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Focus on: Law Enforcement

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Body-Worn Cameras:
What the Evidence Tells Us

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David B. Muhlhausen, Ph.D.

Director, National Institute of Justice

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DIRECTOR'S MESSAGE



NIJ is a research institution, but at the end of the day we exist to serve law enforcement and other criminal justice practitioners. My biggest priority as NIJ director is to ensure that our work is relevant and responsive to the needs of the field, and never lives in an ivory tower. This thematic issue of the *NIJ Journal* discusses some of the many ways NIJ has committed to advancing the law enforcement profession through science, from building in-house law enforcement research capacity to understanding the ways that artificial intelligence (AI), body-worn cameras, and other technologies have transformed criminal justice.

Officer safety, health, and wellness is a major area of focus. Motor vehicle crashes are consistently the leading cause of officer line-of-duty deaths. One article in this issue discusses how NIJ has teamed up with federal, state, and local partners to conduct reviews of these fatalities. The reviews are an opportunity to learn from these tragedies and generate recommendations that will help prevent their recurrence. Preliminary evaluation findings have also found a comprehensive motor vehicle safety program in Las Vegas to significantly reduce crash and injury rates.

Firearms continue to be one of the most dangerous threats faced by law enforcement officers. Ballistic-resistant body armor has saved thousands of officers' lives, and NIJ's Body Armor Performance Standards Program has set minimum standards for this armor, conducted testing to ensure compliance, and sponsored research to improve armor. We are currently developing updated standards, set to release in 2019, to ensure continued high-quality armor and increased officer safety.

Technology has infiltrated and transformed our lives — and criminal justice. As technologies emerge and are implemented, research and rigorous evaluation often struggle to keep pace. In this issue, we discuss what the evidence tells us — and where gaps remain — about body-worn cameras. A second article describes the benefits and potential drawbacks of two innovative ways to process digital evidence. An additional article explains NIJ's AI research portfolio, AI applications in criminal justice, and the great potential of AI in promoting public safety and reducing crime.

I am constantly advocating for research and connection to the field. Two of our articles discuss the value of building in-house research capacity within a law enforcement agency. I want to thank one of our NIJ Law Enforcement Advancing Data and Science (LEADS) scholars, Lt. Jason Potts, for writing about his firsthand experience leading in-house research projects, including randomized controlled trials, at the Vallejo Police Department. Another LEADS scholar, Maj. Wendy Stiver from Dayton, Ohio, recently joined NIJ part-time at our Washington, D.C., headquarters as our first law enforcement practitioner-in-residence. I am eager to see the perspective, insight, and energy she will bring to NIJ's work.

With more than 18,000 unique agencies across the country, law enforcement is a diverse and complex field. Rigorous research and evaluation studies, as well as replication of these studies, help us understand what works — and what doesn't — to help us best allocate limited resources and improve officer safety, health, and wellness. Law enforcement is one of NIJ's most important stakeholders and I'm proud to release this issue detailing some of the many ways NIJ research has affected various facets of the field. I give my thanks for what they do to advance public safety across the country.

A handwritten signature in black ink that reads "David B. Muhlhausen". The signature is written in a cursive style with a long horizontal line extending to the right.

David B. Muhlhausen, Ph.D.
Director, National Institute of Justice

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NIJ BULLETIN



Publications in Brief

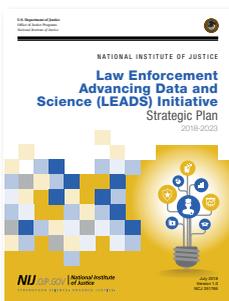


Lessons Learned from the Second Chance Act: Moving Forward to Strengthen Offender Reentry

The federal Second Chance Act (SCA) aims to enhance public safety by breaking the cycle of criminal recidivism and improving outcomes for people returning to their communities from prisons, jails, and juvenile facilities. The SCA allows grantee sites to tailor their programs and services to the needs of participants in their local communities. NIJ is sponsoring evaluations to determine the effectiveness of SCA offender reentry programs, and in the summer of 2018 NIJ released an information sheet summarizing what has been learned from the first two evaluation reports.

The evaluations found that, generally, participation in an SCA reentry program did not affect a range of reentry outcomes, including substance use and compliance with supervision conditions. However, participation in an SCA program increased access to and receipt of reentry services and programs, and it improved partnerships between criminal justice and community-based agencies. Still, these benefits did not significantly reduce recidivism. The information sheet recommends that rigorous evaluations of promising reentry programs continue in order to identify what works and who is most likely to reenter successfully.

Read “Lessons Learned from the Second Chance Act” at NIJ.ojp.gov, keyword: 251704.

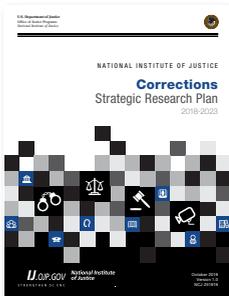


Law Enforcement Advancing Data and Science (LEADS) Initiative: Strategic Plan, 2018-2023

NIJ and the International Association of Chiefs of Police launched the Law Enforcement Advancing Data and Science (LEADS) Scholars program in 2014 to support the professional development of research-minded law enforcement officers. Under LEADS, NIJ awards merit-based scholarships to sworn, mid-rank officers who have either partnered on a research project or infused research into policy development within their agency. In 2017, NIJ launched the LEADS Agencies program, which is intended to increase agency effectiveness. The program is tailored to agencies’ needs for capacity-building and assistance.

In July 2018, NIJ published the LEADS Strategic Plan to lay out a vision for the next five years of these two programs. The plan offers a roadmap for expanding the LEADS Initiative and puts forward four strategic priorities for LEADS: advancing evidence-based policing, improving the capacity of law enforcement to conduct policy-relevant research, supporting the professional development of research-oriented officers, and fostering a community of practice around evidence-based policing.

Learn more about the LEADS Initiative and read the Strategic Plan at NIJ.ojp.gov, keyword: LEADS.



Corrections Strategic Research Plan

NIJ's new Corrections Strategic Research Plan defines research priorities and objectives for addressing the challenges of corrections in the coming years. By advancing multidisciplinary research and facilitating connections between researchers and practitioners, NIJ will be better able to inform corrections leaders, personnel, and policymakers.

The plan describes current and projected efforts to enhance public safety by promoting and supporting research in three priority areas: workforce development for corrections personnel, innovations in corrections practices, and experiences of incarceration and reentry.

Read the plan at nij.ojp.gov, keyword: strategic plans.



News & Events



Research for the Real World: NIJ Marks 50 Years of Helping the Criminal Justice Community

To commemorate NIJ's 50th anniversary in 2018, NIJ hosted a special session of its *Research for the Real World* series in July. Two former NIJ directors reflected on their days leading the agency and offered their observations of how the agency has changed over time. Alongside them, two police chiefs discussed the importance of research for guiding law enforcement and the impact NIJ-funded research has had on their own work. In his opening remarks, NIJ Director David Muhlhausen described the anniversary as “a time to reflect on where we’re going over the next 50 years and beyond. NIJ has accomplished a lot in the first 50 years, and we have a bright future ahead. . . . Over the next 50 years, I see data, evidence, and research becoming more central for practitioners and also indispensable to all aspects of the criminal justice field.”

Watch a video of the event or read a complete transcript at nij.ojp.gov, keyword: nij50th.



Best Practices Guidance for Advancing Research Initiatives and Combatting the Synthetic Drug Epidemic

One of the major challenges today in the field of forensic drug chemistry and forensic toxicology is the emergence and proliferation of novel psychoactive substances. Laboratories struggle to keep up with the most current list of emerging drugs and face challenges associated with development and validation of analytical methods for their measurement.

The Center for Forensic Science Research and Education (CFSRE) is a world-leading center in novel drug identification and interpretation. In July 2018, CFSRE partnered with NIJ's Forensic Technology Center of Excellence to deliver a series of three presentations providing insight into the challenges forensic laboratories face when analyzing novel psychoactive substances. The goal of the workshops was to provide resource materials to forensic science practitioners and promote a better understanding of evidence-based best practices regarding the synthetic drug epidemic.

Read more at <https://forensiccoe.org/webinar/best-practices-synthetic-drug-epidemic/>.



Research for the Real World: Seminar on Evidence-Based Policing

NIJ's Law Enforcement Advancing Data and Science (LEADS) Initiative encourages law enforcement officers and agencies to use data and research to inform their policies and practices. In June 2018, NIJ convened a panel in its ongoing Research for the Real World series focused on "Evidence-Based Policing: The Importance of Research and Evidence." Moderated by NIJ Director David Muhlhausen, the panel included Oregon's statewide police training manager, the leader of New York's Gun Involved Violence Elimination program, the founder of nonprofit research facilitator BetaGov, and the president of the International Association of Chiefs of Police.

Watch a video of the panel discussion or read a complete transcript at [NIJ.ojp.gov](https://nij.ojp.gov), keyword: rfrwreentry.



Opioids Research Summit

Across the Department of Justice, combatting the opioid crisis is a top priority. In the fall of 2018, the Department announced that it is awarding nearly \$320 million to help those most affected by the deadliest drug crisis in U.S. history.

As the Department's research, development, and evaluation agency, NIJ has a unique role to play in finding and disseminating effective, evidence-based strategies for addressing opioids and other drugs. In September 2018, NIJ hosted "Fighting the Opioid Crisis: Convening Police Leaders and Researchers to Learn Promising Practices and Inform the Research Agenda." While reaffirming NIJ's commitment to thorough research, the summit responded to the urgency and immediacy of the opioid crisis by providing a place for leaders from law enforcement, public health, medicine, and the research community to share the latest information across disciplines.

Learn more about the summit and read the opening remarks from NIJ Director David Muhlhausen at [NIJ.ojp.gov](https://nij.ojp.gov), keyword: opioid remarks.



Multimedia



LEADS Scholars Spotlights

Each year, NIJ supports a new class of Law Enforcement Advancing Data and Science (LEADS) Scholars — the next generation of law enforcement leaders who are committed to conducting their own research on evidence-based policies and practices. LEADS scholars come from different regions of the United States and from agencies pursuing different objectives based on their communities' particular needs. The LEADS program allows these officers to discover what works and what is promising for their own communities and in their own context.

NIJ has released a series of brief profiles of LEADS scholars that highlight their work testing technologies like body-worn cameras, evaluating practices like predictive policing, and applying new solutions to problems like gun violence and officers' exposure to trauma. Across their diverse areas of inquiry, all of the scholars have benefitted from the resources, collaboration, and mutual support afforded by the LEADS program.

Hear from LEADS scholars how they have used the program to make an impact in their agencies and communities at <https://youtu.be/U4sx56ATkkl>.



Research Findings



How Evaluation Toolkits Can Help Sexual Assault Nurse Examiner Programs Assess Their Impact

In a sexual assault nurse examiner (SANE) program, specially trained nurses provide comprehensive psychological, medical, and forensic services to victims of sexual assault. Although hundreds of SANE programs are operating across the United States today, evaluations of the programs are scarce. NIJ's SANE Practitioner-Oriented Toolkit was created to help SANE programs evaluate themselves. To test the impact of the toolkit, a recent study looked at six SANE programs using the toolkit to understand how it affected their evaluation process.

Aggregating the evaluation results of these programs, the researchers found that cases processed after implementation of a SANE program were almost 80 percent more likely to progress further through the criminal justice system than cases processed before SANE programs were in place. Moreover, the researchers concluded that the evaluation process itself was a positive influence on the SANE programs.

Read an article about the study at NIJ.ojp.gov, keyword: sane toolkit.



How Effective Are Lethality Assessment Programs for Addressing Intimate Partner Violence?

Preventing intimate partner violence means protecting those who are most at risk. Since 2003, social service providers have encouraged law enforcement officers to screen victims of intimate partner violence, using a short series of questions to determine who is most at risk for suffering lethal violence. Officers warn high-risk victims of the danger they are in and offer to put them in contact with a social services provider who can offer victim advocacy and safety planning. If victims agree, officers call the provider immediately.

To help determine the effectiveness of these lethality assessment programs, NIJ-funded researchers in Oklahoma spent almost four years interviewing victims of intimate partner violence across the state. They concluded that the programs significantly reduced the severity and frequency of violence that survivors experienced. The programs also appeared to increase survivors' help seeking and safety planning.

Read an article about the Lethality Assessment Program evaluation at NIJ.ojp.gov, keyword: lethality assessment.



Domestic Radicalization Research Yields Possible Keys to Identifying Extremists on the Path to Terrorism

Countering and preventing terrorism is a primary concern for state and local law enforcement agencies as well as the federal government. On the prevention side, law enforcement agencies need to be able to identify who is likely to commit acts of terror before those individuals have a chance to commit the acts; understanding the path of radicalization is crucial for stopping terrorism before it occurs.

A recent group of NIJ studies has examined this issue, using data to uncover risk factors and indicators for radicalization along with the facilitating factors and events characteristic of the radicalization process. The research has distilled 16 potential risk factors associated with engaging or attempting to engage in terrorism among both group-based terrorists and lone actors. In addition, research on radicalization trajectories has isolated a number of specific facilitators for radicalization found throughout the histories of radicalized individuals.

Read an article about the risk factors, indicators, and pathways associated with radicalization to terrorism at NIJ.ojp.gov, keyword: identifying extremists.



Harmonizing Police Technology Acquisitions with Policing Strategy

Over the past few decades, law enforcement agencies have adopted sophisticated technologies to enhance their operational effectiveness in fighting crime, deterring external threats, and positively engaging the community. To better understand the implementation and impact of these technologies, an NIJ-supported research team recently examined how and why agencies select, implement, and integrate new technology; how that technology is used; and whether new technology improves law enforcement in a meaningful way for both the agency and the community.

After surveying more than 1,200 state and local law enforcement agencies, the team found that technology had improved agencies' efficiency, communication, information sharing, and analytical capacities. Technologies with the greatest impact across all surveyed agencies were automated records management and computer-aided dispatch. Nevertheless, the researchers underscored that technology acquisitions were often not aligned with an agency's overall strategy. They recommended that law enforcement agencies have a robust internal technology evaluation process to ensure that newly adopted technologies are integrated with agency goals, organizational culture, and strategies.

Read an article on the study at NIJ.ojp.gov, keyword: harmonizing.



How Research Is Translated to Policy and Practice in the Criminal Justice System

As a research and development agency, NIJ is deeply invested in translating research results into evidence-based policies and practices. A recent NIJ-funded study of Florida's correctional system investigated this translation process, examining what role research plays in the development of correctional policy and practice in Florida. The study found that the main sources from which policymakers and practitioners acquire evidence to inform their decision-making are government-sponsored or -conducted research, peer networking, and intermediary policy and research organizations. Major barriers to research translation include difficulty in interpreting and using research, lack of support from leadership in using research, and differences in training between practitioners and researchers. According to the results of the study, the most successful way to translate research is through relationships, partnerships, and two-way communication between researchers and practitioners.

Read an article about the study at NIJ.ojp.gov, keyword: translating research.



Sharing Data to Improve Science



Secondary data analysis allows researchers to build on existing findings, replicate results, and conduct new analyses. Through NIJ's Data Resources Program, data collected as part of NIJ research are archived in the National Archive of Criminal Justice Data and made available to support new research aimed at reproducing original findings, replicating results, and testing new hypotheses.

- Learn about NIJ's Data Resources Program at NIJ.ojp.gov, keyword: DRP.

Recent data sets updated or added to the National Archive include the following:

- Community-Level Influences on the Sentencing of Convicted Sex Offenders, Pennsylvania, 2004-2010
- Evaluating the Crime Control and Cost-Benefit Effectiveness of License Plate Recognition (LPR) Technology in Patrol and Investigations, United States, 2014
- Forensic Markers of Physical Elder Abuse, Los Angeles, California, 2014-2017
- Long-term Impact of a Positive Youth Development Program on Dating Violence Outcomes During the Transition to Adulthood
- Predicting Intimate Partner Violence for At-Risk Young Adults and Their Romantic Partners, United States, 1991-2009
- Questioning Bias: Validating a Bias Crime Assessment Tool in California and New Jersey, 2016-2017
- Religion and Violence by Race and Ethnicity, United States Counties, 2006-2014

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IMPROVING OFFICER SAFETY ON THE ROADWAYS

BY BRIAN MONTGOMERY

NIJ and the National Institute for Occupational Safety and Health have teamed up to help prevent officer fatalities from motor vehicle crashes and roadside incidents.

The FBI reports that, between 2007 and 2016, crashes involving motor vehicles — including collisions¹ and being struck by moving vehicles while working on roadways — were the single leading cause of officer line-of-duty deaths.² According to the National Law Enforcement Officers Memorial Fund, there were 50 motor vehicle-related officer fatalities in 2014 (37 percent of all officer fatalities), 49 in 2015 (35 percent), and 54 in 2016 (38 percent).³ Of these fatalities, automobile crashes were the number one cause.

Understanding the circumstances behind line-of-duty deaths from vehicle crashes and roadside incidents is a critical step in reducing officer fatalities. To that end, NIJ conducts and funds research, develops technologies and standards, and partners with other federal agencies to address the concerns and issues related to motor vehicle safety, whether the officer is inside or outside a vehicle. Some of NIJ's efforts over the past few decades have included funding research into vehicle visibility and conspicuity, supporting the development of reflective vest standards, and participating in research advisory groups.

Since 2013, NIJ and the National Institute for Occupational Safety and Health (NIOSH) have been collaborating on two projects that investigate ways to improve officer safety on the roadways. The first project evaluates a comprehensive motor vehicle

safety program in Las Vegas; the second investigates specific officer fatalities to identify risk factors and develop recommendations. The goal of both projects is to help increase safety for law enforcement officers as they perform their duties on the nation's streets and highways.

Evaluating a Comprehensive Safety Program

In 2009, the Las Vegas Metropolitan Police Department lost three officers to motor vehicle crashes in a six-month period. Following these incidents, the department completely overhauled its motor vehicle safety program. It changed its vehicular policies and driver training and implemented a major internal safety campaign, which included posters and signs in frequented areas, decals on law enforcement vehicles, and safety reminders from both dispatchers and supervisors and at roll calls.⁴

An NIJ-supported NIOSH research team reviewed crash and injury data for three years prior to the safety program's inception, the initial year of implementation, and three years afterward. Preliminary findings showed statistically significant decreases in the agency's motor vehicle crash and injury rates after the program was implemented.⁵ Seatbelt usage also improved. Three years after implementation, there were no line-of-duty officer fatalities caused by vehicle

The goal of the NIJ-NIOSH projects is to help increase safety for law enforcement officers as they perform their duties on the nation's streets and highways.

crashes, and the reduction in motor vehicle injuries and associated lost duty days saved the department an estimated \$1.1 million.

The study included data gathered over the same time period from two similar-sized agencies that did not institute comparable safety programs. These agencies did not see any substantial changes in line-of-duty officer motor vehicle crash or injury rates.⁶

Examining Specific Officer Fatalities

NIJ and NIOSH have also created a fatality investigation team to examine law enforcement officer fatalities that occur during traffic-related operations. The goal of the pilot program — modeled after the existing NIOSH firefighter fatality investigation program — is to identify risk factors for fatal motor vehicle-related events and develop recommendations for preventing future fatalities and injuries. This program not only gives the affected agency greater insight into the specific event but also spreads the lessons learned to the broader law enforcement community.

The investigation team — made up of researchers, epidemiologists, and engineers from NIJ and NIOSH — examines officer deaths caused by motor vehicle crashes or by a vehicle striking an officer who is directing traffic, investigating vehicle incidents, responding to calls for service, or conducting traffic stops. The team investigates the scene of the incident and interviews witnesses, agency leadership, trainers, dispatchers, and any other individuals who may have information about the incident or may have been

involved in it. They also collect radio traffic, vehicle GPS information, video, training records, and any other data that they can use to analyze the incident.⁷

The team then describes the event and contributing factors in a report and offers recommendations. Reports are available on the NIJ and NIOSH websites, where law enforcement agencies, officer organizations, and safety and health researchers can easily access them.⁸

As of December 2017, the team had conducted five investigations. Following is a synopsis of three of the completed investigation reports.

New Mexico

On December 5, 2013, a 47-year-old sheriff's office sergeant was investigating multiple minor motor vehicle crashes on an interstate highway during blizzard conditions. Disabled vehicles were situated on the shoulders of the northbound and southbound interstate lanes as well as in the median. Officers from both state and county law enforcement agencies had responded at the scene.

Having crossed the highway to speak to other officers, the sergeant was walking along the northbound shoulder, facing traffic, when a passing motorist lost control of his vehicle and slid onto the shoulder, striking the sergeant. After fire and rescue personnel stabilized him at the scene, the sergeant was transported to a nearby Level 1 trauma center, where he succumbed to his injuries the following day.

Some key contributing factors to the incident included severe atypical weather with little to no warning, lack of traffic control or scene management due to limited resources, and civilian motorists who failed to appropriately adjust to driving conditions. Snow squalls had begun about 90 minutes prior to the incident, temperatures were below freezing, and the roads became icy. Multiple disabled vehicles littered the shoulders and median of the interstate. As officers responded, they identified disabled vehicles and provided assistance. As more officers arrived on the scene, they continued to assist motorists, but they

did not develop a scene management plan or institute traffic control. Traffic was still allowed to flow freely through the area. From dashcam video, it appears that a passing motorist attempted to change lanes while traveling into the incident area and lost control of his vehicle on the icy road, striking the officer.

Based on the team's investigation, some recommendations include providing resources for oversight at a scene, ensuring that officers are properly trained in traffic management, providing officers with temporary traffic control devices, and ensuring that officers are provided with and use reflective vests while working traffic incidents. When multiple officers respond to a scene, at least one officer should be responsible for oversight. This officer should continually assess the scene, request resources as needed, and verify that all of the traffic control measures implemented are effective.⁹

Oklahoma

On January 31, 2015, a 30-year-old Oklahoma Highway Patrol trooper was at the scene of a crash involving a tanker truck when he was struck by a passing motorist and fatally injured. The tanker truck was overturned; it blocked the left westbound lane of the interstate and extended into the median. One additional trooper and two officers from the local county sheriff's office also responded to the crash.

The two troopers were standing in a westbound lane, upstream of the lane closure, in an area that was partially blocked to traffic. They had their backs toward oncoming traffic as they assessed the scene. At that time, a motorist driving in the westbound lane partially left the roadway, went around a patrol car, and struck both troopers. One trooper died on impact; the other was critically injured and transported to a Level 1 trauma center.

A distracted motorist, distracted officers, and vehicle and officer positioning were all contributing factors to this incident, according to the investigation team. The motorist who struck the officers had been using a cellphone for a long time prior to reaching the crash scene. The driver recognized that there were police

vehicles present; however, the driver believed that it was a traffic stop and not a crash blocking part of the roadway.

When the officers arrived on the scene, they were unable to place their vehicles in an optimal configuration. The drivers of multiple civilian vehicles, including a tractor trailer, had stopped to assist the overturned tanker truck. The officers instructed these drivers to move their vehicles; however, they did not reposition their patrol vehicles before the fatality occurred. The officers were also distracted by civilian bystanders who were trying to provide the officers with information about the incident and were walking near moving traffic next to the crash.

The investigation team recommended that agencies consider providing training and instituting a campaign to remind officers that safety for themselves and others is the top priority when responding to traffic incidents. After officers provide proper traffic management, assess what other assets are needed (ambulance, fire service, tow truck), and verify that all individuals in the area are in a safe location, then they can begin to investigate the crash. Agencies should also consider implementing or continuing to promote public awareness campaigns to remind the driving public to be more cautious when approaching incident scenes and emergency response vehicles.

Lastly, the investigation team recommended that law enforcement agencies consider advocating for policies or agreements with neighboring jurisdictions to provide both law enforcement and fire service responses to all traffic incidents. In this case, the fire service was not dispatched until after the officers had been struck. The investigation team found that if the fire service had been dispatched to the original call, there may have been more opportunity to provide a safer scene for all involved.¹⁰

Tennessee

On May 10, 2014, a 25-year-old police officer was fatally injured when he was struck by a motor home and dragged under its trailer on a four-lane interstate highway. The officer had responded to a jackknifed

and overturned pickup/trailer combination that was blocking an entrance ramp to the interstate's northbound lanes. To assist with traffic control, the officer positioned his patrol unit south of the entrance ramp in Lane 3 (the lane second from the right). A Tennessee Department of Transportation help-truck operator positioned his vehicle next to the patrol unit to block the shoulder and Lane 4 (the far right lane).

The officer and help-truck operator were standing between their vehicles, near the driver's side door of the help truck, when a motor home pulling a trailer approached the scene in Lane 3. The driver of the motor home reported that the speed and volume of traffic in Lanes 1 and 2 prevented him from moving to the left; as a result, he attempted to drive between the police car and the help truck. The help-truck operator saw the oncoming motor home, yelled to the officer, and ran out of the way; the officer was unable to do so. The motor home and trailer sideswiped the help truck and struck the officer. The officer was dragged underneath the trailer for 116 feet before the motor home came to a stop. He died at the scene.

The investigation team identified the following contributing factors in this incident: failure of the motor home driver to slow down and merge left, the position of the patrol unit, the position of the officer (standing in a partially open lane, facing away from oncoming traffic), and a delay in updating the dynamic message sign. The positioning of the response vehicles allowed just enough room for a vehicle to drive between them. Cones were placed to warn oncoming motorists to move over; however, they did not provide a barrier to protect the responders on the roadway.

The investigation team noted that all workers on the roadway need to be fully aware of their surroundings at all times and identify hazardous areas to avoid — in this case, the space between the response vehicles. Mobile dynamic signs are useful when kept up to date. In this incident, the sign indicated only that the far right lane was closed; however, at the time of the incident, the two right lanes were closed. Although drivers should always use caution when approaching an incident, providing

accurate and timely information to motorists may help prevent these types of crashes.¹¹

Officers Must Remain Vigilant

One of the commonalities in these investigations has been officers who are distracted by processing the scene or who become complacent while on or near the roadways. Even though officers routinely respond to roadway incidents, conduct traffic stops, and assist other first responders, they must always be aware of their surroundings and should not assume that motorists will drive in a safe manner when approaching emergency response vehicles. Situational awareness is key, no matter the volume or speed of traffic in and around the response area.

Training Is Critical

Another underlying theme from these two NIJ-NIOSH projects, as well as other research, is that strong officer safety policies and training can mitigate the underlying causes of fatalities and injuries sustained by officers if they are constantly reinforced, implemented consistently across the entire agency, and hold officers and supervisors accountable. Agencies should have a mechanism for assessing the effectiveness of their policies and training, the impact of any changes to those policies and training, and other factors that may influence their officers' environment.

About the Author

Brian Montgomery is a general engineer in NIJ's Office of Science and Technology.

For More Information

To learn more about NIJ's work in police roadside safety, visit NIJ.ojp.gov, keyword: roadside safety.

This article discusses the following interagency agreements:

- Interagency agreement number 2013-ER-R-3794
 - Interagency agreement number 2013-ER-R-3795
-

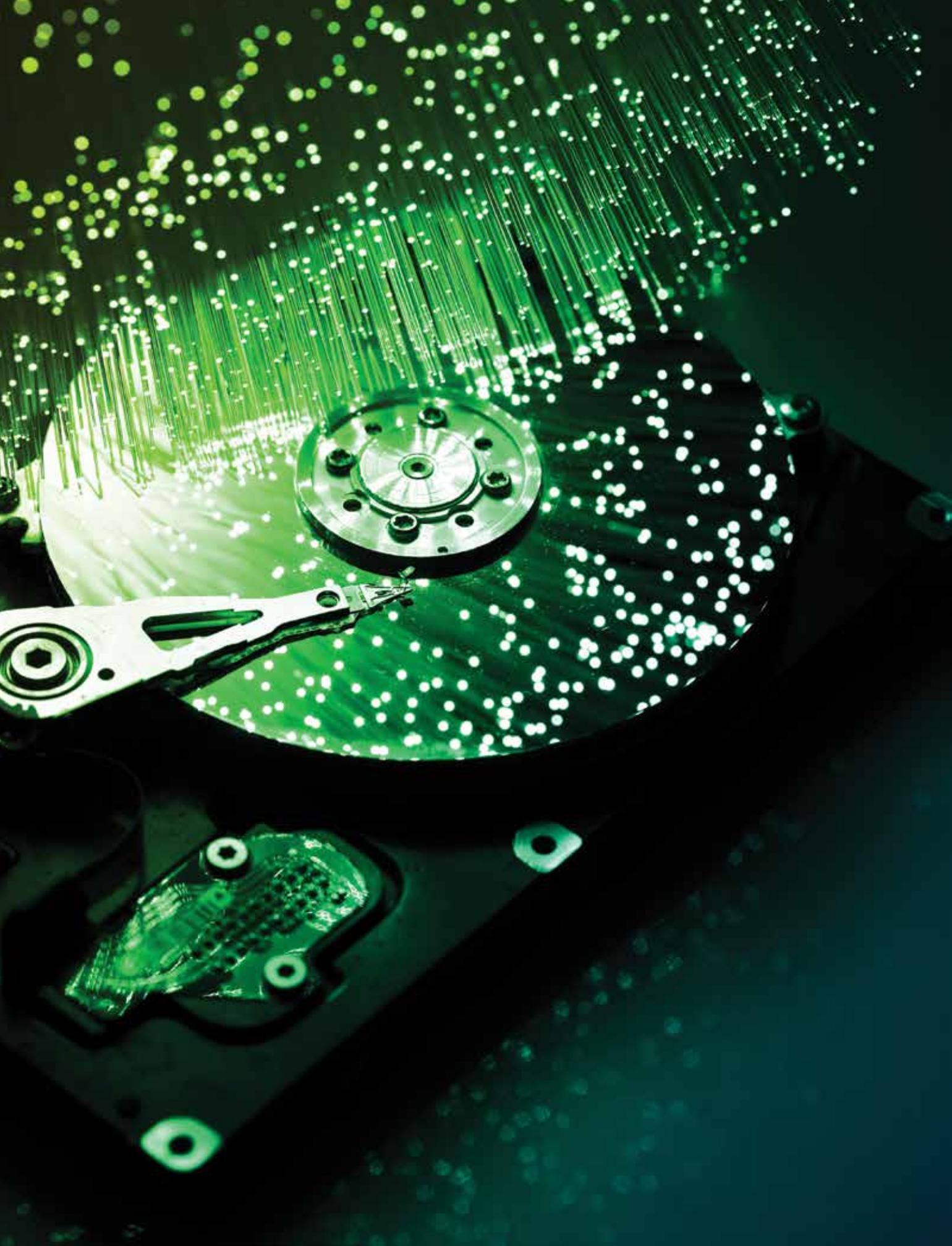
Notes

1. This includes all types of collisions, whether the fault of the officer or the other driver.
2. U.S. Department of Justice, 2016 Law Enforcement Officers Killed & Assaulted (Washington, DC: Federal Bureau of Investigation, Criminal Justice Information Services Division), <https://ucr.fbi.gov/leoka/2016>.
3. National Law Enforcement Officers Memorial Fund, Causes of Law Enforcement Deaths Over the Past Decade (2008-2017) (Washington, DC: National Law Enforcement Officers Memorial Fund).
4. For more information on the Las Vegas Metropolitan Police Department's safety program, contact Sergeant Lou Maldonado at L4070M@LVMPD.com or (702) 828-4010.
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6. Ibid.
7. Under this pilot program, the investigation team analyzes both new incidents and incidents from the past year involving motor vehicle-related fatalities. The team selects cases that differ from previous investigations so they can generate a broader set of lessons learned and determine

what types of incidents might generate the most useful information. The team then contacts the agency to determine whether it is interested in participating in an investigation. After the agency and investigation team reach an agreement, investigators gather information through interviews and review available records to develop a description of the conditions and circumstances leading to the death or deaths. Participation in the investigation is voluntary, interviewees are not asked to sign any statements, and interviews are not recorded. The reports do not name the deceased officer, the law enforcement agency, or those interviewed.

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 9. Division of Safety Research, *Sergeant Struck by a Motor Vehicle on Interstate Highway — New Mexico* (Morgantown, WV: National Institute for Occupational Safety and Health, January 21, 2016), <https://www.cdc.gov/niosh/topics/leo/pdfs/L201401.pdf>.
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NCJ 252032



NEW APPROACHES TO DIGITAL EVIDENCE ACQUISITION AND ANALYSIS

BY MARTIN NOVAK, JONATHAN GRIER, AND DANIEL GONZALES

Two NIJ-supported projects offer innovative ways to process digital evidence.

Computers are used to commit crime, but with the burgeoning science of digital evidence forensics, law enforcement can now use computers to fight crime.

Digital evidence is information stored or transmitted in binary form that may be relied on in court. It can be found on a computer hard drive, a mobile phone, a CD, and a flash card in a digital camera, among other places. Digital evidence is commonly associated with electronic crime, or e-crime, such as child pornography or credit card fraud. However, digital evidence is now used to prosecute all types of crimes, not just e-crime. For example, suspects' email or mobile phone files might contain critical evidence regarding their intent, their whereabouts at the time of a crime, and their relationship with other suspects.

In an effort to fight e-crime and to collect relevant digital evidence for all crimes, law enforcement agencies are incorporating the collection and analysis of digital evidence into their infrastructure.

Digital forensics essentially involves a three-step, sequential process:¹

1. Seizing the media.

2. Acquiring the media; that is, creating a forensic image of the media for examination.

3. Analyzing the forensic image of the original media. This ensures that the original media are not modified during analysis and helps preserve the probative value of the evidence.

Large-capacity media typically seized as evidence in a criminal investigation, such as computer hard drives and external drives, may be 1 terabyte (TB) or larger. This is equivalent to about 17,000 hours of compressed recorded audio. Today, media can be acquired forensically at approximately 1.5 gigabytes (GB) per minute. The forensically acquired media are stored in a RAW image format, which results in a bit-for-bit copy of the data contained in the original media without any additions or deletions, even for the portions of the media that do not contain data. This means that a 1 TB hard drive will take approximately 11 hours for forensic acquisition.² Although this method captures all possible data stored in a piece of digital media, it is time-consuming and creates backlogs. In 2014, there were 7,800 backlogged cases involving digital forensics in publicly funded forensic crime labs.³

Sifting Collectors has the potential to significantly reduce digital forensics backlogs and quickly get valuable evidence to the people who need it.

To help address these challenges, NIJ funded two projects in 2014: Grier Forensics received an award to develop a new approach to acquiring digital media, and RAND Corporation received an award to work on an innovative means for analyzing digital media. Four years later, these software applications are coming to fruition.

Identifying Disk Regions That May Contain Evidence

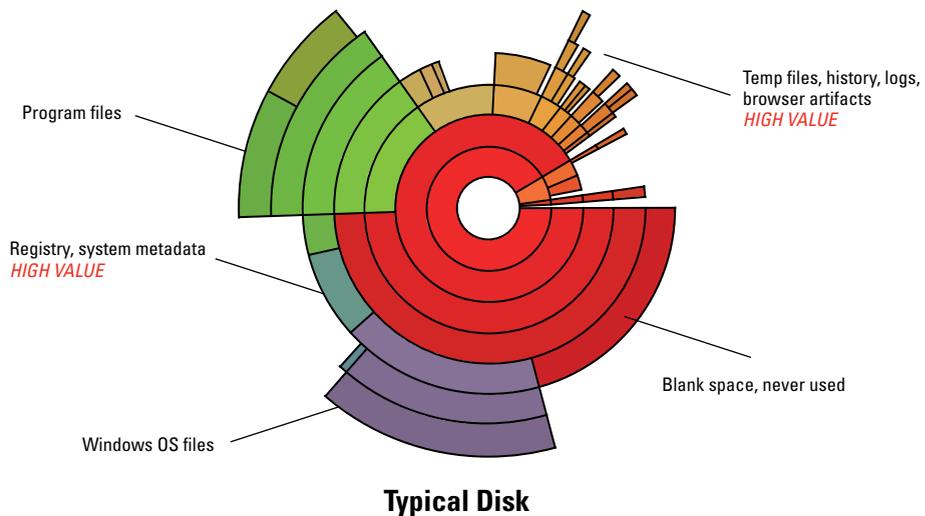
Traditional disk acquisition tools produce a disk image that is a bit-for-bit duplicate of the original media. Therefore, if a piece of acquired media is 2 TB in size, then the disk image produced will also be 2 TB in size. The disk image will include all regions of the original

media, even those that are blank, unused, or irrelevant to the investigation. It will also include large portions devoted to operating systems (e.g., Windows 10 or Mac OSX), third-party applications, and programs supplied by vendors such as Microsoft or Apple (see exhibit 1).

For some cases, such as software piracy, it is important to collect these programs so investigators can understand the computer’s original environment. However, for the vast majority of cases, these regions are not important. For most computer forensic investigations, the evidence lies in the user’s documents, emails, internet history, and any downloaded illicit images.

Grier Forensics proposed a novel approach that images only those regions of a disk that may contain evidence. Called the Rapid Forensic Acquisition of Large Media with Sifting Collectors (Sifting Collectors for short), this software application bypasses regions that contain exclusively third-party, unmodified applications and, instead, zeroes in on the regions that contain data, artifacts, and other evidence. (The software can be easily configured to collect third-party applications when necessary for certain types of cases.)

Exhibit 1. Typical Disk Regions



Source: Courtesy of Grier Forensics.

Exhibit 2. Visualization of Disk Regions



Source: Courtesy of Grier Forensics.

Exhibit 2 is a visualization of disk regions generated by the Sifting Collectors diagnostic package. The green areas represent user-created files and the black areas represent portions of the media that have never been used.

Sifting Collectors has the potential to significantly reduce digital forensics backlogs and quickly get valuable evidence to the people who need it. In laboratory testing,⁴ it accelerated the imaging process by three to 13 times while still yielding 95 to 100 percent of the evidence.

Sifting Collectors is designed to drop right into existing practices. The software creates an industry-standard forensic file — known as an “E01 file” — that is accessible from standard forensic tools, just like current imaging methods.⁵ Grier Forensics is working with major forensics suite manufacturers to allow Sifting Collectors to work seamlessly with their existing tools.

Potential Limitations of Sifting Collectors

Perhaps the most significant drawback of Sifting Collectors is that, unlike traditional imaging, it does not collect the entire disk. Instead, Sifting Collectors discovers which regions of the disk may contain evidence and which do not.

This might not be a significant drawback, however. Digital evidence is typically handled in one of two ways:

- The investigators seize and maintain the original evidence (i.e., the disk). This is the typical practice of law enforcement organizations.
- The original evidence is not seized, and access to collect evidence is available only for a limited duration. This is common in cases involving ongoing intelligence gathering — for example, when law enforcement has a valid search warrant to collect evidence but, because of an ongoing investigation, does not plan to seize the evidence.

In the second scenario, computer forensics examiners have a limited time window for entering the site and collecting as much evidence as possible. Consequently, they will focus only on the most valuable devices and then image each device, spending more than half of their time collecting unmodified regions (as described above). Sifting Collectors would allow them to accelerate the process and collect evidence from many more devices. Either way, given the limited time window, it is difficult to collect all digital evidence. The choice for the computer forensics examiner is whether to collect all regions, including blanks, from a small number of devices or to collect only modified regions containing evidence from a large number of devices. Sifting Collectors allows examiners to make that choice.

When investigators retain the original evidence, the mitigation is even simpler: Sifting Collectors allows users to collect and analyze disk regions expected to contain evidence. It allows them to acquire evidence quickly and start the case more rapidly, and it potentially reduces case backlogs. If, at any time, users need to analyze other regions, they can go back to the original and collect those regions.

Another potential drawback concerns hash verification — using an electronic signature or verification code, known as a hash, to verify that a disk image matches the original evidence disk. Existing methods of hash verification depend on verifying the entire disk and thus are not compatible with Sifting Collectors. However, this problem is not limited to Sifting Collectors; modern, solid-state drives (SSDs) are often incompatible with hash verification because certain SSD regions are unstable due to

maintenance operations. In both cases, the solution is the same: moving from disk-based verification to more granular verification strategies. As the industry adopts newer verification strategies to accommodate SSDs, Sifting Collectors will likely benefit as well.

The process that Sifting Collectors uses to analyze the disk and distinguish relevant regions from unmodified or irrelevant ones takes time. The amount of time varies greatly based on the disk, but it could be up to 10 percent of the imaging time. This means that if Sifting Collectors determines that it is necessary to collect the entire disk or nearly all of it, the software will not save the user any time and will, in fact, be somewhat slower than current imaging methods. To help mitigate this, Grier Forensics is using advanced parallel processing, concurrency, and compression algorithms. However, even with these modifications, Sifting Collectors will end up being slightly slower than traditional imaging in cases where nearly all of the disk is collected.

Perhaps the drawback that is likely to cause the most resistance is simply that Sifting Collectors necessitates a break with current practice. Indeed, reluctance to change current practice will be a substantial obstacle to overcome if Sifting Collectors is to achieve widespread adoption.

Accelerating Digital Forensics Analysis

Each year, the time it takes to conduct digital forensics investigations increases as the size of hard drives continues to increase. With NIJ support, RAND has developed an open-source digital forensics processing application designed to reduce the time required to conduct forensically sound investigations of data stored on desktop computers. The application, called the Digital Forensics Compute Cluster (DFORC2), takes advantage of the parallel-processing capability of stand-alone high-performance servers or cloud-computing environments (e.g., it has been tested on the Amazon Web Services cloud).

DFORC2 is an open-source project. It uses open-source software packages such as dc3dd,⁶ Apache Kafka,⁷ and Apache Spark.⁸ Users interact with

DFORC2 through Autopsy, an open-source digital forensics tool that is widely used by law enforcement and other government agencies and is designed to hide complexity from the user. RAND has designed DFORC2 so the application can also use the Kubernetes Cluster Manager,⁹ an open-source project that provides auto-scaling capabilities when deployed to appropriate cloud-computing services. (See exhibit 3 for a detailed description of how DFORC2 works.)

The primary advantage of DFORC2 is that it will significantly reduce the time required to ingest and process digital evidence. DFORC2's speed advantage, however, will depend on two factors. The first factor is the speed and memory of the server. For smaller servers (those with 16 GB of RAM or less and an older microprocessor), the original stand-alone version of Autopsy will perform better than DFORC2. On a larger server (one with 28 GB of RAM or more and a new high-end multicore microprocessor), DFORC2 will be faster.

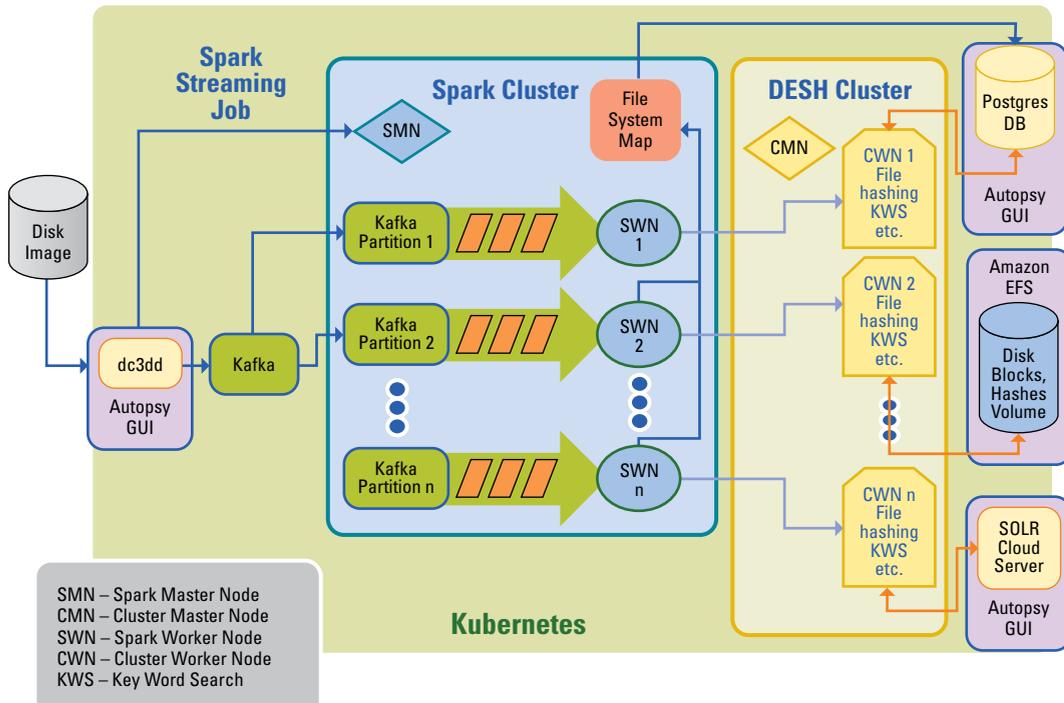
The second factor is the number of worker nodes that can be allocated to the clusters. DFORC2 organizes resources into a cluster manager and worker nodes. Worker nodes perform computing tasks assigned to them by the cluster manager. More worker nodes will significantly reduce evidence ingest and processing times. However, there is a limit to the number of worker nodes that can be implemented on a server, even one that is equipped with a state-of-the-art multicore microprocessor. To get the full benefit of large numbers of worker nodes, the cloud-based version of DFORC2 is needed; the Kubernetes Cluster Manager can spread data-processing tasks over multiple machines in the cloud.

Potential Limitations of DFORC2

The first potential limitation is the complexity of the current prototype. Currently, distributed computing expertise is needed to set up and implement the stand-alone version of DFORC2. RAND is working to simplify its installation on a stand-alone server.

A different set of complex tasks is required to implement DFORC2 in a commercial cloud. Although

Exhibit 3. DFORC2 System Architecture



Source: Courtesy of RAND Corporation.

Note: A compute cluster has its resources organized into a cluster manager and worker nodes. Worker nodes perform computing tasks assigned to them by the cluster manager. DFORC2 ingests data from the hard drive (using dc3dd) and streams it in “blocks” to the Apache Spark cluster. Apache Spark worker nodes search for logical file metadata and send their findings to the PostgreSQL database. Data blocks are hashed before and after receipt to ensure integrity. As the streamed data are received, worker nodes in a second cluster, the Digital Evidence Search and Hash (DESH) cluster, identify and reconstruct “complete” files and process these files using local copies of the Autopsy application. An essential part of the core workflow is the reconstruction of the master file system during the file ingestion process. This is done by the Apache Spark cluster, during rather than after file ingestion, to speed up the forensics analysis process. The master file system map or table and logical file metadata are stored in the PostgreSQL database.

the Kubernetes Cluster Manager simplifies much of the system’s internal setup and configuration, a number of complex steps are required to ensure secure communications with a DFORC2 cloud installation.

In developing its prototype, RAND is using the Amazon Web Services computing cloud. It communicates with the DFORC2 prototype through the firewalls protecting RAND’s enterprise network. RAND has had to work through a number of security and firewall exception issues to enable the smooth installation and startup of DFORC2 in Amazon Web Services. This is another

setup and installation issue that RAND is working to simplify so law enforcement agencies can securely access their own DFORC2 cloud installations from their enterprise networks.

Another potential concern with the use of DFORC2 in criminal investigations is the chain of custody for evidence when commercial cloud-computing services are used to process and store evidence. Additional processing and communication steps are involved when using DFORC2.¹⁰ RAND is conducting a chain-of-custody analysis to strengthen the integrity of the digital forensics processing paths used by DFORC2

in a commercial cloud. Additional cloud security features can also be enabled to protect user data and strengthen the chain of custody in the cloud.

Finally, an additional source of concern is how compute clusters handle data. The chain-of-custody analysis now underway will examine this issue and will include a comprehensive review of the distributed computing software components used in DFORC2.

Need for Evaluation

With the support of NIJ, Grier Forensics and RAND are moving the field forward by developing new means for processing digital evidence. Grier Forensics' Sifting Collectors provides the next step in the evolution of evidence acquisition. RAND's DFORC2 combines the power of compute clusters with open-source forensic analysis software to process evidence more efficiently.

Both of these projects introduce new paradigms for the acquisition and analysis of digital evidence. Whether the criminal justice community accepts these approaches will depend on the admissibility of the evidence each produces. That admissibility will ultimately be determined by the threshold tests of the *Daubert* standard in court. These new approaches will need to be independently tested, validated, and subjected to peer review. Known error rates and the standards and protocols for the execution of their methodologies will need to be determined. In addition, the relevant scientific community must accept them.

RAND will release DFORC2 software code to their law enforcement partners and members of the digital forensics research community in the near future. They will test it, find bugs, and improve the code. Eventually, it will be released as an open-source project.

Grier Forensics will release Sifting Collectors to their law enforcement partners for field trials to verify its preliminary laboratory findings with real cases. It recently benchmarked Sifting Collectors against conventional forensic imaging technology and found

that Sifting Collectors was two to 14 times as fast as conventional imaging technology, depending on the mode and the source disk, and produced an image file requiring one-third the storage space — and it still achieved 99.73 percent comprehensiveness (as measured by a third-party tool).

Meanwhile, NIJ plans to have both DFORC2 and Sifting Collectors independently tested by the NIJ-supported National Criminal Justice Technology Research, Test and Evaluation Center, which is hosted by the Applied Physics Laboratory at Johns Hopkins University.

About the Authors

Martin Novak is a senior computer scientist in NIJ's Office of Science and Technology. **Jonathan Grier** has performed security research, consulting, and investigation for more than 15 years. He developed new security technology for the Defense Advanced Research Projects Agency, the Massachusetts Institute of Technology Lincoln Laboratory, the National Institute of Standards and Technology, and the United States Air Force. **Daniel Gonzales**, Ph.D., is a senior physical scientist at RAND Corporation. He has expertise in command, control, and communications systems; electronic warfare; cybersecurity; digital forensics; critical infrastructure protection; and emergency communications.

For More Information

Read the results of an NIJ-sponsored research effort to identify and prioritize criminal justice needs related to digital evidence collection, management, analysis, and use at [NIJ.ojp.gov](https://www.ojp.gov), keyword: 248770.

Read the findings of an NIJ-sponsored expert panel on the challenges facing law enforcement when accessing data in remote data centers at https://www.rand.org/pubs/research_reports/RR2240.html.

This article discusses the following grants:

- “Rapid Forensic Acquisition of Large Media with Sifting Collectors,” grant number 2014-IJ-CX-K001
 - “Rapid Forensic Acquisition of Large Media with Sifting Collectors,” grant number 2014-IJ-CX-K401
 - “Accelerating Digital Evidence Analysis Using Recent Advances In Parallel Processing,” grant number 2014-IJ-CX-K102
-

Notes

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2. Steven Branigan, “Identifying and Removing Bottlenecks in Computer Forensic Imaging,” poster session presented at NIJ Advanced Technology Conference, Washington, DC, June 2012.
3. Matthew R. Durose, Andrea M. Burch, Kelly Walsh, and Emily Tiry, *Publicly Funded Forensic Crime Laboratories: Resources and Services, 2014* (Washington, DC: U.S. Department of Justice, Bureau of Justice Statistics, November 2016), NCJ 250151, <https://www.bjs.gov/content/pub/pdf/pffclrs14.pdf>.
4. The tests used disk images from DigitalCorpora.org, a website of digital corpora for use in computer forensics education research that is funded through the National Science Foundation.
5. Simson L. Garfinkel, David J. Malan, Karl-Alexander Dubec, Christopher C. Stevens, and Cecile Pham, “Advanced Forensic Format: An Open Extensible Format for Disk Imaging,” in *Advances in Digital Forensics II*, ed. Martin S. Olivier and Sujeet Sheno (New York: Springer, 2006), 13-27.
6. The application dc3dd, created by the Department of Defense’s Cyber Crime Center, is capable of hashing files and disk blocks “on the fly” as a disk is being read. The application can be downloaded at SourceForge.
7. Apache Kafka is an open-source stream processing platform that provides a unified, high-throughput, low-latency platform for handling real-time data feeds.

8. Apache Spark provides an interface for programming entire clusters with implicit data parallelism and fault tolerance.
9. Kubernetes Cluster Manager is an open-source platform that automates deployment, scaling, and operations of applications on compute clusters. If the Kubernetes Cluster Manager is not used (e.g., if DFORC2 is deployed to a single server), then the user will fix the number of worker nodes performing forensics analysis tasks at runtime. Because of this, digital forensics analysts using DFORC2 would have to estimate the number of Apache Spark and Digital Evidence Search and Hash cluster worker nodes needed for a specific size of hard disk and for a specific type of investigation. The number of compute nodes needed could depend on many factors, which the analyst may not know before the investigation is started. This limitation would likely require the analyst to overprovision the cloud compute cluster to ensure timely processing of the evidence. The Kubernetes Cluster Manager solves this problem. It is designed to deploy or shut down cluster computing resources, depending on the level of demand on each virtual machine. Furthermore, it is compatible with a wide range of cloud-computing environments. The Kubernetes Cluster Manager can deploy applications on demand, scale applications while processes are running in containers (i.e., add additional worker nodes to compute tasks), and optimize hardware resources and limit costs by using only the resources needed.
10. The DFORC2 chain of custody relies on cryptographic hashes to verify the content of disk blocks and logical files found on the hard disk that is the subject of investigation. All disk blocks are hashed twice, first by dc3dd when the disk is read into DFORC2. This hashing takes place outside the cloud, on a local computer that is used to ingest the hard disk and stream it into the cloud. Autopsy then hashes the disk blocks a second time inside the cloud. These two hashes can be compared to prove that the copy of the disk in the cloud is identical to the disk block ingested from the original piece of evidence. Logical files are not hashed during data ingestion. However, they can be hashed on the local computer using an accepted standard digital forensics tool if this is required to verify evidence found in a specific file by DFORC2 in the cloud. All logical file hashes are retained by DFORC2 in the cloud to enable the analyst to trace the chain of custody for specific pieces of evidence on an as-needed basis.

NCJ 250700



POLICE

BODY ARMOR: PROTECTING OUR NATION'S OFFICERS FROM BALLISTIC THREATS

BY **MARK GREENE**

NIJ creates standards for body armor, oversees compliance testing to performance standards, and funds innovative research to help safeguard law enforcement officers.

Law enforcement is a dangerous profession. The Bureau of Labor Statistics reports that in 2007, police officers and sheriffs' patrol officers in the United States experienced an on-the-job fatality rate of approximately 20 in 100,000 officers — five times higher than the overall on-the-job fatality rate of four in 100,000 workers across all U.S. industries that year.¹

Firearms continue to be one of the most dangerous threats faced by U.S. law enforcement officers. Although a majority of accidental fatalities each year are traffic related, a majority of felonious fatalities are due to assaults with firearms. The FBI's Law Enforcement Officers Killed and Assaulted (LEOKA) statistics show that from 1987 through 2015, more than 70,000 officers were assaulted with firearms. Of the 1,708 officers feloniously killed in the line of duty during that period, 1,574 were killed by firearms. This means that 92 percent of all felonious deaths of officers in the line of duty were due to firearms.²

Body armor is critical safety equipment for officers' personal protection. Although there is no such thing as *bulletproof* armor, ballistic-resistant body armor can protect against many types of handgun and rifle ammunition (see sidebar, "Different Types of

Body Armor"). Since it was founded in 1987, the International Association of Chiefs of Police/DuPont Kevlar Survivors' Club has recognized more than 3,100 officers who have been saved from death or serious injury by wearing body armor.³

NIJ has been pivotal in the development of modern police body armor.⁴ NIJ establishes and updates voluntary minimum performance standards for body armor and operates a body armor certification program based on testing by accredited third-party ballistics laboratories. NIJ also sponsors research to better understand the impact of body armor and agency policies on our nation's public safety officers.

Quality Assurance

NIJ's predecessor, the National Institute of Law Enforcement and Criminal Justice (NILECJ), published the first performance standard for ballistic-resistant police body armor in 1972.⁵ NIJ then funded the development of body armor to meet that standard, followed by a field test and evaluation of approximately 5,000 sets of that armor, involving 15 law enforcement agencies in geographically diverse cities in 1975 and 1976.⁶ This field test had its first recorded body armor "save" on December 23, 1975,

Different Types of Body Armor

Protective vests for law enforcement officers include ballistic- and stab-resistant body armor that provides coverage and protection primarily for the torso. Different kinds of armor protect officers against different kinds of threats. Ballistic-resistant body armor protects against bullet penetrations and the blunt trauma associated with bullet impacts. These vests include soft body armor that protects against handgun bullets, and less flexible tactical armor composed of soft and hard components that protect against rifle bullets. Stab-resistant body armor protects against knives and spikes. Manufacturers also make combination armor that protects against both types of threats. When purchasing body armor, law enforcement agencies must consider the kinds of threats their officers will likely face and choose body armor with suitable properties to protect officers against those threats.

when an assailant shot a Seattle Police Department officer during an armed robbery at a local business. Several other officers in different participating cities were also saved during the field evaluation period.

Building on that success, NIJ established body armor compliance testing in 1978.⁷ Today, the NIJ Compliance Testing Program (CTP) provides confidence that body armor for use by U.S. law enforcement officers meets minimum performance requirements through standardized ballistic testing to current NIJ Standard 0101.06, *Ballistic Resistance of Body Armor*, published in 2008.⁸ Body armor manufacturers provide samples to an NIJ-approved laboratory in the United States that is accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) and pay the laboratory to conduct ballistic testing. When NIJ determines that the body armor is compliant, the model is added to a publicly available list of armor models for law enforcement use.⁹

NIJ's CTP is the recognized authority on body armor for law enforcement use — not only in the United States but across the world. Since testing body armor to the current standard began in 2009, a total of 1,194 unique armor models have been submitted for compliance testing (as of June 2018). Of these, 582 unique armor models have been found to be compliant; 114 of them are designed specifically for female officers. However, 315 unique armor

models have failed compliance testing due to ballistic test failures, and more than 50 additional models have failed because of inconsistent construction, underscoring the importance of independent testing and certification.

The CTP also includes a form of market surveillance — called Follow-up Inspection Testing (FIT) — to provide confidence that NIJ-certified armor models continue to be manufactured in compliance with the current NIJ standard. Manufacturers participating in the CTP currently manufacture body armor at 87 locations in 19 countries. Independent inspectors periodically visit manufacturing facilities and select body armor units from the production line. They send the units to NIJ-approved laboratories for ballistic testing, which sometimes uncovers issues with the body armor. For example, a manufacturer recalled more than 12,000 units from the field in 2016 because of issues uncovered by follow-up testing. NIJ removed the model from its compliant list.

Researching the Impact of Body Armor

In 2012, NIJ funded the National Opinion Research Center (NORC) to provide independent, evidence-based knowledge on the impact of body armor on officer safety.¹⁰ NORC analyzed detailed information from the FBI's LEOKA data set on 1,789 officers who were assaulted with firearms or knives/other cutting instruments and consequently killed or severely

injured between 2002 and 2011. The researchers looked specifically for cases in which officers were shot in the torso. They found that among the 637 officers who were shot in the torso, those who wore body armor were 76 percent less likely to be killed than those who did not wear armor (controlling for an array of individual and incident characteristics).¹¹

NORC also examined how the variation among law enforcement agencies' body armor policies may help explain the variation in officers' deaths and injuries across agencies.¹² The researchers looked at the state of body armor use policies — whether different agency profiles correlate with more or less rigorous policies, and whether these profiles can be predicted by agency characteristics and other factors. The researchers analyzed data provided by 2,719 U.S. law enforcement agencies in response to the 2013 Law Enforcement Management and Administrative Statistics (LEMAS) survey¹³ and found that agencies fall into four distinct profiles based on their body armor policies. Close to half of the agencies had comprehensive coverage of body armor policies in all aspects. Nearly one in five agencies had very weak body armor policies in all aspects. The rest of the agencies split into two groups: Half had strong body armor selection and fitting policies but relatively weak wearing, training, and inspection policies; the other half had strong wearing policies but weaker selection policies.

Finally, NORC examined trends over time in body armor wear policies and factors that predict change over time in these policies.¹⁴ Researchers analyzed data from responses to both the 2007 and 2013 LEMAS surveys from 724 law enforcement agencies with 100 or more officers. They found that agencies have increased their use of mandatory body armor wear policies, from 57.7 percent of agencies in 2007 to 78.4 percent in 2013. It should also be noted that since 2011, the Bureau of Justice Assistance has required that all agencies applying for Bulletproof Vest Partnership (BVP) program funds must have a written mandatory-wear policy for uniformed patrol officers, a factor that likely contributed to the observed increase in the wearing of body armor over time.¹⁵

These analyses demonstrate quantitatively that body armor is an effective tool for reducing harm from ballistic threats; the observed increase in body armor wear by the law enforcement community shows continued emphasis on officer safety. Agencies should continue to require that all purchased body armor — regardless of whether it is purchased with grant funds — be in compliance with NIJ standards and should continue to have strong written policies in place that make the wearing of body armor mandatory.

Revising the NIJ Standard

NIJ is currently working with state and local practitioners and ballistic testing laboratories to revise the standard for the ballistic resistance of body armor. The revised standard — anticipated to be published in 2019 as NIJ Standard 0101.07 — will include improved test methods for female body armor and updated body armor protection levels that incorporate additional rifle threats faced by U.S. law enforcement. NIJ Standard 0101.07 for body armor will also incorporate a stand-alone specification of ballistic threats for testing ballistic-resistant equipment for U.S. law enforcement applications.

NIJ, the National Institute of Standards and Technology, and the U.S. Army have been cooperating to harmonize laboratory test procedures and practices with ASTM,¹⁶ an accredited standards development organization that has published thousands of standards across numerous industries. Unlike the current and previous versions of the NIJ body armor standard, which have been stand-alone documents, NIJ Standard 0101.07 will incorporate, by reference, a suite of standardized test methods and practices developed through ASTM. This will harmonize laboratory test procedures and practices in the use of ballistic-resistant armor and other ballistic-resistant equipment across both law enforcement and military applications and allow these communities to have ultimate control over product specifications.

About the Author

Mark Greene, Ph.D., is the director of the Policy and Standards Division in NIJ's Office of Science and Technology.

For More Information

Read more about NIJ's body armor work at NIJ.ojp.gov, keyword: body armor.

Visit PoliceArmor.org for the latest information on how to select, wear, and care for body armor that meets the NIJ standard.

This article discusses the following grant:

- "Evaluating the Impact of the NIJ Body Armor Program," grant number 2012-R2-CX-K008
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Notes *from the Field*

Sharing Insights from Leaders in Criminal Justice

Research and evidence should always inform criminal justice decisions. But that's not always possible. Sometimes research on emerging issues isn't yet available, and leaders need to make quick decisions based on limited information.

Notes from the Field shares tactics and strategies from law enforcement executives and other on-the-ground leaders. It is not a research-based publication. Instead, this series of articles presents lessons learned from years of experience in law enforcement in areas such as the opioid epidemic, prison reform, violent crime, civil disturbance, and terrorism.

**Read *Notes from the Field* at [NIJ.ojp.gov](https://www.nij.ojp.gov),
keyword: notesfrom.**



RESEARCH IN THE RANKS: EMPOWERING LAW ENFORCEMENT TO DRIVE THEIR OWN SCIENTIFIC INQUIRY

BY **MAUREEN Q. MCGOUGH**

NIJ seeks to advance the law enforcement profession through science with its innovative LEADS Scholars and LEADS Agencies programs.

Law enforcement is increasingly expected to ground policies and practices in evidence, and evidence-based policing is rightfully encouraged as the new gold standard of practice. Somewhat absent from the discussion, however, has been the reality that most law enforcement agencies lack the capacity to identify and incorporate research results into policy and practice. Policy-relevant research results are often published only in academic journals (many of which are behind a paywall) that are written for an academic audience. As such, research articles are often full of jargon and fail to consider the relevance of the findings for on-the-ground application.

Although the relatively recent trend toward translational criminology has put a spotlight on the importance of collaboration between researchers and practitioners, much work remains to ensure that research is relevant to law enforcement practitioners, timely, accessible, and communicated effectively. Further, much of the existing research on policing focuses on larger departments in urban areas

(due largely to the benefits of a large sample size), with limited applicability to most of the agencies in this country. This leaves a large number of law enforcement agencies underserved and ill-equipped to ground their practices in relevant evidence.

NIJ has noted an increasing number of law enforcement officers — from those who are self-taught to those who pursue advanced degrees — who are taking matters into their own hands and self-producing the research needed to answer their agencies' high-priority questions about what works and what matters in policing. These efforts are often nimbly responsive to current priorities and narrowly tailored to specific agencies, negating many of the limitations of traditional research noted above.

To support these officers and acknowledge their unique role in advancing the law enforcement profession, NIJ has partnered with the International Association of Chiefs of Police (IACP) to create the Law Enforcement Advancing Data and Science (LEADS) Scholars program and the LEADS Agencies

The goal of the innovative LEADS Scholars and LEADS Agencies programs is to empower law enforcement officers throughout the country to answer many of their own high-priority research questions and proactively integrate existing research into their agencies' policies and practices.

program. The goal of both programs is to empower law enforcement officers throughout the country to answer many of their own research questions and proactively integrate existing research into their agencies' policies and practices.

The LEADS Scholars program works directly with law enforcement officers to create a community where research-minded officers can interact with like-minded professionals and jointly pursue research interests. Through this program, NIJ supports scholars' attendance at the annual IACP Conference, an NIJ policing research symposium in Washington, D.C., and the Center for Evidence-Based Crime Policy's annual symposium. NIJ also provides scholars with technical and substantive support for research projects, literature reviews, and connectivity to subject matter experts across a wide range of law enforcement issues. The program specifically aims to develop mid-rank officers, with the goal of supporting tomorrow's law enforcement leaders. (Hear from a current LEADS scholar in "Using Officer-Driven Research to Meet Policing Challenges," on page 33.)

Inspired by the dedication of the scholars and their significant impact within their departments and beyond, NIJ launched the LEADS Agencies program in 2017 to help agencies increase their effectiveness by improving internal capacity to collect and analyze data, conduct research, and use evidence to inform policies and practices. Currently in its first phase, the program is supporting evidence production and integration in eight police departments of varying sizes, capacities, and geographic locations. NIJ aims to integrate lessons learned and promising practices from these efforts into a practical guide for evidence-based policing later this year.

NIJ acknowledges that even practitioner-driven research has limits in applicability and suitability, and it is just one of many relevant factors to consider when developing policy and practice. However, there are no better judges of whether and how best to apply research to practice than the practitioners themselves, and NIJ is committed to ensuring that law enforcement has both the capacity and ability to make these crucial decisions moving forward.

About the Author

Maureen Q. McGough, J.D., is senior policy advisor in NIJ's Office of the Director.

For More Information

Learn more about the LEADS programs and the work of LEADS scholars over the years at NIJ.ojp.gov, keyword: LEADS.

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Using Officer Driven Research to Meet Policing Challenges

by **Lt. Jason Potts**

The challenges of implementing evidence-based policing are immense. Policing is a career in which relationship building and sound emotional intelligence are critical to success — but these elements are not necessarily scientifically based.

Policing is also highly nuanced and varies by agency based on the demographics it serves, its internal culture, and criminogenic issues particular to the agency's location.¹ The

United States has 18,000 police departments, and many of them have fewer than 10 officers as well as significant budgetary and resource limitations.² Given the variety in size, culture, and demographics among agencies, many law enforcement practices are based on traditions, experiences, and instincts that are indoctrinated through police academy and field training programs — these traditions are not typically based on data or research. This indoctrination is problematic, not only for its lack of empirical evidence but also because training may occur in unorganized, chaotic environments, with little standardization across the United States. A significant challenge in bringing research into the ranks of policing is addressing the anecdotal tradition of policing practices while still recognizing the significance of officer discretion.

Also, a distinct disconnect often exists between the policing research of academic researchers and the experiences of frontline officers.³ This researcher-practitioner disconnect is worsened by the slow pace of university research and the academic writing style scholars use in journals — journals that are rarely accessible to the broader law enforcement community. Further, officers typically do not have the time or interest to sift through lengthy academic articles full of theory and regression analysis. They want to know how the data may make them more efficient and effective.

Research partners from academia are not always accepted by the broader law enforcement community, so their advocacy of research findings is not heeded in the same way that it might be if it came from an officer within a department. If research-minded law enforcement officers arrive at and disseminate the benefits of research, other officers will likely be more willing to apply these evidence-based policies and best practices and perhaps see the value of engaging in research themselves.

To help bridge this divide, NIJ and the frontline officers of the newly formed American Society of Evidence-Based Policing (ASEBP) are leading practitioner-driven efforts to support research from within the ranks of policing. Now in its fourth year, NIJ's Law Enforcement Advancing Data and Science (LEADS) Scholars program has supported 40 research-oriented officers. NIJ also recently launched the LEADS Agencies program to provide research support to entire agencies. Meanwhile, ASEBP, which held its second conference in May 2018, has 250 members and more than 3,000 followers on Twitter — proof that the evidence-based policing movement is ready to grow exponentially. The NIJ LEADS scholars



Lt. Jason Potts

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and members of ASEBP are actively involved in research at their departments; they are looking to transform the law enforcement culture into one that accepts and uses evidence-based practices.

For example, I recently completed a randomized controlled trial — in partnership with BetaGov, a nonprofit organization based at New York University that emphasizes homegrown practitioner-led trials — to test the effectiveness of automatic license plate readers (LPRs).⁴ The results indicated that patrol cars equipped with automatic LPRs (the treatment group) had a 140-percent improvement in ability to detect stolen cars versus patrol cars in which the automatic LPR technology was turned off (the control group). Further analysis of the data revealed, however, that the LPR technology identified more lost or stolen plates than the controls — as many as eight times more. Many of these were duplicates that desensitized officers to legitimate hits. The data also showed that fixed LPRs were much more efficient in making arrests than mobile LPRs. Finally, the control data showed that 35 percent of all hits were misreads.

The power of this randomized controlled trial was the simplicity of its design to inform policy; other law enforcement agencies can replicate it for future comparison. In fact, as part of this work we conducted an officer survey, which had a 75-percent response rate. Of note was that only one out of 37 officers stated that he would *not* participate in a similar study in the future.

Fellow NIJ LEADS scholar and founding ASEBP member Sgt. Greg Stewart (Portland Police Department) recently completed another randomized controlled trial to ascertain what patrol dosage in a particular hotspot area is needed for crime prevention and police legitimacy efforts. The results indicated that treatment areas did not experience any difference in crime or calls for service when compared with controls.⁵

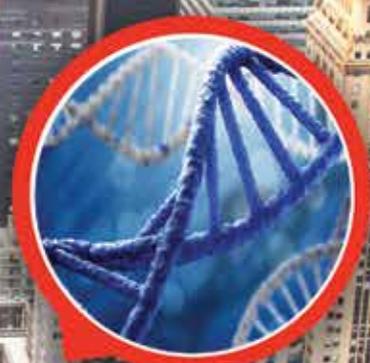
Law enforcement officers want to be trusted while coming to sound decisions through their own discretion — they do not want to be second-guessed. Some officers seem to perceive emerging technologies like body-worn cameras as doing just that. Change in any profession is difficult, but discretion and the autonomy of policing continue to be important. By allowing for discretion, we empower and show trust in our officers. This is vital because much of what they do is constrained by time, and these time constraints are often uncertain and rapidly evolving. These dynamic demands require law enforcement to shift priorities, using discretion paired with informed, sound policy.⁶ Much of what law enforcement does is rooted in training, anecdotal experiences, and good instincts. However, research should play a large part in responding to the day-to-day challenges of policing. The hope is that data and science, coupled with the craft of policing and leadership support for evidence-based policing, will empower officers with the evidence to be more effective.⁷

About the Author

Jason Potts is a lieutenant with the Vallejo (CA) Police Department, an NIJ LEADS scholar, an ASEBP board member, a Police Foundation Fellow, and a reserve special agent with the Coast Guard Investigative Service. He earned a master of advanced studies degree in criminology, law, and society from the University of California, Irvine.

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USING ARTIFICIAL INTELLIGENCE TO ADDRESS CRIMINAL JUSTICE NEEDS

BY CHRISTOPHER RIGANO

NIJ is committed to realizing the full potential of artificial intelligence to promote public safety and reduce crime.

“Intelligent machines” have long been the subject of science fiction. However, we now live in an era in which artificial intelligence (AI) is a reality, and it is having very real and deep impacts on our daily lives. From phones to cars to finances and medical care, AI is shifting the way we live.

AI applications can be found in many aspects of our lives, from agriculture to industry, communications, education, finance, government, service, manufacturing, medicine, and transportation. Even public safety and criminal justice are benefiting from AI. For example, traffic safety systems identify violations and enforce the rules of the road, and crime forecasts allow for more efficient allocation of policing resources. AI is also helping to identify the potential for an individual under criminal justice supervision to reoffend.¹

Research supported by NIJ is helping to lead the way in applying AI to address criminal justice needs, such as identifying individuals and their actions in videos relating to criminal activity or public safety, DNA analysis, gunshot detection, and crime forecasting.

What Is Artificial Intelligence?

AI is a rapidly advancing field of computer science. In the mid-1950s, John McCarthy, who has been credited as the father of AI, defined it as “the science and engineering of making intelligent machines” (see sidebar, “A Brief History of Artificial Intelligence”).² Conceptually, AI is the ability of a machine to perceive and respond to its environment independently and perform tasks that would typically require human intelligence and decision-making processes, but without direct human intervention.

One facet of human intelligence is the ability to learn from experience. Machine learning is an application of AI that mimics this ability and enables machines and their software to learn from experience.³ Particularly important from the criminal justice perspective is pattern recognition. Humans are efficient at recognizing patterns and, through experience, we learn to differentiate objects, people, complex human emotions, information, and conditions on a daily basis. AI seeks to replicate this human capability in software algorithms and computer hardware. For example, self-learning algorithms use data sets to understand how to identify people based on their images, complete

Artificial intelligence has the potential to be a permanent part of our criminal justice ecosystem, providing investigative assistance and allowing criminal justice professionals to better maintain public safety.

intricate computational and robotics tasks, understand purchasing habits and patterns online, detect medical conditions from complex radiological scans, and make stock market predictions.

Applications for Criminal Justice and Public Safety

AI is being researched as a public safety resource in numerous ways. One particular AI application — facial recognition — can be found everywhere in both the public and the private sectors (see sidebar, “The National Artificial Intelligence Research and Development Strategic Plan”).⁴ Intelligence analysts, for example, often rely on facial images to help establish an individual’s identity and whereabouts. Examining the huge volume of possibly relevant images and videos in an accurate and timely manner is a time-consuming, painstaking task, with the potential for human error due to fatigue and other factors. Unlike humans, machines do not tire. Through initiatives such as the Intelligence Advanced Research Projects Activity’s Janus computer-vision project, analysts are performing trials on the use of algorithms that can learn how to distinguish one person from another using facial features in the same manner as a human analyst.⁵

The U.S. Department of Transportation is also looking to increase public safety through researching, developing, and testing automatic traffic accident detection based on video to help maintain safe and

efficient commuter traffic over various locations and weather, lighting, and traffic conditions.⁶ AI algorithms are being used in medicine to interpret radiological images, which could have important implications for the criminal justice and medical examiner communities when establishing cause and manner of death.⁷ AI algorithms have also been explored in various disciplines in forensic science, including DNA analysis.⁸

AI is also quickly becoming an important technology in fraud detection.⁹ Internet companies like PayPal stay ahead of fraud attempts by using volumes of data to continuously train their fraud detection algorithms to predict and recognize anomalous patterns and to learn to recognize new patterns.¹⁰

NIJ’s Artificial Intelligence Research Portfolio

The AI research that NIJ supports falls primarily into four areas: public safety video and image analysis, DNA analysis, gunshot detection, and crime forecasting.

Public safety video and image analysis

Video and image analysis is used in the criminal justice and law enforcement communities to obtain information regarding people, objects, and actions to support criminal investigations. However, the analysis of video and image information is very labor-intensive, requiring a significant investment in personnel with subject matter expertise. Video and image analysis is also prone to human error due to the sheer volume of information, the fast pace of changing technologies such as smartphones and operating systems, and a limited number of specialized personnel with the knowledge to process such information.

AI technologies provide the capacity to overcome such human errors and to function as experts. Traditional software algorithms that assist humans are limited to predetermined features such as eye shape, eye color, and distance between eyes for facial recognition or demographics information for pattern analysis. AI video and image algorithms not only learn complex

tasks but also develop and determine their own independent complex facial recognition features/parameters to accomplish these tasks, beyond what humans may consider. These algorithms have the potential to match faces, identify weapons and other objects, and detect complex events such as accidents and crimes (in progress or after the fact).

In response to the needs of the criminal justice and law enforcement communities, NIJ has invested in several areas to improve the speed, quality, and specificity of data collection, imaging, and analysis and to improve contextual information.

For instance, to understand the potential benefits of AI in terms of speed, researchers at the University of Texas at Dallas, with funding from NIJ and in partnership with the FBI and the National Institute of Standards and Technology, are assessing facial identification by humans and examining methods for effectively comparing AI algorithms and expert facial examiners. Preliminary results show that when the researchers limit the recognition time to 30 seconds, AI-based facial-recognition algorithms developed in 2017 perform comparably to human facial examiners.¹¹ The implications of these findings are that AI-based algorithms can potentially be used as a “second pair of eyes” to increase the accuracy of expert human facial examiners and to triage data to increase productivity.

In addition, in response to the need for higher quality information and the ability to use lower quality images more effectively, Carnegie Mellon University is using NIJ funding to develop AI algorithms to improve detection, recognition, and identification. One particularly important aspect is the university’s work on images in which an individual’s face is captured at different angles or is partially to the side, and when the individual is looking away from the camera, obscured by masks or helmets, or blocked by lamp posts or lighting. The researchers are also working with low-quality facial image construction, including images with poor resolution and low ambient light levels, where the image quality makes facial matching difficult. NIJ’s test and evaluation center is currently testing and evaluating these algorithms.¹²

Finally, to decipher a license plate (which could help identify a suspect or aid in an investigation) or identify a person in extremely low-quality images or video, researchers at Dartmouth College are using AI algorithms that systematically degrade high-quality images and compare them with low-quality ones to better recognize lower quality images and video. For example, clear images of numbers and letters are slowly degraded to emulate low-quality images. The degraded images are then expressed and catalogued as mathematical representations. These degraded mathematical representations can then be compared with low-quality license plate images to help identify the license plate.¹³

Also being explored is the notion of “scene understanding,” or the ability to develop text that describes the relationship between objects (people, places, and things) in a series of images to provide context. For example, the text may be “Pistol being drawn by a person and discharging into a store window.” The goal is to detect objects and activities that will help identify crimes in progress for live observation and intervention as well as to support investigations after the fact.¹⁴ Scene understanding over multiple scenes can indicate potentially important events that law enforcement should view to confirm and follow. One group of researchers at the University of Central Florida, in partnership with the Orlando Police Department, is using NIJ funding to develop algorithms to identify objects in videos, such as people, cars, weapons, and buildings, without human intervention. They are also developing algorithms to identify actions such as traffic accidents and violent crimes.

Another important aspect of AI is the ability to predict behavior. In contrast to the imaging and identification of criminal activity in progress, the University of Houston has used NIJ funding to develop algorithms that provide continuous monitoring to assess activity and predict emergent suspicious and criminal behavior across a network of cameras. This work also concentrates on using clothing, skeletal structure, movement, and direction prediction to identify and reacquire people of interest across multiple cameras and images.¹⁵

A Brief History of Artificial Intelligence

1950: Alan Turing publishes his paper on creating thinking machines.¹

1956: John McCarthy presents his definition of artificial intelligence.²

1956-1974: Reason searches or means-to-end algorithms were first developed to “walk” simple decision paths and make decisions.³ Such approaches provided the ability to solve complex mathematical expressions and process strings of words. The word processing is known as natural language processing. These approaches led to the ability to formulate logic and rules to interpret and formulate sentences and also marked the beginning of game theory, which was realized in basic computer games.⁴

1980-1987: Complex systems were developed using logic rules and reasoning algorithms that mimic human experts. This began the rise of expert systems, such as decision support tools that learned the “rules” of a specific knowledge domain like those that a physician would follow when performing a medical diagnosis.⁵ Such systems were capable of complex reasoning but, unlike humans, they could not learn new rules to evolve and expand their decision-making.⁶

1993-2009: Biologically inspired software known as “neural networks” came on the scene. These networks mimic the way living things learn how to identify complex patterns and, in doing so, can complete complex tasks. Character recognition for license plate readers was one of the first applications.⁷

2010-present: Deep learning and big data are now in the limelight. Affordable graphical processing units from the gaming industry have enabled neural networks to be trained using big data.⁸ Layering these networks mimics how humans learn to recognize and categorize simple patterns into complex patterns. This software is being applied in automated facial and object detection and recognition as well as medical image diagnostics, financial patterns, and governance regulations.⁹ Projects such as Life Long Learning Machines, from the Defense Advanced Research Projects Agency, seek to further advance AI algorithms toward learning continuously in ways similar to those of humans.¹⁰

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DNA analysis

AI can also benefit the law enforcement community from a scientific and evidence processing standpoint. This is particularly true in forensic DNA testing, which has had an unprecedented impact on the criminal justice system over the past several decades.

Biological material, such as blood, saliva, semen, and skin cells, can be transferred through contact with people and objects during the commission of a crime. As DNA technology has advanced, so has the sensitivity of DNA analysis, allowing forensic scientists to detect and process low-level, degraded, or otherwise unviable DNA evidence that could not have been used previously. For example, decades-old DNA evidence from violent crimes such as sexual assaults and homicide cold cases is now being submitted to laboratories for analysis. As a result of increased sensitivity, smaller amounts of DNA can be detected, which leads to the possibility of detecting DNA from multiple contributors, even at very low levels. These and other developments are presenting new challenges for crime laboratories. For instance, when using highly sensitive methods on items of evidence, it may be possible to detect DNA from multiple perpetrators or from someone not associated with the crime at all — thus creating the issue of DNA mixture interpretation and the need to separate and identify (or "deconvolute") individual profiles to generate critical investigative leads for law enforcement.

AI may have the potential to address this challenge. DNA analysis produces large amounts of complex data in electronic format; these data contain patterns, some of which may be beyond the range of human

analysis but may prove useful as systems increase in sensitivity. To explore this area, researchers at Syracuse University partnered with the Onondaga County Center for Forensic Sciences and the New York City Office of Chief Medical Examiner's Department of Forensic Biology to investigate a novel machine learning-based method of mixture deconvolution. With an NIJ research award, the Syracuse University team worked to combine the strengths of approaches involving human analysts with data mining and AI algorithms. The team used this hybrid approach to separate and identify individual DNA profiles to minimize the potential weaknesses inherent in using one approach in isolation. Although ongoing evaluation of the use of AI techniques is needed and there are many factors that can influence the ability to parse out individual DNA donors, research shows that AI technology has the potential to assist in these complicated analyses.¹⁶

Gunshot detection

The discovery of pattern signatures in gunshot analysis offers another area in which to use AI algorithms. In one project, NIJ funded Cadre Research Labs, LLC, to analyze gunshot audio files from smartphones and smart devices "based on the observation that the content and quality of gunshot recordings are influenced by firearm and ammunition type, the scene geometry, and the recording device used."¹⁷ Using a well-defined mathematical model, the Cadre scientists are working to develop algorithms to detect gunshots, differentiate muzzle blasts from shock waves, determine shot-to-shot timings, determine the number of firearms present, assign specific shots to firearms, and estimate probabilities

The National Artificial Intelligence Research and Development Strategic Plan

On May 3, 2016, the White House announced a series of actions to spur public dialogue on artificial intelligence (AI), identify challenges and opportunities related to this technology, aid in the use of AI for more effective government, and prepare for the potential benefits and risks of AI. As part of these actions, the White House directed the creation of a national strategy for AI research and development. Following is a summary of the plan's areas and intent.¹

Manufacturing

- Increase U.S. manufacturing by using robotics
- Improve worker health and safety
- Improve product quality and reduce costs
- Accelerate production capabilities
- Improve demand forecasting
- Increase flexibility in operations and the supply chain
- Predict impacts to manufacturing operations
- Improve scheduling of processes and reduce inventory requirements

Logistics

- Improve supply chains with adaptive scheduling and routing
- Provide more robust supply chains

Finance

- Allow early detection of risk
- Reduce malicious behavior and fraud
- Increase efficiency and reduce volatility
- Prevent systemic failures

Transportation

- Improve structural health monitoring and infrastructure management
- Reduce the cost of repair and reconstruction
- Make vehicular travel safer
- Provide real-time route information
- Improve transportation networks and reduce emissions

Agriculture

- Improve production, processing, and storage
- Improve distribution and consumption of agricultural products
- Gather data about crops to remove weeds and pests more efficiently
- Apply treatments (water, fertilizer, etc.) strategically
- Fill labor gaps

Marketing

- Provide a better match of supply with demand
- Drive up revenue for private-sector development
- Anticipate consumer needs, and find products and services
- Reduce costs

Communications

- Maximize efficient bandwidth use
- Automate information storage and retrieval
- Improve filter, search, translation, and summarization functions

Science and Technology

- Assist in knowledge accumulation
- Refine theories
- Generate hypotheses and perform experiments using simulations

Education

- Provide automated tutoring and instruction
- Improve personalized programs and evaluation
- Provide life-long learning and new skills for the total population

Medicine

- Use bioinformatics to identify genetic risk from large-scale studies
- Predict safety and efficacy of pharmaceuticals
- Develop new pharmaceutical compounds
- Customize medicine
- Diagnose conditions and recommend treatment

Law

- Analyze case law history
- Assist with discovery process
- Summarize evidence

Personal Services

- Provide natural language systems for an easier interface and user experience
- Provide automated personal assistants
- Allow group scheduling

Security and Law Enforcement

- Detect patterns and anomalous behavior
- Predict crowd behavior and crime patterns
- Protect critical infrastructure
- Uncover criminal networks

Safety and Prediction

- Predict infrastructure disruptions with distributed sensor systems and pattern information
- Adapt operations for minimal impact

Note

1. Networking and Information Technology Research and Development Subcommittee of the National Science and Technology Council, *National Artificial Intelligence Research and Development Strategic Plan*, Office of Science and Technology Policy, October 2016, 8-11.

of class and caliber — all of which could help law enforcement in investigations.¹⁸

Crime forecasting

Predictive analysis is a complex process that uses large volumes of data to forecast and formulate potential outcomes. In criminal justice, this job rests mainly with police, probation practitioners, and other professionals, who must gain expertise over many years. The work is time-consuming and subject to bias and error.¹⁹

With AI, volumes of information on law and legal precedence, social information, and media can be used to suggest rulings, identify criminal enterprises, and predict and reveal people at risk from criminal enterprises. NIJ-supported researchers at the University of Pittsburgh are investigating and designing computational approaches to statutory

interpretation that could potentially increase the speed and quality of statutory interpretation performed by judges, attorneys, prosecutors, administrative staff, and other professionals. The researchers hypothesize that a computer program can automatically recognize specific types of statements that play the most important roles in statutory interpretation. The goal is to develop a proof-of-concept expert system to support interpretation and perform it automatically for cybercrime.²⁰

AI is also capable of analyzing large volumes of criminal justice-related records to predict potential criminal recidivism. Researchers at the Research Triangle Institute, in partnership with the Durham Police Department and the Anne Arundel County (Maryland) Sheriff’s Office, are working to create an automated warrant service triage tool for the North Carolina Statewide Warrant Repository. The

NIJ-supported team is using algorithms to analyze data sets with more than 340,000 warrant records. The algorithms form decision trees and perform survival analysis to determine the time span until the next occurrence of an event of interest and predict the risk of reoffending for absconding offenders (if a warrant goes unserved). This model will help practitioners triage warrant service when backlogs exist. The resulting tool will also be geographically referenced so that practitioners can pursue concentrations of high-risk absconders — along with others who have active warrants — to optimize resources.²¹

AI can also help determine potential elder victims of physical and financial abuse. NIJ-funded researchers at the University of Texas Health Science Center at Houston used AI algorithms to analyze elder victimization. The algorithms can determine the victim, perpetrator, and environmental factors that distinguish between financial exploitation and other forms of elder abuse. They can also differentiate “pure” financial exploitation (when the victim of financial exploitation experiences no other abuse) from “hybrid” financial exploitation (when physical abuse or neglect accompanies financial exploitation). The researchers hope that these data algorithms can be transformed into web-based applications so that practitioners can reliably determine the likelihood that financial exploitation is occurring and quickly intervene.²²

Finally, AI is being used to predict potential victims of violent crime based on associations and behavior. The Chicago Police Department and the Illinois Institute of Technology used algorithms to collect information and form initial groupings that focus on constructing social networks and performing analysis to determine potential high-risk individuals. This NIJ-supported research has since become a part of the Chicago Police Department’s Violence Reduction Strategy.²³

The Future of AI in Criminal Justice

Every day holds the potential for new AI applications in criminal justice, paving the way for future possibilities to assist in the criminal justice system and ultimately improve public safety.

Video analytics for integrated facial recognition, the detection of individuals in multiple locations via closed-circuit television or across multiple cameras, and object and activity detection could prevent crimes through movement and pattern analysis, recognize crimes in progress, and help investigators identify suspects. With technology such as cameras, video, and social media generating massive volumes of data, AI could detect crimes that would otherwise go undetected and help ensure greater public safety by investigating potential criminal activity, thus increasing community confidence in law enforcement and the criminal justice system. AI also has the potential to assist the nation’s crime laboratories in areas such as complex DNA mixture analysis.

Pattern analysis of data could be used to disrupt, degrade, and prosecute crimes and criminal enterprises. Algorithms could also help prevent victims and potential offenders from falling into criminal pursuits and assist criminal justice professionals in safeguarding the public in ways never before imagined.

AI technology also has the potential to provide law enforcement with situational awareness and context, thus aiding in police well-being due to better informed responses to possibly dangerous situations. Technology that includes robotics and drones could also perform public safety surveillance, be integrated into overall public safety systems, and provide a safe alternative to putting police and the public in harm’s way. Robotics and drones could also perform recovery, provide valuable intelligence, and augment criminal justice professionals in ways not yet contrived.

By using AI and predictive policing analytics integrated with computer-aided response and live public safety video enterprises, law enforcement will be better able to respond to incidents, prevent threats, stage interventions, divert resources, and investigate and analyze criminal activity. AI has the potential to be a permanent part of our criminal justice ecosystem, providing investigative assistance and allowing criminal justice professionals to better maintain public safety.

About the Author

Christopher Rigano is a senior computer scientist in NIJ's Office of Science and Technology.

This article discusses the following grants:

- "Design and Implementation of Forensic Facial Identification Experts Test," grant number 2015-IJ-CX-K014
 - "A Simultaneous Low Resolution and Off-Pose Angle Face Matching Algorithm as an Investigative Lead Generative Tool for Law Enforcement," grant number 2013-IJ-CX-K005
 - "Studying the Impact of Video Analytics for Pre, Live and Post Event Analysis on Outcomes of Criminal Justice," grant number 2015-R2-CX-K025
 - "Learning Models for Predictive Behavioral Intent and Activity Analysis in Wide Area Video Surveillance," grant number 2009-MU-MU-K004
 - "DeGrade It," grant number 2016-R2-CX-0012
 - "A Hybrid Machine Learning Approach for DNA Mixture Interpretation," grant number 2014-DN-BX-K029
 - "Development of Computational Methods for the Audio Analysis of Gunshots," grant number 2016-DN-BX-0183
 - "A Recommendation System for Statutory Interpretation in Cybercrime," grant number 2016-R2-CX-0010
 - "Applying Data Science To Justice Systems: The North Carolina Statewide Warrant Repository (NCAWARE)," grant number 2015-IJ-CX-K016
 - "Elder Financial Exploitation Victimization," grant number 2013-IJ-CX-0050
 - "Chicago Police Predictive Policing Demonstration and Evaluation Project," grant number 2011-IJ-CX-K014
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12. "A Simultaneous Low Resolution and Off-Pose Angle Face Matching Algorithm as an Investigative Lead Generative Tool for Law Enforcement" at Carnegie Mellon University, NIJ award number 2013-IJ-CX-K005.
13. "DeGrade It" at Dartmouth College, NIJ award number 2016-R2-CX-0012.
14. "Studying the Impact of Video Analytics for Pre, Live and Post Event Analysis on Outcomes of Criminal Justice" at the University of Central Florida, NIJ award number 2015-R2-CX-K025.

15. "Learning Models for Predictive Behavioral Intent and Activity Analysis in Wide Area Video Surveillance" at the University of Houston, NIJ award number 2009-MU-MU-K004.
16. "A Hybrid Machine Learning Approach for DNA Mixture Interpretation" at Syracuse University, NIJ award number 2014-DN-BX-K029.
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21. "Applying Data Science to Justice Systems: The North Carolina Statewide Warrant Repository (NCAWARE)" at RTI International, NIJ award number 2015-IJ-CX-K016.
22. "Exploring Elder Financial Exploitation Victimization" at the University of Texas Health Science Center at Houston, NIJ award number 2013-IJ-CX-0050.
23. "Chicago Police Predictive Policing Demonstration and Evaluation Project" at the Chicago Police Department and Illinois Institute of Technology, NIJ award number 2011-IJ-CX-K014.

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BODY-WORN CAMERAS: WHAT THE EVIDENCE TELLS US

BY **BRETT CHAPMAN**

Current research suggests that body-worn cameras may offer benefits for law enforcement. However, additional research is needed to understand the value of the technology for the field.

In 1829, Sir Robert Peel — regarded by many as the father of modern policing — developed what came to be known as the Nine Principles of Law Enforcement, which were given to British law enforcement officers as general instructions. Peel's second principle stated, "The ability of the police to perform their duties is dependent upon *public approval* of police existence, actions, behavior and the ability of the police to secure and maintain *public respect*."¹

Nearly 200 years later, Peel's principle still holds true: The ability of law enforcement to fight crime effectively continues to depend on the public's perception of the legitimacy of the actions of officers. A number of recent civil disturbances across the United States subsequent to instances of lethal use of force by officers highlight the ongoing challenges in maintaining the public's perceptions of law enforcement legitimacy, particularly as it concerns the use of force.

Body-worn cameras have been viewed as one way to address these challenges and improve law enforcement practice more generally. The technology, which can be mounted on an officer's eyeglasses or chest area, offers real-time information when used by officers on patrol or other assignments that bring them into contact with members of the community. Another benefit of body-worn cameras is their ability to provide law enforcement with a surveillance tool to promote officer safety and efficiency and prevent crime.

This technology has diffused rapidly across the United States. In 2013, approximately one-third of U.S. municipal police departments had implemented the use of body-worn cameras.² Members of the general public also continue to embrace the technology. But what does the research tell us? Current studies suggest that body-worn cameras may offer benefits for law enforcement, but additional research is needed to more fully understand the value of the technology for the field.

Potential Benefits

Proponents of body-worn cameras point to several potential benefits.

Better transparency. First, body-worn cameras may result in better transparency and accountability and thus may improve law enforcement legitimacy. In many communities, there is a lack of trust and confidence in law enforcement. This lack of confidence is exacerbated by questions about encounters between officers and community members that often involve the use of deadly or less-lethal force. Video footage captured during these officer-community interactions might provide better documentation to help confirm the nature of events and support accounts articulated by officers and community residents.³

Increased civility. Body-worn cameras may also result in higher rates of citizen compliance to officer

commands during encounters and fewer complaints lodged against law enforcement. Citizens often change their behavior toward officers when they are informed that the encounter is being recorded. This “civilizing effect” may prevent certain situations from escalating to levels requiring the use of force and also improve interactions between officers and citizens.⁴

Quicker resolution. Body-worn cameras may lead to a faster resolution of citizen complaints and lawsuits that allege excessive use of force and other forms of officer misconduct. Investigations of cases that involve inconsistent accounts of the encounter from officers and citizens are often found to be “not sustained” and are subsequently closed when there is no video footage nor independent or corroborating witnesses. This, in turn, can decrease the public’s trust and confidence in law enforcement and increase perceptions that claims of abuse brought against officers will not be properly addressed. Video captured by body-worn cameras may help corroborate the facts of the encounter and result in a quicker resolution.

Corroborating evidence. Footage captured may also be used as evidence in arrests or prosecutions. Proponents have suggested that video captured by body-worn cameras may help document the occurrence and nature of various types of crime, reduce the overall amount of time required for officers to complete paperwork for case files, corroborate evidence presented by prosecutors, and lead to higher numbers of guilty pleas in court proceedings.

Training opportunities. The use of body-worn cameras also offers potential opportunities to advance policing through training. Law enforcement trainers and executives can assess officer activities and behavior captured by body-worn cameras — either through self-initiated investigations or those that result from calls for service — to advance professionalism among officers and new recruits. Finally, video footage can provide law enforcement executives with opportunities to implement new strategies and assess the extent to which officers carry out their duties in a manner that is consistent with the assigned initiatives.

Current Research Findings

The increasing use of body-worn cameras by law enforcement agencies has significantly outpaced the body of research examining the relationship between the technology and law enforcement outcomes. As detailed below, although early evaluations of this technology had limitations, some notable recent research has helped advance our knowledge of the impact of body-worn cameras.

In a 2014 study funded by the Office of Justice Programs Diagnostic Center, researcher Michael White noted that earlier evaluations of body-worn cameras found a number of beneficial outcomes for law enforcement agencies.⁵ The earliest studies conducted in the United Kingdom indicated that body-worn cameras resulted in positive interactions between officers and citizens and made people feel safer. Reductions in citizen complaints were noted, as were similar reductions in crime. The studies found that the use of body-worn cameras led to increases in arrests, prosecutions, and guilty pleas.⁶ From an efficiency standpoint, the use of the technology reportedly enabled officers to resolve criminal cases faster and spend less time preparing paperwork, and it resulted in fewer people choosing to go to trial.

Studies that followed in the United States also provided support for body-worn cameras; however, a number of them were plagued with dubious approaches that called the findings into question. According to White, the few studies that were conducted between 2007 and 2013 had methodological limitations or were conducted in a manner that raised concerns about research independence. For example, several studies included small sample sizes or lacked proper control groups to compare officers wearing body-worn cameras with officers not wearing them. Some studies were conducted by the participating law enforcement agency and lacked an independent evaluator. Finally, a number of the studies focused narrowly on officer or citizen perceptions of body-worn cameras instead of other critical outcomes, such as citizen compliance

and officer or citizen behavior in instances involving use of force.

Over time, scientific rigor improved, and studies conducted in U.S. law enforcement agencies produced findings that indicated promising support for body-worn cameras. For example, in 2014, researchers at Arizona State University (funded through the Bureau of Justice Assistance's Smart Policing Initiative) found that officers with body-worn cameras were more productive in terms of making arrests, had fewer complaints lodged against them relative to officers without body-worn cameras, and had higher numbers of citizen complaints resolved in their favor.⁷ Another study conducted with the Rialto (California) Police Department noted similar decreases in citizen complaints lodged against officers wearing body-worn cameras as well as decreases in use-of-force incidents by the police.⁸ In addition, Justin Ready and Jacob Young from Arizona State University found that officers with body-worn cameras were more cautious in their actions and sensitive to possible scrutiny of video footage by their superiors. Also, contrary to initial concerns, officers who wore cameras were found to have higher numbers of self-initiated contacts with community residents than officers who did not wear cameras.⁹

Recent randomized controlled trials, which are considered the scientific gold standard for evaluating programs, have also been conducted on body-worn cameras. Of the various scientific methods available, these trials have the greatest likelihood of producing sound evidence because random assignment is able to isolate a specific treatment of interest from all of the other factors that influence any given outcome. In a 2016 global, multisite randomized controlled trial, Barak Ariel and colleagues found that use-of-force incidents may be related to the discretion given to officers regarding when body-worn cameras are activated during officer-citizen encounters. The researchers found decreases in use-of-force incidents when officers activated their cameras upon arrival at the scene. Alternatively, use-of-force incidents by officers with body-worn cameras increased when

the officers had the discretion to determine when to activate their cameras during citizen interactions.¹⁰

In 2017, with NIJ support, researchers from CNA conducted a randomized controlled trial on 400 police officers in the Las Vegas Metropolitan Police Department. The research team found that officers with body-worn cameras generated fewer use-of-force reports and complaints from citizens compared to officers without body-worn cameras. Additionally, officers with body-worn cameras issued higher numbers of arrests and citations compared to officers without body-worn cameras.¹¹

More Research Is Needed

An increasing number of studies have emerged to help fill knowledge gaps in the current body of research on body-worn cameras. Researchers at George Mason University noted that 14 studies have been completed and at least 30 others are currently examining the impact of body-worn cameras on various outcomes.¹² The most common outcomes examined include the impact of body-worn cameras on the quality of officer-citizen interactions measured by the nature of the communication, displays of procedural justice and professionalism, and misconduct or corruption; use of force by officers; attitudes about body-worn cameras; citizen satisfaction with law enforcement encounters; perceptions of law enforcement and legitimacy; suspect compliance with officer commands; and criminal investigations and law enforcement-initiated activity.¹³

However, knowledge gaps still exist. The George Mason University researchers highlighted the need to examine organizational concerns regarding body-worn cameras. For example, little attention has been focused on improvements in training and organizational policies. Additional information is also needed on how body-worn cameras can help facilitate investigations of officer-involved shootings or other critical incidents, and on the value of video footage captured by body-worn cameras in court proceedings.

Current research varies by level of rigor and methods used, but the results continue to help law enforcement executives decide whether to adopt this technology in their agencies. Overall, the research on body-worn cameras suggests that the technology may offer potential benefits for law enforcement. However, the true extent of its value will depend on the continuation of research studies to keep pace with the growing adoption and implementation of body-worn cameras by law enforcement agencies in the United States.

About the Author

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For More Information

Read more about NIJ's work in body-worn cameras at NIJ.ojp.gov, keyword: body-worn.

Visit the Bureau of Justice Assistance's Body-Worn Camera Toolkit at <https://www.bja.gov/bwc>.

This article discusses the following grant:

- "Research on the Impact of Technology on Policing Strategies," grant number 2013-IJ-CX-0016

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