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Final Summary Overview

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Abstract

This publication represents a technical summary report of the Urban Institute's evaluation of the implementation, use, and impact of Gunshot Detection Technology (GDT) by law enforcement agencies in three cities: Denver, CO; Milwaukee, WI; and Richmond, CA. The goal of this study was to conduct a rigorous process and impact evaluation of GDT to inform policing researchers and practitioners about the impact GDT may have. To achieve this goal, we implemented a mixed-methods research design. Qualitative data collection included 46 interviews with criminal justice stakeholders to learn implementation processes and challenges associated with its GDT, and 6 focus groups with 49 community members to learn how residents feel about policing efforts to reduce firearm violence and its use of GDT. Quantitative data collection included administrative data on calls for service (CFS), crime, and GDT alerts, as well as comprehensive case file reviews of 174 crimes involving a firearm. Quantitative analyses examined the impact of GDT by (1) comparing counts of gunshot notifications for GDT alerts to shooting-related CFS, (2) comparing response times of GDT alerts to shooting-related CFS, (3) examining the impact GDT has had on CFS and crimes, and (4) conducting a cost-benefit analysis of the GDT. Evaluation findings suggest that GDT is generally but not consistently associated with faster response times and more evidence collection, with impact on crime more uneven but generally cost-beneficial. We also conclude that agencies should implement GDT sensors strategically, train officers thoroughly, ensure that GDT data are used and integrated with other systems, and engage with community members early and often. More detailed information from this study will be available in forthcoming journal articles.

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Introduction and Purpose

In 2015, the National Institute of Justice (NIJ) funded the Urban Institute (Urban) to investigate the degree to which gunshot detection technology (GDT) aids in the response, investigation, and prevention of firearms violence and related crime. GDT consists of a network of acoustic sensors strategically placed throughout an area with high levels of firearm crimes. Sensors are installed in high locations (e.g., on top of buildings or light poles) with unobstructed paths to other nearby sensors to improve triangulations of identified gunshots. The technology has the capability of detecting whether single or semi-automatic shots are fired, which aids police in the investigation of these crimes (Watkins et al., 2002). The sensors are nondescript and discrete so that the public cannot identify or tamper with them in any way. This study focused on the application of ShotSpotter, Inc.'s GDT, in which the alerts on the detection, location, and identification of gunshots are sent to human operators at ShotSpotter headquarters within a few seconds after the shot is recognized by the system (Aguilar, 2015; ShotSpotter, 2018). These individuals are trained to identify and screen out incidents that were not recorded accurately and to confirm true gunfire incidents, thus ensuring the information that is sent to the department's computer aided dispatch (CAD) system is accurate (ShotSpotter, 2018). A detailed logic model of this technology can be found in a grant-funded article on the implementation process and challenges documented in the three evaluation cities (Lawrence et al., 2019).

The goal of this study was to conduct a rigorous process and impact evaluation to inform policing researchers and practitioners about the impact GDT may have. To achieve this goal, we implemented a mixed-methods research design with the Denver, CO; Milwaukee, WI; and Richmond, CA police departments. This technical summary provides an overview of the data, the methodologies of and results from the process and impact evaluations, and implications for criminal justice policy and practice in the United States. More detailed information from this study will be available in forthcoming journal articles.

Methods and Data

Study Jurisdictions

The three study sites vary considerably in terms of size, geographic location, and demographics. Denver has a population of roughly 660,000 people with just over half (53.4%) of the population identifying as white, a substantial Hispanic population (30.8%), and a much smaller (9.4%) African American population compared to the other two sites (U.S. Census Bureau, 2018). From January 2008 to June 2016, the average number of shooting-related calls for service (CFS) per month in Denver was 304.34 (SD = 81.39). Denver first deployed GDT in January 2015. The department added two additional coverage areas in April 2016 and September 2016, resulting in GDT sensors covering 11.54 square miles of the city. The data associated with the two GDT coverage expansions occurred late in the study and were therefore not included in our evaluation. As such, Denver analyses cover the original GDT implementation from January 2015 to June 2016.

Milwaukee has a population of 600,000 people with roughly equal shares of white and African-American populations (35.9 and 38.8%, respectively), and a Hispanic population of 18.2% (U.S. Census Bureau, 2018). From January 2008 to December 2016, the average number of shooting-related CFS per month was 848.31 (SD = 298.14). Milwaukee first deployed its GDT in February 2011, with two subsequent expansion periods: one in which the original coverage area in the North was expanded in April 2012 and another in August 2014 when the coverage area was again expanded, and a new coverage area was added on the south side of the city. The city's GDT covered a total of 12.68 square miles once these expansions were complete. The following analyses cover GDT implementation from February 2011 to December 2016.

Richmond has a population of roughly 107,000 people with a large (40.2%) Hispanic population and smaller African American and white populations (21.7 and 17.6%, respectively; U.S. Census Bureau, 2018). The city has experienced persistently high rates of crime: analyses of CFS data from January 2006 to October 2015 found that the average number of shooting-related CFS per month in Richmond was 74.13 (SD = 43.13). Richmond was an early adopter of GDT, deploying the technology in June 2009. Six months later, in January 2010, the department added additional sensors, expanding the original area and adding a second coverage area within the city, which resulted in a total coverage of 5.69 square miles (as of December 2016). The following analyses cover GDT implementation from June 2009 to December 2015.

Data & Analyses

The research team worked closely with the partnering departments to collect robust data associated with firearm violence strategies and GDT programs. Qualitative data collection included 46 interviews with criminal justice stakeholders to learn implementation processes and challenges associated with its GDT, and six focus groups with

49 community members to learn how residents feel about policing efforts to reduce firearm violence and its use of GDT. Quantitative data collection included administrative data on CFS, crime, and GDT alerts, as well as comprehensive case file reviews of 174 crimes involving a firearm. Quantitative analyses examined the impact of GDT by (1) comparing counts of gunshot notifications for GDT alerts to shooting-related CFS, (2) comparing response times of GDT alerts to shooting-related CFS, (3) examining the impact GDT has had on CFS and crimes, and (4) conducting a cost-benefit analysis of the GDT.

Findings

Process Evaluation

Review and analyses of the notes and data from the interviews, focus groups, and case files generated both quantitative and qualitative data on how the three study sites planned for, acquired, and deployed GDT (and GDT-generated data) in their efforts to respond to, investigate, and prevent firearms violence and related crime, and how the community was engaged in the deployment and use of GDT.

STAKEHOLDER INTERVIEWS

Semi-structured interviews with law enforcement stakeholders, civilian employees, and staff from each city prosecutor's office and the Bureau of Alcohol, Tobacco, Firearms, and Explosives were conducted over a period of nine months, from November 2016 through July 2017. The interviews covered issues on planning GDT implementation, acquisition, installation and monitoring, policies and procedures, training, use on the ground and investigations, and perceived value and impact of GDT. Overall, the agencies viewed GDT as a useful technology that aids in investigations. While training of officers on GDT use was uneven and has diminished over time, agency policies to hold officers accountable for using the technology were robust and officer compliance was high. In addition, GDT data were routinely integrated into crime analysis activities, guiding deployment of officers and enhancing crime trend analyses that support both strategic and tactical activities. Moreover, GDT data were viewed by law enforcement stakeholders as a useful tool to employ in concert with ballistics and firearms tracing databases. Despite the documented benefits of GDT, it is not without its challenges. Stakeholders reported uneven training and some degree of skepticism in the accuracy of the technology, which may dissuade officers from using it to its full potential, although agency accountability mechanisms for compliance with GDT response protocols appear to be strong. GDT can also be difficult to integrate into existing, often antiquated CAD systems, and generates massive volumes of data, creating burdens for staff in managing intel and using the information for more strategic and proactive purposes. The data generated by GDT not only informs officer responses but also creates information that a department must store, manage, and integrate into its systems. A crucial aspect to maximizing the utility of GDT is having sufficient personnel to respond to alerts in a timely manner, collect and process GDT-generated evidence, and act upon the intelligence generated by that evidence. Law enforcement stakeholders expressed concerns that their agency did not have enough capacity to handle the volume of work created by its GDT.

COMMUNITY FOCUS GROUPS

In addition to stakeholder interviews, we conducted two 90-minute focus groups with community members within each site, one inside the GDT coverage area and one outside the coverage area; although neither group knew the exact coverage of GDT in their city. We recruited participants in partnership with local community-based organizations to take part in the focus group, participants had to live in the neighborhood and be 18 years or older. Participation averaged 8.2 people per focus group, and recruiting efforts attracted groups ranging in racial/ethnic identity, age, and socioeconomic background, and number of years living in the community. Participants received $50 for their time and insights on how their police department responds to firearm-related crime and to assess knowledge of the presence, purpose, and use of GDT.

Focus group participants representing high-crime communities in each jurisdiction reported low levels of trust and confidence in the police. Despite these negative views of police on the part of residents, law enforcement stakeholders expressed that they were pleasantly surprised by the community's willingness to assist the agency in installing GDT sensors upon their outreach to them. Overall, residents had a limited to basic understanding of how GDT works and how the police use the information collected by sensors. At least one focus group participant reported they no longer felt the need to call the police when they heard gunfire because they know the technology will detect it.

CASE FILE REVIEWS

Of the case files we reviewed, we requested partner agencies to randomly select half to be of firearm-related incidents that occurred before the implementation of GDT and the other half of incidents that occurred after implementation; all cases represented types of offenses likely to be associated with firearms use: weapon

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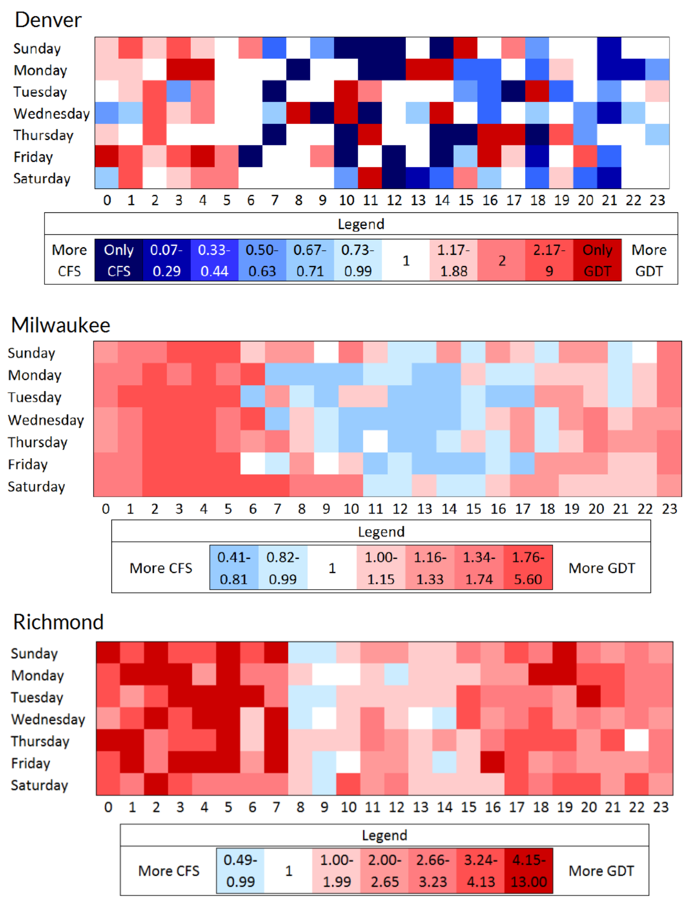
violation, robbery, aggravated assault, and homicide. Analyses of the change in outcomes associated with the coded case files suggest a high degree of fidelity to officer GDT-response protocols. Specific to canvassing a shooting event, aggregate data from the three sites showed an increase from 57.6% to 70.8% in the number of cases where a canvass was conducted from the period before GDT implementation compared to the period following ($t(172)=-1.82$, $p<.10$). In line with the increased canvasses, the total number of people interviewed as part of the case, which included victims, suspects, and witnesses, increased from 1.95 people to 2.32 people from before and after GDT implementation, but this difference was not statistically significant. The number of victims interviewed in Richmond significantly increased from an average of 1.17 to 1.62 from before and after GDT deployment, respectively ($t(56)= -2.30$, $p<.05$). There was a marginally significant increase in whether bullet shell casings were found at the scene from before GDT implementation (55.3%) compared to after (68.5%; $t(172)=-1.81$, $p<.10$). This increase was largest in Richmond, where the number of cases that included the retrieval of shell casings increased from 24.1% to 58.6% after GDT implementation ($t(56)=-2.80$, $p<.01$). The change in the number of cases resulting in an arrest and those for which a weapon was recovered at the scene was not significant either within or across sites. When separating the cases by the type of crime, we observed 50.0% of homicide cases involving a firearm were noted to have retrieved shell casings in the time period prior to GDT, and this increased to 88.9% after the implementation ($t(15)=-1.82$, $p<.10$). Robbery cases with shell casings saw a larger increase, from 11.8% to 41.2% before and after GDT ($t(32)=-2.00$, $p<.10$).

Impact Evaluation

GUNSHOT NOTIFICATIONS

Calls for service and GDT data were used to assess the degree that GDT identifies more or less firearm shootings compared to shooting-related CFS from community members. We assessed these data using a ratio of GDT-to-CFS, where a ratio greater than 1 indicates that there are more GDT alerts compared to CFS, a ratio less than 1 indicates that there are less GDT alerts compared to CFS, and a ratio of 1 indicates that the number of GDT alerts matches the number of CFS. The unit of analysis was shooting events, so that multiple gunfire discharges or multiple CFS for the same discharge were filtered to a single event (i.e., GDT alerts or CFS within 5 minutes and one-quarter mile were reduced to a single shooting event for each). This was to help ensure a one-to-one relationship of notifications for a shooting event. **Figure 1** displays the heat map of this ratio within each day by hour for each city. The red cells indicate the varying degrees that GDT notifies the department of shootings than are reported by CFS, whereas blue cells indicate that there are more CFS than there are GDT alerts. Patterns in Milwaukee and Richmond indicate that GDT alerts far outweigh CFS during the early morning hours for the entire week but that when people are more likely to be outside and/or working during daytime hours, results show that more CFS come in for a shooting than what the GDT alerts the department, especially in Milwaukee. We observed much greater parity between the notification types in Denver; no clear pattern was observed.

FIGURE 1. **Notification Heat Maps**



RESPONSE TIMES

In order to assess response times associated with GDT, we mapped CFS associated with a gun being fired using the CFS data within each individual GDT coverage area and timeframe. These included CFS events categorized as a "Shooting," "Shots Fired," and "ShotSpotter." Multivariate regression analyses were conducted on three different response time outcomes to compare times between these shooting-related CFS. The three response times are the time from 1) the citizen's 911 call to dispatch assigning an officer, 2) the officer assignment to their arrival at the scene, and 3) the call to officer arrival. While all three response times are important measures of police operations, the following will focus on the call-to-arrival response times as these times are often the most critical to citizen satisfaction and improving relations. Examination of all available data in Denver estimated call-to-arrival response times to GDT alerts to be 14.37 percent faster than CFS for a shooting and 25.73 percent faster than CFS for shots fired. In Milwaukee, call-to-arrival response times to GDT alerts were 17.19 percent slower than CFS for a shooting but 3.55 percent faster than CFS for shots fired. And in Richmond, call-to-arrival response times to GDT alerts were 28.53 percent faster than CFS for a shooting and 6.18 percent faster than CFS for shots fired. The result of slower response times in Milwaukee shooting events is perhaps not surprising, considering that the "shooting" CFS category is designated for events where a person was hit by gunfire and therefore indicates that there is a likelihood of life-threatening injury or death to an individual. As such, shooting calls in Milwaukee are distinguished by a higher likelihood of having a victim present and in need of help, which likely leads to officers responding more quickly than they would to a GDT alert.

IMPACT ON CALLS FOR SERVICE AND CRIMES

To assess the impact of GDT on CFS and crime levels, we first conducted negative binominal panel regressions analyses to assess the percent difference in the outcomes between pre- and post-implementation of GDT, on average. As such, the percent change is specific to the full time period before and after the technology was deployed, specific to the examined coverage area. We also conducted two types of interrupted time series (ITS) analyses. The first determined the change in the outcomes within the GDT coverage area after the GDT's deployment and the second did the same but in comparison to a statistically matched area. This second analysis, known as a comparative interrupted time series (CITS), allowed us to estimate the difference between the GDT coverage area's pre-intervention and post-intervention outcomes, relative to the same difference for the matched area where GDT was not deployed.

We examined the following outcomes: (1) CFS for violent crimes (homicide, aggravated assault, robbery, rape), (2) CFS for shooting-related crimes, (3) violent crimes (homicide, aggravated assault, robbery, rape), (4) robberies, (5) crimes involving a firearm, and (6) arrests for crimes involving a firearm. **Table 1** presents the significant findings for the panel, interrupted time-series, and comparative interrupted time-series analyses for each coverage area across the outcomes.

COST-BENEFIT ANALYSES

We conducted a cost-benefit analyses to determine whether the benefits in crime reduction associated with GDT outweigh the costs of the technology. Each study site completed a cost-collection tool, from which we were able to calculate system, personnel, and training costs of GDT for each year the technology was used. After a detailed literature review that rigorously estimated the costs of the crimes under review, we

TABLE 1

Panel Regressions on the Impact of GDT on Calls for Service and Crimes

Coverage Area	CFS Violent crimes	CFS – Shooting-related crimes	Violent Crimes	Robberies	Crimes involving a firearm	Arrests for crimes involving a firearm
Denver - Original Area						
Panel	n.s.	33% ***	n.s.	n.s.	133% ***	45% *
ITS	n.s.	n.s.	S: -0.50 (0.27) t	n.s.	V: 13.02 (5.30) * S: -1.10 (0.58) t	S: -0.62 (0.34) t
CITS	n.s.	n.s.	n.s.	n.s.	V: 10.34 (5.87) t	n.s.
Milwaukee - North – Original Area						
Panel	-15% ***	88% ***	-11% **	-12% **	n.s.	n.s.
ITS	V: 49.98 (25.01) *	V: 165.15 (27.69) *** S: 2.65 (1.46) t	n.s.	n.s.	n.s.	n.s.
CITS	n.s.	V: 121.63 (30.72) ***	n.s.	n.s.	n.s.	n.s.
Milwaukee - North – 1st Expansion						
Panel	-16% ***	119% ***	n.s.	n.s.	30% t	n.s.
ITS	S: 0.54 (0.29) t	V: 25.30 (6.33) *** S: 1.26 (0.23) ***	n.s.	n.s.	n.s.	n.s.
CITS	n.s.	V: 23.69 (8.67) **	n.s.	n.s.	n.s.	n.s.
Milwaukee - North – 2nd Expansion						
Panel	-7% ***	152% ***	n.s.	-13% ***	n.s.	-17% t
ITS	n.s.	V: 213.45 (51.32) ***	S: -0.83 (0.38) *	S: -0.97 (0.25) ***	S: -0.21 (0.12) t	n.s.
CITS	n.s.	V: 150.68 (61.19) *	n.s.	n.s.	n.s.	n.s.
Milwaukee - South						
Panel	n.s.	189% ***	19% ***	28% ***	n.s.	n.s.
ITS	n.s.	V: 28.75 (10.76) **	n.s.	n.s.	n.s.	n.s.
CITS	n.s.	S: 1.86 (0.86) *	n.s.	n.s.	n.s.	n.s.
Richmond - Original Area						
Panel	n.s.	41% ***	-24% ***	-29% ***	-36% ***	n.s.
ITS	S: 1.91 (0.37) ***	V: 81.38 (17.10) ***	V: -7.66 (3.19) *	V: -6.38 (2.59) *	S: -0.33 (0.17) t	S: -0.07 (0.04) t
Richmond - Expansion – Main Area						
Panel	n.s.	70% ***	-18% **	-26% ***	-29% **	n.s.
ITS	n.s.	V: 15.01 (4.17) **	n.s.	S: 0.09 (0.05) t	n.s.	S: -0.02 (0.01) *
Richmond - Expansion – Minor Area						
Panel	n.s.	78% ***	-37% **	-35% *	-43% t	n/a
ITS	n.s.	V: 3.71 (1.06) **	-0.89 (0.50) t	V: -0.96 (0.42) *	n.s.	n/a

Notes: t*p*<.10, **p*<.05, ***p*<.01, ****p*<.001, n.s. = non-significant change, n/a = model could not be run. Panel = Negative binominal random effects panel regressions, controlling for month of the year, land use, concentrated poverty levels, immigrant populations. Percent difference in outcome between pre- and post-implementation of GDT, on average. ITS = Interrupted time-series. CITS = Comparative interrupted time-series. V =Value change of outcome in month immediately following GDT implementation, S = Difference between preintervention and postintervention slopes of the outcome.

separated costs into four categories: criminal justice costs, victim costs, societal costs, and pain and suffering costs (La Vigne et al. 2011; McCollister et al. 2010; Miller 2012). We estimated the costs for the following crime types: aggravated assaults, homicides, rapes, robberies, crimes involving a firearm, and shootings. Individual cost-benefits figures were calculated in four ways, using: (1) all calculated costs associated with the crimes, when including homicides; (2) the costs specific to the criminal justice system, when including homicides; (3) all calculated costs associated with the crimes, when excluding homicides; and (4) the costs specific to the criminal justice system, when excluding homicides. Amounts from (1) & (3) acknowledge the averted societal costs associated with prevented crimes, the amounts from (2) & (4) provide a more relevant ratio from a local financing perspective for criminal justice stakeholders, as any victimization cost savings that might be attributed to GDT are not transferred to governments' budgets. We also provide the estimated costs when excluding homicides (figures from 3 & 4). Homicides are rare events with extraordinary costs both to criminal justice agencies as well as to victims and society. Excluding these costs provides a more reliable estimate on true costs incurred or averted.

TABLE 2

Cost-benefit results for Gunshot Detection Technology use

	Denver			**Milwaukee**			**Richmond**		
	GDT Cost	Crime Benefit	GDT Cost	GDT Cost	Crime Benefit	GDT Cost	GDT Cost	Crime Benefit	GDT Cost
Estimates when including homicides									
(1) Societal	$214 +	-$1,769	=-$1,555	$2,757 +	$8,982	=$11,739	$2,450 +	-$16,310	=-$13,860
(2) Criminal Justice	$214 +	-$63	= $151	$2,757 +	-$155	=$2,602	$2,450 +	-$1,345	= $1,105
Estimates when excluding homicides									
(3) Societal	$214 +	-$404	=-$191	$2,757 +	-$4,273	=-$1,517	$2,450 +	-$1,058	=$1,391
(4) Criminal Justice	$214 +	-$3	= $211	$2,757 +	-$734	= $2,023	$2,450 +	-$678	=$1,771

All dollars are calculated as 2016 dollars, presented in thousands.

Table 2 provides the estimated cost-benefit results for each city. In Denver, significant savings were observed in the models that account for costs across society. A $1.6 million net-savings to society as a whole was calculated when homicides were included in the estimates. A smaller net-savings of $191 thousand was noted in the model that excludes homicides. In Milwaukee, when the high costs associated with homicides were *excluded* from the models, criminal justice costs were estimated at $2.0 million but a $1.5 million net-savings to society as a whole was calculated. In Richmond, no net savings were observed in the models where homicides were excluded. When the high costs associated with homicides were *included*, we estimated a $13.9 million net-savings to Richmond society.

Implications for Criminal Justice Policy and Practice

How GDT is implemented and used by the police is crucial in its success in achieving its intended gun violence reduction impacts. While the accuracy and utility of GDT is relatively high and has been documented in the extant research, this evaluation sheds new light on how officers are trained and held accountable for GDT use, how GDT data are integrated in existing systems and with other investigative techniques, and how departments involve the community both prior to GDT implementation and throughout its use. The findings from our evaluation yield five recommendations for best practice in GDT deployment and use.

1. **Engage in thorough and ongoing officer training**. Provide academy and ongoing in-service training on the purpose, value, and accuracy of GDT. Effective and consistent training on department policies and procedures of GDT use increases officer buy-in and the likelihood that officers will adhere to policies on responding to and investigating GDT alerts. Education on how the accuracy and use of GDT has continued to improve can decrease skepticism about the technology's value, further ensuring strong compliance with GDT response protocols.

2. **Develop strong accountability mechanisms**. Alongside training, consider establishing accountability measures to reinforce officer compliance with GDT response protocols, such as exiting patrol cars to canvass for shell casings, conducting field interviews, and identifying witnesses. Two promising accountability measures that could be utilized are (1) requiring officers to submit reports following each GDT alert response and (2) requiring supervisors to conduct field checks and canvassing follow ups.

3. **Facilitate data management and integration**. Consider the capacity of existing data systems (i.e., CAD, RMS, etc.) to integrate GDT data, and update or modify systems accordingly, prior to GDT deployment, if possible. Using GDT data in concert with existing data systems has implications for improving efficiency, investigative utility, and impact of GDT.

4. **Improve access to complementary technologies**. There are marked increases in the investigative utility and potential impact of GDT when the data it generates can be used jointly with other policing technologies. For example, a comprehensive and efficient NIBIN system that can produce prompt, accurate results that enable investigators to link cases within and between jurisdictions.

5. **Engage community members early and often**. Partnering with the community is key for enhancing investigations and reducing gun violence. Agency outreach to community members on GDT installation and use should clearly communicate that GDT is not a replacement for resident engagement with and outreach to police upon knowledge of gun violence and other public safety concerns. Police departments should carefully consider whether the benefits of allowing people to believe that GDT covers the entire jurisdiction outweigh the potential unintended consequence that community members will no longer report gunfire to police based on the assumption officers already know that a shooting incident has occurred.

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