.00
	MCV	University of Washington	Cross-Layer (PHY/MAC) Modeling & Performance Evaluation of 5G Public Safety based on NR C-V2X Sidelink	\$500,000.00
	Security	Georgia Tech Applied Research Corporation	Advancing Trusted Information Sharing, Safeguarding, and Federated ICAM in the Public Safety Community Through the Maturation of the Trusted Framework	\$1,499,995.67
	UI/UX	Culture Catalyst LLC	Developing an Understanding of Users and User Needs in Public Safety Communications	\$378,687.64
NIST MSE Rolling Grant Total				\$2,644,459.31
Public Safety Innovation Accelerator Program (PSIAP-2017)	Analytics	Carnegie Mellon University	Real-Time Video Analytics for Situation Awareness	\$1,800,000.00
	Analytics	New Jersey Office of Homeland Security and Preparedness	Fiscal Year 2017 Public Safety Innovation Acceleration Program	\$1,662,873.74
	Analytics	Prominent Edge LLC	StatEngine: A real-time open source data analytics and visualization platform for Public Safety	\$500,205.82
	Analytics	Regents of the University of Michigan	BOCA BODY-WORN CAMERA ANALYTICS IN PUBLIC SAFETY	\$688,120.16
	Analytics	Southern Methodist University	SAFE-NET: An Integrated Connected Vehicle and Computing Platform for Public Safety Applications	\$1,242,846.07
	Analytics	The Rector & Visitors of the University of Virginia	Towards Cognitive Assistant Systems for Emergency Response	\$1,104,466.11
	Analytics	University of Cincinnati	Information-Driven Video Communication for Public Safety Networks	\$500,357.81
	Analytics	University of Houston	Multi-tiered Video Analytics for Abnormality Detection and Alerting to Improve Response Time for First Responder Communications and Operations	\$1,773,534.24
	Analytics	Voxel51 LLC	ETA: Extensible Tools for Analytics in Public Safety	\$1,241,189.42
	Analytics	Western Fire Chiefs Association, INC.	CREATION OF A UNIFIED ANALYSIS FRAMEWORK AND THE DATA COMPARISON CENTER	\$1,705,192.81
	LBS	Carnegie Mellon University	Hyper-Reality Helmet for Mapping and Visualizing Public Safety Data	\$642,026.60
	LBS	Carnegie Mellon University	An Infrastructure-Free Localization System for Firefighters	\$782,162.74
	LBS	Chancellor, Masters and Scholars of the University of Oxford	Pervasive, Accurate and Reliable Location Based Services for Emergency Responders	\$1,182,903.71

Grant Program Name	Portfolio	Participant Name	Project Title	Federal Budgeted
	LBS	Massachusetts Institute of Technology	Situational Awareness For Emergencies Through Network-Enabled Technologies (SafeT-Net)	\$798,389.78
	LBS	Regents of the University of Michigan	Decimeter Accurate, Long Range Non-Line-of-Sight RF Localization Solution for Public Safety Applications	\$936,474.55
	LBS	The Regents of the University of California, Irvine	Ultimate Navigation Chip (uNavChip): Chip-Scale Personal Navigation System Integrating Deterministic Localization and Probabilistic Signals of Opportunity	\$1,960,612.96
	LBS	TRX Systems, Inc.	TRX First Responder Location and Mapping Service	\$1,414,605.00
	LBS	University of Cincinnati	First Responder Indoor Location Using LTE Direct Mode Operations	\$398,866.26
	MCV	Harris Corporation	ProSe	\$180,010.63
	MCV	New York University	End-to-End Research Platform for Public Safety Millimeter Wave Communications	\$2,259,990.06
	MCV	Perspecta Labs Inc. (Vencore Labs)	Device-to-Device System for Public Safety (DDPS)	\$1,879,593.01
	MCV	Software Radio Systems Limited	OpenFirst - the open-source LTE software-radio platform for first responders	\$1,453,100.00
	MCV	Sonim Technologies, Inc.	End-to-End Mission Critical Push-to-Talk with Direct Mode Operation	\$1,151,147.00
	MCV	The George Washington University	Coverage, Capacity, and Resilience Enhancement in Limited PSN	\$699,998.11
	MCV	Universidad del Pais Vasco/Euskal Herriko Unibertsitatea	MCOP: Mission Critical Open Platform	\$1,259,142.88
	MCV	University of Southern California	Propagation channel models and system performance for device-to-device communications for public safety applications	\$449,100.98
	MCV	University of Washington	Modeling, Simulation and Performance Evaluation for Future Public Safety Networks	\$996,132.25
	Resilient Systems	Cornell University	Towards an Emergency Edge Supercloud	\$1,241,785.84
	Resilient Systems	Michigan Technological University	Resilient System Solutions for Data Sharing for Wildland Fire Incident Operations	\$1,004,675.42
	Resilient Systems	Misram LLC dba Spectronn	Heterogeneous Fog Communications and Computing for Resilience	\$649,984.00
	Resilient Systems	Texas A&M Engineering Experiment Station	DistressNet-NG: Resilient Mobile Broadband Communication and Edge Computing for FirstNet	\$1,799,920.73
	Resilient Systems	The Regents of the University of California	Modeling and Development of Resilient Communication for First Responders in Disaster Management	\$1,223,527.00
	Resilient Systems	The Regents of the University of Colorado	SDR LTE Network Testbed and RESPON	\$1,502,795.69
PSIAP 2017 Total				\$38,085,731.38

Grant Program Name	Portfolio	Participant Name	Project Title	Federal Budgeted
PSIAP Artificial Intelligence for IoT Information Prize Competition (PSIAP-AI3)	Analytics	Texas A&M University	Smart Communities, Smart Responders: An Ai for IoT Prize Competition	\$1,199,206.00
PSIAP-AI3Total				\$1,199,206.00
Public Safety Innovation Accelerator Program - Augmented Reality (PSIAP-AR)	UI/UX	BadVR, Inc.	Augmented Reality Interface for Public Safety	\$1,082,130.00
	UI/UX	Carnegie Mellon University	Extreme Reality (EXR) Telemetry Interface for Real-Time Operation and Training in Public Safety	\$1,272,523.00
	UI/UX	Cyber Bytes Foundation	Natural Authentication for Emergency Management Augmented Reality Systems	\$992,767.09
	UI/UX	Pison Technology Inc.	ARCHANGEL: Augmented Reality Control with a Handsfree Activated Neural Gesture Engagement Library	\$1,200,000.00
	UI/UX	Research Triangle Institute	NIST Public Safety Innovation Acceleratory Program - First Responder Augmented Reality (FRAR) Test Bed	\$748,730.00
	UI/UX	The Board of Regents of the University of Wisconsin System	EasyVizAR: Edge-supported, Assistive Augmented Reality for Indoor First Responder Scenarios	\$1,798,769.00
	UI/UX	The Rector and Visitors of the University of Virginia	Context Aware Augmented Reality for Cognitive Assistance in Emergency Medical Services	\$1,139,275.00
	UI/UX	University of Florida	Adaptive AR System for Emergency Search and Rescue based on Formative User Experience Process and Cognitive Load Analysis	\$1,395,470.00
PSIAP AR Total				\$9,629,664.09
Public Safety Innovation Accelerator Program - First Responder 3D Indoor Tracking Prize (PSIAP-FR3D)	LBS	Trustees of Indiana University	The Indiana First Responder 3D Indoor Tracking Challenge	\$8,000,000.00
PSIAP-FR3DTotal				\$8,000,000.00
Public Safety Innovation Accelerator Program - iAxis (PSIAP-iAxis)	LBS	National Alliance for Public Safety GIS Foundation	Accelerating Adoption and Use of Emerging LBS by Public Safety	\$598,454.95
PSIAP-iAxis Total				\$598,454.95
Public Safety Innovation Accelerator Program - Mission Critical Voice Quality of Experience (PSIAP-MCV QoE)	MCV	Georgia Tech Applied Research Corporation	ARTEMIS QUARC - QUALITY UNDER ADJUSTABLE REALISTIC CONDITIONS	\$2,925,000.00
	MCV	The Trustees of Columbia University in the City of New York	Experimentally-driven mapping of QoS-to-QoE for Mission-Critical Voice	\$2,646,587.00
PSIAP MCV QoE Total				\$5,571,587.00

Grant Program Name	Portfolio	Participant Name	Project Title	Federal Budgeted
Public Safety Innovation Accelerator Program - Mission Critical Voice Test Equipment (PSIAP-MCV TE)	MCV	Polaris Networks	Mission Critical Test Equipment Delivery, to Test UE Communication Devices, with respect to MCPTT, MCVideo, MCData protocols (3GPP Rel 13 and 14 standards)	\$2,123,680.00
	MCV	Universidad del Pais Vasco/Euskal Herriko Unibertsitatea	MCS TaaSTING	\$3,606,532.86
	MCV	Valid8.com, Inc.	Valid8 Mission Critical Client Conformance Tester	\$774,049.00
PSIAP MCV TE Total				\$6,504,261.86
Public Safety Innovation Accelerator Program – Point Cloud City (PSIAP-PC2)	LBS	City of Memphis	Map901: Building Rich Interior Hazard Maps for First Responders	\$450,953.00
	LBS	Enfield Fire District No 1	Investigation & Development of Point Cloud datasets using 3D LiDAR & Imaging Technology to Accelerate Geo-Locating Technology & Information Critical to First Responder & Public Safety	\$178,121.04
	LBS	Hancock County, Mississippi	Indoor Mapping of 32 buildings (1,873,381 sq ft) in Hancock County Mississippi including LiDAR; 360-degree, high-resolution color photos, derivative colorized LiDAR, and tagged attributes.	\$180,000.00
PSIAP PC2 Total				\$809,074.04
Public Safety Innovation Accelerator Program - Public Safety Radio Data (PSIAP-PSRD)	MCV	Texas A&M University	Creating a Shared Public Safety Radio Data Set for Sharing and Analysis	\$904,806.00
PSIAP-PSRD Total				\$904,806.00
Public Safety Innovation Accelerator Program - User Interface (PSIAP-UI)	UI/UX	Georgia Tech Applied Research Corporation	ARTEMIS: Augmented Reality Testing of Equipment in Multiple Immersive Simulations	\$1,270,000.00
	UI/UX	NC State University	Investigating Emergency Response Performance with VR-Based Intelligent User Interfaces	\$1,104,082.86
	UI/UX	NextGen Interactions LLC	FirstSimVR: Evaluating Future Tools Using Today's VR	\$1,199,873.00
	UI/UX	"The Optera Group		
	Health Scholars, Inc."	NIST Public Safety Innovation Accelerator Program- User Interface	\$611,000.85	
	UI/UX	TRAC Labs Inc.	Virtual and Augmented Laboratory for Objective Realities (VALOR)	\$1,167,478.87
	UI/UX	"University of Florida		
	University of Florida Board of Trustees"	Cognition-driven Display for Navigation Activities (Cog-DNA): Personalized Spatial Information System Based on Information Personality of Firefighters	\$459,407.26	
PSIAP UI Total				\$599,610.28
PSIAP UI Total				\$6,411,453.12

Grant Program Name	Portfolio	Participant Name	Project Title	Federal Budgeted
Public Safety Innovation Accelerator Program 2022 (PSIAP-2022)	LBS	George Mason University	5G-enabled Indoor Positioning System for Firefighters using UAVs (5G-IPS)	\$1,199,950.00
	LBS	The Regents of the University of California, Irvine	Navigation Environment merging Virtuality, Ecotone, and Reality enabled by microtechnology for Localization Of Subjects and Things (NEVERLOST)	\$1,398,273.00
	LBS	Western Fire Chief Association Inc.	Rapid, Scalable Outdoor and Indoor Machine Learning Based Mapping of Fire Department Pre-Plans	\$1,031,417.00
	MCV	NEMERGENT SOLUTIONS SL	BroadImPort: Importing European BroadPort MCX concepts to U.S. market needs	\$989,027.00
	UI/UX	JANUS Research Group LLC	Augmented Reality WUI Mitigation Framework and Applicati	\$1,198,168.45
	UI/UX	Texas A&M University	A Digital-Twin Enabled Testbed for Public Safety Communication Technologies	\$1,200,000.00
	UI/UX	The University of North Carolina at Greensboro	FirstModuLAR: Designing and Integrating Augmented Reality User Interface Modules for First Responders	\$1,799,040.00
	UI/UX	TRAC Labs, Inc	First Responder Intelligent Agent (FRIA)	\$1,199,557.89
PSIAP-2022 Total				\$10,015,433.34
PSIAP Follow-on Funding for Technical and Business Assistance (TAB A)	Analytics	University of Houston	Customizable Video Analytics & Houston Public Safety Video - A Demonstration Project	\$199,944.00
	LBS	TRX Systems	TRX Systems' Extended Field Deployment of 3D Indoor Localization Technology with Arlington County, VA Fire Department for Performance Validation and Enhancements	\$200,000.00
	LBS	University of California Irvine	Demonstration Project: Ultimate Personal Indoor Navigator (uPIN) for Emergency Responders	\$200,000.00
	MCV	Squishy Robotics Inc.	Demonstration Project: Sensing and Communications for Improved First Responder Situational Awareness	\$199,989.00
	Resilient Systems	Michigan Technological University	Resilient data sharing: A demonstration of the WildfireDLN data ferry system	\$199,997.00
	Security	RIIS LLC	Public Safety Demonstration for BFDI-AP Cybersecurity device	\$199,541.00
	UI/UX	ARCortex Inc.	Demonstration assistance for ERIS team of the NIST CharIoT challenge 2020	\$199,900.00
	UI/UX	NextGen Interactions LLC	HazVR: Hazardous Material Training with Virtual Reality	\$199,903.22
	UI/UX	Peak Response Inc.	Peak Response Demonstration Project with Partnering Public Safety Agency	\$199,767.00
	UI/UX	University of North Carolina at Greensboro	Validation and Demonstration of Customizable Virtual Reality-Based Traffic Stop Simulation for Training and Practice with the Hillsborough Police Department	\$198,561.00
TAB A				\$1,997,602.22

SELECT PROTOTYPES

Select Prototypes

Portfolio	Organization	Impact
Analytics	Apollo A.I.	First Responder AI Software
Analytics	QuantaSTAT	Modern Triage Management
Analytics	Zenext	Transforming Public Safety through AI-enabled Hands-free Technology
LBS	The Regents of the University of California, Irvine	uNavChip localization system
LBS	TRX Systems	NEON system with GPS-Beacon
LBS	University of Cincinnati	LTE ProSe mode for location purpose
MCV	Home Pro-Tech	Developed ML-generated pre-incident plans, floor plans, and safety checklists for homeowners through image recognition and semantic classification
MCV	Map my LTE	LTE Coverage tool extension
MCV	New York University	Pi-Radio: mmWave front-ends for advanced software-defined radio platforms
MCV	Next-Gen MCPTT	Prototype that enables store, pause, and replay of messages, text message, speech-to-text, and text-to-speech
MCV	Team Talk	PTT mobile application where users can seamlessly change channels and administrators can easily add new users
MCV	Trailblazer	Resource mapping application with mission critical PTT for first responders
MCV	University of Southern California	Channel Sounder Measurement setup
Resilient Systems	Cornell University	Vegvisir: partition-tolerant blockchain suitable for the IoT space
Resilient Systems	Michigan Technological University	WDLN Data Ferry prototype software and documentation
Resilient Systems	Texas A&M Engineering Experiment Station	DistressNet-NG
Security	BlueBible	BluePrint mobile app for fingerprint capture
Security	ENGR Dynamics	Mobile app for fingerprint capture that incorporates the laser time-of-flight sensor to measure the distance to the finger
Security	IDEMIA	Mobile biometric check application
Security	Identy	Contactless fingerprint capture software development kit
Security	T3K & TeelTech	Biocapture software development kit
Security	Tech 5	T5-AirSnap Finger
Security	Telos	Telos Shield: an innovative law enforcement-focused mobile device application
Security	The Slapshot SDK Team	Slapshot SDK mobile app
UAS	Team DV8 Tech	On Demand Support UAS: designed for both heavy lift and long endurance missions
UAS	MaxPran	Long Endurance C2 X8 UAS: designed to be used by First Responders for reliable Command and Control
UAS	Team EndureAir	Helicopter UAS with rotors in a tandem configuration, powered by a single gasoline engine
UAS	Advanced Aircraft Company (AAC)	The Hybrid Advanced Multi-Rotor (HAMR) Solution is a hybrid electric multi-rotor UAS with a 3.5 hour maximum endurance

Portfolio	Organization	Impact
UAS	Intelligent Energy	The Fuel Cell Gryphon UAS is a hexacopter designed by Intelligent Energy and optimized for use with the IE-Soar 2.4kW Fuel Cell Power Module
UAS	Autonomous Robotics Competition Club at Penn State	Hybrid heavy lift quadcopter
UI/UX	ARCortex	Emergency Response Information System
UI/UX	AREA	AR Extrication Assistant
UI/UX	BadVR, Inc.	Immersive data visualization components to lower cognitive load and increase situational awareness during collaborative emergency response
UI/UX	Bio1 Systems	PhysioCap: clinical data capture and transfer system for mass casualty incidents
UI/UX	Carnegie Mellon University	Extreme Reality Telemetry Adaptive HUD prototype
UI/UX	Carnegie Mellon University	Hyper-Reality Helmet
UI/UX	Engineering Dynamics	Mobile Automatic Path Wayfinding Incident Command Helper (MAPWICH)
UI/UX	FireHUD	Biometric IoT System for First Responders
UI/UX	Headwall	Virtual command center dashboard that allows personnel involved in emergency response to glean actionable information from a location and situation
UI/UX	JANUS Research Group	AR Wildland Urban Interface (WUI) Mitigation Framework and Application
UI/UX	NC State University	Prototype intelligent UI Heads Up Display
UI/UX	Peak Response	Patient Triage Management Mobile App
UI/UX	TRAC Labs Inc.	Virtual and Augmented Laboratory for Objective Realities (VALOR) Mixed Reality training
UI/UX	TurnRock Labs	SpaceJam™ Commander
UI/UX	University of Florida Board of Trustees	Cognition-driven Display for Navigation Activities (Cog-DNA): Personalized UI system to control the real-time cognitive load of firefighters in emergency wayfinding
UI/UX	vTriage	Triage patient tracking software

Select Software Resources

Analytics	
Carnegie Mellon University	AVI-R Package, https://pypi.org/project/avi-r/
	Peeking into the Future: Predicting Future Person Activities and Locations in Videos, https://github.com/google/next-prediction
	The Garden of Forking Paths: Towards Multi-Future Trajectory Prediction, https://github.com/JunweiLiang/Multiverse
	MSNet: A Multilevel Instance Segmentation Network for Natural Disaster Damage Assessment in Aerial Videos, https://github.com/zgzy001/MSNET
	Object Detection & Tracking for Surveillance Video Activity Detection, https://github.com/JunweiLiang/Object_Detection_Tracking
	Pyturbo Package, https://pypi.org/project/py-turbo/
	Social Distancing Early Forecasting System, https://github.com/JunweiLiang/social-distancing-prediction
	VERA - The Shooter Localization System, https://github.com/JunweiLiang/VERA_Shooter_Localization
New Jersey Office of Homeland Security and Preparedness	Elaborative Rehearsal for Zero-shot Action Recognition, https://github.com/DeLightCMU/ElaborativeRehearsal
	Low Altitude Disaster Imagery (LADI) Dataset, https://github.com/ladi-dataset
	PSIAP FirstNet Video Streaming Test Architecture, https://github.com/mit-ll/PSIAP-FirstNet-Streaming-Video-Testing-Platform
	PSIAP Civil Air Patrol Annotation, https://github.com/mit-ll/PSIAP-CAP-Annotation
	PSIAP DL YouTube Creative Commons, https://github.com/mit-ll/PSIAP-DL-YouTube-CC
	PSIAP Video Classifier Deployment, https://github.com/mit-ll/PSIAP-Video-Classifier-Deployment
NIST	Disaster Scene Description and Indexing (DSDI), https://www-nlpir.nist.gov/projects/tv2020/dsdi.html
	Analytics Container Environment (ACE), https://github.com/usnistgov/ACE <ul style="list-style-type: none"> • Total file downloads: downloads not available for file type • Network (Forks): 6 • Subscribers (Watchers): 7
	Analytics Container Environment (ACE) Nano, https://github.com/usnistgov/ace-nano <ul style="list-style-type: none"> • Total file downloads: 0 • Network (Forks): 0 • Subscribers (Watchers): 3
	Analytics Container Environment (ACE) User Interface, https://github.com/usnistgov/ACE-UI <ul style="list-style-type: none"> • Total file downloads: downloads not available for file type • Network (Forks): 3 • Subscribers (Watchers): 7
	ASAPS Development Dataset, https://asapsdata.nist.gov/ <ul style="list-style-type: none"> • Total file downloads: 70 • Total dataset downloads: 35 • Total bytes downloaded: 20.89 MB • Total unique users: 30 • Last downloaded: Jul 10, 2023
	SDNist: Synthetic Data Report Tool, https://github.com/usnistgov/SDNist <ul style="list-style-type: none"> • Total file downloads: 1,126 • Network (Forks): 8 • Subscribers (Watchers): 3

Analytics

	Use Case Reference Model Database, https://github.com/usnistgov/atlas <ul style="list-style-type: none"> • Total file downloads: 0 • Network (Forks): 2 • Subscribers (Watchers): 2
Prominent Edge LLC	StatEngine Kibana Fixtures, https://github.com/StatEngine/se-fixtures
	StatEngine Github: Accelerating data analytics for public safety, https://github.com/StatEngine
	StatEngine Spade: An extensible client-side application for PSOs to send data in a StatEngine instance, https://github.com/StatEngine/spade
	StatEngine Application, https://github.com/StatEngine/stat-engine
	StatEngine Data schemas for the public safety organizations, https://github.com/StatEngine/se-schemas
	Web Based Analytics and Visualization Platform: customized implementation of Kibana, https://github.com/StatEngine/kibana
Regents of the University of Michigan	Adversarial Background-Aware Loss for Weakly-supervised Temporal Activity Localization, https://github.com/MichiganCOG/A2CL-PT
	M-PACT: Michigan Platform for Activity Classification in Tensorflow, https://github.com/MichiganCOG/M-PACT
	TASED-NET: Temporally Aggregating Spatial Encoder-Decoder Network for Video Saliency Detection, https://github.com/MichiganCOG/TASED-Net
Southern Methodist University	Infrastructure for Partially Observable Markov Decision Processes (POMDP), https://cran.r-project.org/web/packages/pomdp/index.html
The Rector & Visitors of the University of Virginia	Data Analytics Pipeline for Emergency Medical Services (EMS), https://github.com/UVA-DSA/EMS-Pipeline
University of Houston	A Day on Campus (ADOC) dataset, qil.uh.edu/datasets
	University of Houston Camera Tampering Detection dataset (UHCTD) for development and testing of camera, qil.uh.edu/datasets
Voxel51 LLC	Voxel51 Platform SDK, https://github.com/voxel51/platform-sdk
	ETA: Extensible Toolkit for Analytics, https://github.com/voxel51/et
Western Fire Chiefs Association, INC.	Fire Data Lab results, firedatalab.org

LBS

Carnegie Mellon University	Beluga: Decawave DWM1001-DEV board firmware for building ad-hoc distance measurement network, https://github.com/WiseLabCMU/Beluga
City of Memphis	Map901 tools and data, http://map901.memphis.edu
	Memphis city web portal for sharing Map901 data, https://www.memphistn.gov/map901/
Enfield Fire District No 1	Enfield Data Dissemination Portal: Indoor Mapping with Handheld LiDAR, https://www.edc.uri.edu/apps/uri::indoor-mapping-with-handheld-lidar/explore
Hancock County, Mississippi	NVision Solution's Point Cloud City Data, https://www.nvisionsolutions.com/nist
	Almalioglu, Y., Turan, M., Lu, C. X., Trigoni, N., & Markham, A. (2021) Milli-RIO: Ego-Motion Estimation With Low-Cost Millimetre-Wave Radar. In IEEE Sensors Journal, 21(3), 3314-3323. doi: 10.1109/JSEN.2020.3023243.
	Almalioglu, Y., Turan, M., Saputra, M. R. U., de Gusmão, P. P. B., Markham, A., & Trigoni, N. (2022) SelfVIO: Self-Supervised Deep Monocular Visual-Inertial Odometry and Depth Estimation. Neural Networks, 150, 119-136. https://doi.org/10.1016/j.neunet.2022.03.005

MCV

NIST

5G New Radio/LTE Sidelink Capacity Estimator, <https://www.nist.gov/services-resources/software/5g-new-radiolte-sidelink-capacity-estimator>

- Total file downloads: 0
- Network (Forks): 1
- Subscribers (Watchers): 3

Common code for MCV QoE Measurement Classes, <https://pypi.org/project/mcvqoe-base/>

- Total file downloads: 18
- Network (Forks): 1
- Subscribers (Watchers): 3

LTE Coverage Tool, <https://github.com/usnistgov/LTECoverageTool/>

- Total file downloads: 0
- Network (Forks): 9
- Subscribers (Watchers): 4

Mission Critical Voice Quality of Experience Access Time Measurement Method, <https://github.com/usnistgov/accessTime>

- Total file downloads: 116
- Total dataset downloads: 60
- Total bytes downloaded: 74.70 MB
- Total unique users: 35
- Last downloaded: May 22, 2023

Mission Critical Voice Quality of Experience Firmware, <https://github.com/usnistgov/MCV-QoE-firmware>

- Total file downloads: 35
- Network (Forks): 1
- Subscribers (Watchers): 3

Mission Critical Voice Quality of Experience Mouth-to-Ear Latency Measurement Method, <https://github.com/usnistgov/mouth2ear>

- Total file downloads: 19
- Network (Forks): 2
- Subscribers (Watchers): 4

Modified Rhyme Test Speech Intelligibility GUI, <https://github.com/usnistgov/mrt>

- Total file downloads: 0
- Network (Forks): 1
- Subscribers (Watchers): 2

NetSimulyzer: Visualization tool for ns-3, <https://github.com/usnistgov/NetSimulyzer>

- Total file downloads: 367
- Network (Forks): 7
- Subscribers (Watchers): 6

New Radio Sidelink Simulator, <https://www.nist.gov/services-resources/software/new-radio-sidelink-simulator>

Open-Source Simulation Platform for Public Safety, <https://www.nist.gov/programs-projects/network-modeling-public-safety-communications/open-source-simulation-tools-public>

Optimal Transmit Volume Conditions for MCV QoE Measurement Systems, <https://github.com/usnistgov/MCV-QOE-TVO>

- Total file downloads: 96
- Total dataset downloads: 35
- Total bytes downloaded: 2.05 TB
- Total unique users: 17
- Last downloaded: Jul 29, 2023

PSCR Mission Critical Voice QPP SIM, <https://github.com/usnistgov/qppsim>

- Total file downloads: 0
- Network (Forks): 1
- Subscribers (Watchers): 2

MCV

	Public Safety Communications Simulation Tool (ns3 based), https://github.com/usnistgov/psc-ns3
	Total file downloads: downloads not available for file type
	Network (Forks): 38
	Subscribers (Watchers): 22
Perspecta Labs Inc.	Additional instructions to support On-net sidelink scenarios, https://gitlab.eurecom.fr/oai/openairinterface5g/blob/LTE-sidelink/targets/DOCS/D2D-on-net-and-relay-setup-instructions.pdf
	Building the code and supporting Off-net sidelink scenarios, https://gitlab.eurecom.fr/oai/openairinterface5g/blob/LTE-sidelink/d2d_emulator_setup.txt
Software Radio Systems Limited	Project Website, www.srslte.com
Universidad del Pais Vasco/Euskal Herriko Unibertsitatea	Mission Critical Open Platform (MCOP), http://www.mcopenplatform.org
	MCOP Online Testing System (must request access), https://demo.mcopenplatform.org
	MCS TaaSting, https://www.mcstaasting.com/
University of Washington	Public safety extension module for ns-3, https://apps.nsnam.org
Cornell University	Vegvisir Website, http://vegvisir.cs.cornell.edu
Michigan Technological University	Resilient System Solutions for Using Data in Wildland Fire Incident Operations Website, https://www.mtu.edu/mtri/research/project-areas/environmental/fire/wildfire-dln/
Texas A&M Engineering Experiment Station	DistressNet Repositories, https://github.com/LENSS
The Regents of the University of California	Ongoing Source Code of Graph-Pub/Sub (and hierarchical namespace) over Click modular router, https://github.com/SAIDProtocol/graphpubsubimpl_v2
	Network Simulator: Ongoing Source Code of Graph-Pub/Sub Simulator, https://github.com/SAIDProtocol/NetworkSimulator
	Other Products Ongoing Source Code of D2D Communication Application, https://github.com/tausif-ah/D2DCommWithDynamicRouting
	Source Code and Website of TechToProtect Codeathon , https://gitlab.orbit-lab.org/jiachen/NG-MCPTT
	Source Code of ICNP'19 and PSCR'20 Demo, https://gitlab.orbit-lab.org/jiachen/ReDiCom
	Websites Project main website, https://redicom493858423.wordpress.com/
University of Colorado	CASTLE evaluation dataset, https://github.com/cu-pscr/CASTLE_data
	Developed software library for CASTLE, https://github.com/cu-pscr/CASTLE_LIBRARY
	Mobile-Edge Cloud extension for NextEPC, https://github.com/cu-pscr/nextepc-mec
	NextEPC Evolved Packet Core controller software, https://nextepc.org/
	NS-3 extension for Multipath-TCP, https://github.com/cu-pscr/mptcp
	ResponsCODE: Elastic EPC and Mobile Edge Cloud, https://gitlab.orbit-lab.org/jiachen/GraphPubSubSecurity
	PERCEIVE(Predicted pERformance by CELLular Inferring deViCe) software, https://github.com/cu-pscr/perceive
	Batphone Serval Mesh , https://github.com/cu-pscr/batphone_cupscr

Security

Georgia Tech Applied Research Corporation

NIEF Snapshot of Trustmark Definitions and Trust Interoperability Profiles, <https://trustmark.nief.org/tpat/>

Trustmark Initiative Snapshot of Trustmark Definitions and Trust Interoperability Profiles, <https://artifacts.trustmarkinitiative.org/>

UI/UX

NIST

PSCR Haptic Challenge Environments - EMS, Fire, & Law Enforcement,

<https://github.com/usnistgov/HapticChallengeUE4>

- Total file downloads: 0
- Network (Forks): 2
- Subscribers (Watchers): 3

PSCR Usability Results Tool: Voices of First Responders, <https://publicsafety.nist.gov/>

- Total file downloads: 24
- Total dataset downloads: 11
- Total bytes downloaded: 90.03 MB
- Total unique users: 11
- Last downloaded: May 13, 2023

Texas A&M

IoT Data: Emergency Scenarios Repository, https://github.com/usnistgov/IoTData_EmergencyScenarios

University of North Carolina at Greensboro

Public Safety User Interface Resource Library resource library, <http://psui.uncg.edu>

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