Document Title: GPS Monitoring Practices in Community Supervision and the Potential Impact of Advanced Analytics, Version 1.0

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Document No.: 249888

Date Received: May 2016

Award Number: 2013-MU-CX-K111

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AOS-16-0088

January 2016

NIJ RT&E Center Project 13-7

GPS MONITORING PRACTICES IN COMMUNITY SUPERVISION AND THE POTENTIAL IMPACT OF ADVANCED ANALYTICS

Version 1.0

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Prepared for:
The National Institute of Justice

NIJ | National Institute of Justice

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1. INTRODUCTION

The first electronic monitoring (EM) devices were developed in the 1960s with the intent of providing feedback to young-adult-offender volunteers to facilitate their rehabilitation, but that approach was not widely accepted (Reference [1])[1]. Following their reemergence in the 1980s in support of a more punitive model of offender treatment, such devices were used principally for home detention applications. By 1990 radio-frequency (RF)[2] technologies were in-use in all 50 states (Reference [2]).

The utility of EM increased considerably in 2000 when the military began permitting civilian Global Positioning System (GPS) receivers to attain much greater accuracy (Reference [3]), and the offender tracking market expanded quickly.[3] At least 44,000 tracking devices were estimated to be in-use in the United States by 2009 (Reference [5]), and the more compact and affordable devices available today can be better tailored to specific needs. Modern features include voice communication, and audible and vibratory alerts to warn participants of schedule violations. These devices also include improved case management software and better mapping technology, with playback capabilities and mobile restriction zones that can be used to keep tracked participants from congregating and separated from former victims (Reference [6]).

Much of the exigency for enhanced usage of offender monitoring systems has resulted from legislative mandates to track sex offenders, but other applications have emerged such as intensively supervising high-risk parolees, developing confinement alternatives for low-risk criminals to facilitate their re-entry into society and alleviate jail overcrowding, or monitoring pre-trial defendants. "By 2010, 33 states had enacted legislation requiring that this technology be used on sex offenders," although many had not yet implemented those programs (Reference [6]). Some states and jurisdictions had also begun using EM to track gang members and domestic abusers, monitor habitual burglars, or alert former victims when offenders were released from custody (References [3] and [7]). Nevertheless, GPS-based systems generate a plethora of data. Without analytical aids to interpret those data, supervising agents can quickly become overwhelmed and unable to take advantage of these tools as they manage their daily caseloads.

The temporal sequences of locations gathered by GPS monitoring systems provide unprecedented opportunities to explore patterns of activity through the application of space-time analytics to individual movements and stops (Reference [8]). Automated processing and alerting

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[1] The authors of Reference [1] speculated that EM technology did not gain traction at that time because social acceptance was lacking for using positive reinforcement to change behavior, and because of an "Orwellian" fear of using electronic technology to remotely monitor individuals. They also noted that in the pre-digital era of the mid 1960's when this work occurred, EM represented such a substantial departure from then-existing correctional practices that it was difficult for most practitioners to conceptualize its use.

[2] Definitions for all of the abbreviations and acronyms used in this document are presented in Appendix A.

[3] Although the term "electronic monitoring" was traditionally associated with "curfew monitoring" of individuals confined to their homes (or other locations) by RF-based systems, it is also used today as a synonym for location-based tracking with GPS technology. Some authors (e.g., Reference [4]) embed these terms within the broader category of electronic supervision, which encompasses a larger array of technologies that includes crime-scene correlation and remote alcohol monitoring.

algorithms developed to more fully exploit gathered data could focus an agent's attention on only those events requiring investigation, and provide the basis for conducting social network analyses to gain intelligence on offender habits (Reference [9]). While analytical capabilities do not appear to have strongly influenced correctional agency selection of their EM vendors and products to date, tools comprising various combinations of statistical analysis procedures, data and text mining, and predictive modeling can be mission enabling through the discovery of hidden behavioral patterns and the prediction of future outcomes.

This paper briefly reviews research on the usage of location-based tracking to motivate an assessment of the potential role of advanced analytics in more strongly leveraging the capabilities of such systems. Relying in part on the results from a recent market survey of commercially-available analytics products suitable for use in correctional applications (Reference [10]), it presents several recommendations for deriving actionable information from GPS tracking data as an aid to managing community-released offender populations. Nevertheless, "… there has been little rigorous research evaluating the impacts of electronic monitoring," and questions remain about the efficacy of this approach in community supervision. "Policy-relevant research" is needed that is "focused toward understanding the potential for supervision with electronic monitoring to improve long-term outcomes" (Reference [11]).

2. GPS SYSTEM UTILIZATION IN OFFENDER MONITORING

In spite of the fact that there has been "… little scientific research documenting the effectiveness of electronic monitoring devices, especially for sex offenders" (Reference [12])[4], the number of early-release candidates has increased over the last 15 years. Early-release programs can reduce incarceration costs and jail overcrowding, and GPS devices render clients highly accountable, although "[e]lectronic supervision technologies by themselves do not foster pro-social behavior (or) reduce recidivism…." However, "[w]hen implemented and operated within an overall strategy of behavioral modification … there is the potential for some electronic supervision tools to enhance community supervision" outcomes (Reference [4]). A recent Danish study by Andersen and Andersen on the social welfare dependence of serving a sentence under electronic monitoring rather than in prisons supports this view. Those authors found that "[e]lectronic monitoring is less harmful than imprisonment on the life-course outcomes of offenders." They conclude that because EM could be less costly than incarceration, "efforts to extend the use of electronic monitoring in the United States could be accelerated" (Reference [14]).

A review of state codes during the late 2000's by Button et al. (Reference [12]) found that 46 states and the District of Columbia had "some type of legislation governing the use of electronic monitoring;" an extensive summary of the legislative patterns found by these authors appears in their Table 1[5]. Of these 47 "states," 27 had "specific policies for monitoring sex offenders, with 19 of these states requiring electronic monitoring for sex offenders." In an early 2015 news article, Wolf (Reference [15]) claimed that "[m]ore than 40 states have passed laws in

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[4] The most thorough review of such work (at least as of the 2009 publication date of this reference) was conducted by Renzema and Mayo-Wilson (Reference [13]).

[5] Colorado, Kentucky, Minnesota, and Nevada did not have some type of legislation governing the use of EM as of that date.

the last decade that call for some type of GPS monitoring of sex offenders, including eight states that monitor them for life…. At least 13 states monitor domestic abusers." However, Payne (Reference [16]) indicated privately that he was unaware of any recent efforts to update the numbers shown in references [2], [4], and [12].

Drake (Reference [5]) lists six application areas in which offender tracking technology offers an attractive option, and an additional category has been added below based on modern usage:

- Sex Offenders: By 2009, California parole officials were electronically monitoring approximately 7,000 sex offenders, as well as several thousand more probationers. Sex-offenders in California communities were still being GPS-monitored at those levels in mid-2011. This corresponds to more than three times the number of units used by Florida, which was the state using the second-largest number of such devices at that time (Reference [3]).

- Gang Disruption: California also implemented an aggressive program for monitoring high-risk gang members during the first decade of this century (References [3] and [17]). Tracking technology can identify gang-member violations of established exclusion zones, and their movements can be used to define mobile exclusion zones for other gang members, and indicate previously-unknown social network connections.

- Domestic Violence: Offender-tracking technology is effective for enforcing temporary restraining orders. By 2009, Michigan and Massachusetts had developed very aggressive programs using tracking technology to keep offenders away from their former victims, and at least two vendors had developed systems that could be used to track both offenders and victims, permitting the victim's location to be used as a mobile exclusion zone for the offender.

- Jail Overcrowding: To help avoid law suits by advocacy groups for the incarcerated that demand less-crowded living conditions, many jurisdictions have begun community supervision programs for low-risk offenders, which often utilize offender tracking.

- Habitual Offenders: Some jurisdictions use remote surveillance equipment to track chronic and troublesome offenders. A related application that was used as early as 2009 by Midland and Dallas, Texas involves the selective tracking of habitually truant students.

- Crime-scene Correlation: GPS tracking technology has great potential for facilitating automated crime-scene analyses by allowing crime-scene data collected by cooperating law enforcement agencies to be cross-referenced with the location history of all offenders being monitored. While only two vendors offered that broad capability in 2009, most system vendors provided at least simple correlation software as part of their basic service that allowed the address of a single crime scene to be checked against the recorded locations of all offenders being monitored.

- Pre-trial supervision: GPS monitoring systems are used at both state and federal levels for pre-trial supervision of individuals awaiting court appearances. For example, U.S. Immigration and Customs Enforcement monitor thousands of people awaiting adjudication by the judicial system.

It is difficult to determine how many individuals are monitored by EM techniques in each of these categories, or in each state. However, the overall sizes of the electronically-monitored populations in several jurisdictions were gauged earlier this year in support of a National Institute of Justice (NIJ)-sponsored analytics market survey to better understand correctional-department missions and needs. Although the departments selected and the questions posed were not chosen to provide statistically-meaningful results, the knowledge acquired helped guide interpretations by the RT&E Center of vendor responses to the associated Request-for-Information (RFI) published in the Federal Register (Reference [10]). The results are summarized in Table 2–1. The number of individuals tracked by GPS techniques ranges from a few hundred to a few thousand clients annually. The electronic monitoring program run by the California Department of Corrections and Rehabilitation (CDCR) is the largest in the nation as measured by the number of offenders monitored by a single law enforcement agency, with as many as 10,000 clients being monitored on a daily basis in 2011 (Reference [18]).

Table 2–1: Community Monitoring Populations for Selected Jurisdictions

Jurisdiction	Monitored Population Totals			Geographic Size	Ref.
	Community Supervised Total	EM Supervised Total	GPS Monitored Subtotal		
Colorado	12,300	1,869	NR	Entire state	20
Oklahoma	26,882	863	755	Entire state	21
Maryland	60,000	6,128	5,561	Entire state	22
Michigan	NR*	5,706	2,235	Entire state	23
California	44,000	6,900	6,400	Entire state	18
Denver	2,626	1,000	NR	City, County, some State	24
Texas**	NR	3,672	2,100	Entire state	25
Florida***	139,883	4,223	4,223	Entire state	26

(Adapted from Reference ([19])

*   NR = Not Reported

** On average

*** As of July 31, 2015

3. CONCEPTUAL SYSTEM FRAMEWORK

Electronic monitoring systems comprise both curfew-enforcement and location-based tracking resources. Figure 3–1 illustrates their principal subsystems, their interfaces, and communications flows. The receiver subsystem within the bracelet affixed to an offender receives synchronously transmitted signals from GPS satellites that are above the offender's horizon, allowing the individual's location to be determined. The ability to determine the individual's location is accomplished by using an internal clock and a reference signal to calculate differences in the arrival times of signals from those satellites, whose positions are precisely known. Most handheld units provide latitude and longitude-based locations to an accuracy of about 15 meters when at least three satellites are available. When four or more satellites are in view, the receiver's position can be estimated in latitude, longitude, and altitude (Reference [3]).
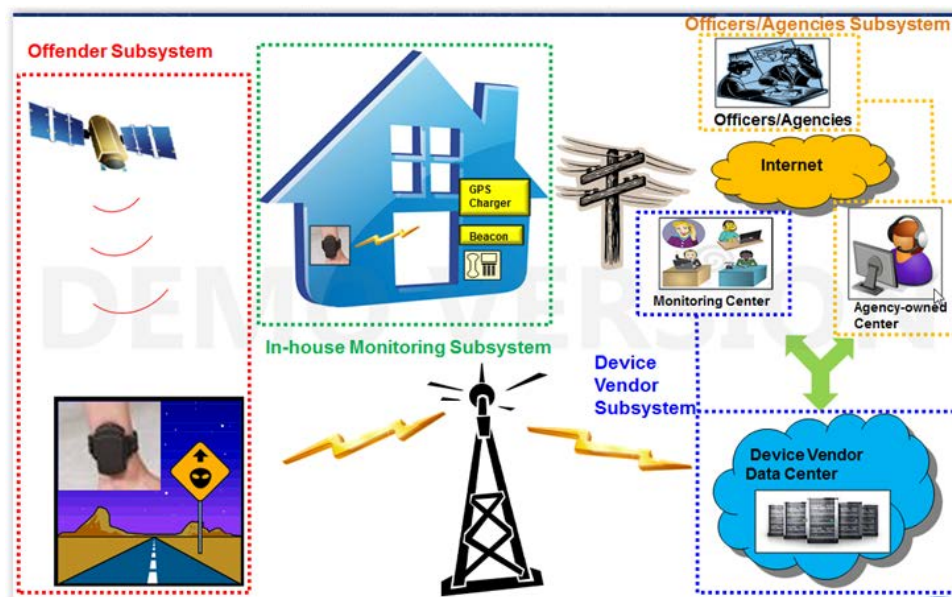
(Courtesy of S. Kandaswamy, JHU/APL)

Figure 3–1: Notional Offender Monitoring System

Within this framework, an agency can select to actively or passively monitor offenders or to implement a hybrid design (References [4], [7] and [27]), using either a single or multi-piece architecture as follows:

- Active systems collect offender location data at rates as great as once per minute, and utilize cellular communications (depicted by the cell tower in Figure 3–1) to provide those data to a monitoring center operated by either the vendor or the agency in near-real time. Many vendors allow the reporting frequency to be configured based on the specific (type of) client, and the monitoring center can also ping the system for more frequent updates.

- Passive systems obtain data throughout the day at rates similar to active systems, but those data are not retrieved typically until the client returns home in the evening. When the unit is placed in its charging station, the collected data are uploaded by

vendor-supplied software to the data/monitoring center over a landline telephone connection (depicted in the figure by the telephone pole).

- Hybrid systems do not have a universally accepted definition, but the term generally refers to a system that operates in the passive mode until any of several predetermined triggering events occur (e.g., zone infractions, tamper indications, low power status), at which time they switch to an active reporting mode. In some metropolitan areas, Wi-Fi nodes are used to supplement GPS systems. Beacon-type devices can also be placed outside the home or other building to monitor offender movements within those structures, which represent areas with impaired GPS coverage.

Regardless of which configuration is chosen, GPS receivers require an unobstructed view of the sky to function properly, and often do not perform well because of interference from buildings, terrain, electronics and at times dense foliage. The accuracy of the derived position can be affected by several factors, such as the altitudes and angular spacing in the sky of the satellites and by timing errors that arise when the signal reflects off tall buildings or rugged terrain before reaching the receiver, unexpectedly increasing its travel time. Accuracy can also be degraded when the clock in the receiver is less accurate than that in the transmitter.

Each vendor has unique software that processes the GPS data acquired from the bracelet's receiver (Reference [27]), but most provide agencies with access to that software over the Internet. Inclusion zones, exclusion zones and schedules can be stored either in the device or in software at the data center, and GPS points from the device are compared against those requirements to identify instances when a client fails to adhere to pre-established parameters. Deviations can result in alerts. The main difference among agency usage of these products pertains to who receives and reviews those alerts and the associated alert-flow processes; the ability to identify and follow-up on infractions depends on how often the data are uploaded and alerts are transmitted. Some agencies prefer a full-service option whereby on-site vendor representatives install equipment and respond to or forward triaged alerts. Others choose to take on this responsibility and only rely on vendors to provide automated alerts (Reference [6]). Key considerations in choosing a vendor include the maintenance, hardware and software upgrade schedules offered, and the vendor's ability to provide an adequate inventory of bracelets. When problems arise, equipment generally must be returned to the vendor for maintenance because there is very little that agencies can repair themselves on-site.

The choice between active, passive, and hybrid tracking options should be driven by the agency's objectives, and may depend on the assessed risk level of the monitored participants, the required response time to alerts, and whether alerts must be sent to former victims. In a 2006 survey of seven community corrections agencies, Brown et al. (Reference [7]) found that 82% of the clients were monitored by passive techniques and only 18% were subject to active tracking. None of those agencies used a hybrid approach. Although the location-reporting subsystem can be implemented in either single or multi-piece configurations, corrections agencies often prefer the former because there are fewer inventories to manage. Drake privately indicated (Reference [27]) that single-piece systems are used more often, by about a 3-to-1 margin, although they are easier to tamper with than multi-piece units. Multi-piece systems generally have more communications options and can offer greater security. In particular, those equipped with motion sensing technology can determine if the subject is at rest, which is important when a

participant enters a heavily shielded indoor structure where tracking is interrupted (Reference [6]).

Although market forces have provided agencies with many attractive and affordable technology options for offender tracking, the development of those technologies has not been governed by standards. This has resulted in considerable end-user confusion about the capabilities of the products that agencies seek to procure. To address this issue, NIJ initiated development in 2009 of a voluntary standard and companion guide. The goals for this action included clearly defining basic concepts, confirming equipment performance claims under realistic and controlled environments, and ensuring that devices are built robustly (References [5] and [6]). The evolving draft versions of these documents have been reviewed during two public comment periods and more recently by the Government Accountability Office (GAO). The latter found that although "NIJ's draft … standard and guide address many common stakeholder needs and challenges, …earlier and ongoing involvement of … manufacturers could have better informed and facilitated [their] development." The GAO indicated that these documents are "expected to be published no later than March 2016" (Reference ([28]).

4. STATE AND LOCAL OFFENDER-MONITORING PRACTICES

A wide variety of location-based community-monitoring programs exist today at the state and local levels, with those operated by CDCR, the Maryland Department of Public Safety and Correctional Services (DPSCS), and the Florida Department of Corrections (FDOC) being among the largest (Reference [27]; see also Table 2–1). In general, programs based on a clear understanding of an agency's objectives are the most effective, because the desired outcomes enable policies and practices to be developed that address the most important actions needed. Among other factors, those policies should carefully consider the impact that an offender tracking program will have on staff workload, which depends in part on the tracking technology chosen and the required level of response notifications.

Using interviews conducted during the summer of 2006[6], Brown et al. (Reference [7]) compared the practices of six state and local agencies, and one Federal Service, that used GPS-based systems to monitor pretrial, probationary, and paroled offenders. Three of the most frequently cited objectives for implementing electronic tracking programs within these groups were ensuring client accountability, deterring additional crimes, and effectively protecting the public while reducing jail or prison over-crowding. The authors documented the successes, challenges, and lessons-learned by these agencies, but they did not evaluate the effectiveness of such systems in modifying behavior, deterring criminal activity, or protecting victims. An earlier study by Bonta et al. (Reference [29]) that used risk and needs factors to statistically-match treated offenders with those not receiving treatment found that the efficacy of using EM

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[6] The participating agencies were the City and County of Denver Colorado Electronic Monitoring Program (pretrial and post-conviction programs); Court Services and Offender Supervision Agency (CSOSA) for the District of Columbia (probation and parole); Marion County Indiana Community Corrections (pretrial and post-conviction); New Mexico Corrections Department (probation and parole); Oakland County Michigan Community Corrections (pretrial); Texas Department of Criminal Justice (parole); and U.S. Pretrial Services, Central District of California (Federal pretrial).

supplemented by treatment depends on the offender's risk level[7], although Renzema and Mayo-Wilson (Reference [13]) cautioned that additional "properly controlled experiments would be required to draw stronger conclusions about the effects of EM."

Additional insights on the current utilization of EM were obtained earlier this year by the aforementioned questionnaire sent to several correctional departments and agencies. For example, the Michigan Department of Corrections (MDOC) provides EM "supervision for county felony probationers, state parolees, and contracted agencies (county jail inmates, work release inmates, and juveniles)," although their predominant population is state parolees. "EM can be used as a form of prison diversion for any felony offender or imposed as a sanction for violation behavior on the same population. Sex offenders are monitored by GPS for at least a portion of their parole term when released from incarceration" (Reference [23]). Fifty-eight employees operate a fulltime call center to monitor offender alerts, but there is no set number of agents that supervise a dedicated EM caseload.

The Colorado Department of Corrections (CDOC) applies electronic monitoring to selected Intensive Supervision Program Parolees (ISP-P), Intensive Supervision Program Inmates (ISP-I), and to Youthful Offender System (YOS) Phase III Inmates. More than three-quarters of this population (1,450 of 1,869 – see Table 2–1) currently comprises offenders from the ISP-P, which are placed into this program by the Colorado Board of Parole "based on a validated risk assessment score using the [Parole Board's] release-decision making tool, the Colorado Actuarial Risk Assessment Score (CARAS)." This tool identifies "a risk-level based on the likelihood [that an individual will] re-offend through commission of a new crime." The targeted population includes "[a]ll Very High, and some High and Medium [-risk offenders] if the current offense is violent, a sex offense or the offender is identified as a member of a security threat group" (Reference ([20]).

Individuals assigned to Maryland's DPSCS electronic monitoring program are primarily sexual offenders and high-risk violent offenders, which are monitored by approximately 166 specialized agents (Reference [22]). GPS-based tracking is used in the Active Tracking Program, which focuses on parolees that are often sex offenders, and by the Violence Prevention Initiative (VPI), which aggressively targets the most violent offenders under state supervision. Parolees of various types are actively monitored for 60–90 days at the start of their parole to make sure they get a "good start," but the number of days can be extended. Such a relatively short monitoring interval is due to the limited availability of resources such as bracelets and staff. Sachwald (Reference [30]) noted that hardware failures occurred for about half of the offenders placed on GPS supervision during the early years of their program, and that equipment occasionally had to be replaced two or three times before it worked properly. Employees from the DPSCS operate Maryland's Command Center on a 24/7 basis, using software that resides at that location (Reference [31]).

At the local level, the City/County of Denver has about 2,625 pre-trial and post-conviction offenders under supervision, and roughly 1,000 of them are monitored electronically. While the

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[7] In this study, lower recidivism was found for the group of high-risk offenders but no effect was evident on those in the lower-risk cohort.

"post-conviction program consists mostly of in-home detention sentences for alcohol or driving under revocation offenses," the majority of their pretrial clients on electronic monitoring "are high-risk cases of all types…. Most of the defendants on pretrial GPS are for crimes involving a victim, with a majority of those being domestic violence" related. Seven officers monitor the post-conviction offenders; 13 monitor the pre-trial case load. Each officer supervises about 75 electronically-monitored defendants (Reference [24]).

Brown et al. (Reference [7]) identified several additional considerations related to planning and managing such programs such as legal, judicial, and agency liability issues. Among the most pressing are whether agencies are liable if they do not respond to applicable GPS alerts within a "reasonable" amount of time or when a victim is harmed by a monitored individual. The methods for addressing these issues vary. For example, early in the City/County of Denver's use of active GPS, officers received notification of every alert generated and subsequently informed former victims. This approach often led to undue alarm and officer burnout. Because GPS tracking is incapable of ensuring victim safety, the focus of that program migrated away from victim protection to providing more effective supervision. In contrast, Oakland County Michigan Community Corrections outsourced the installation, management, and monitoring aspects of their program for supervising sexual and domestic violence offenders.

In post-conviction programs, some jurisdictions use GPS as an alternative form of sentencing to help ensure that clients abide by "no contact" orders or that they meet their defined at-home and at-work schedules. Brown et al. (Reference [7]) reported that officers from the "City/County of Denver Electronic Monitoring Program (met) with local judges on a daily basis to … determine which clients appear[ed] best suited for GPS tracking," and officers were generally notified of priority alerts by the vendor's software. In Marion County Indiana, Community Corrections operated an "in-house 24/7 monitoring center to process alerts," and worked with "local Law Enforcement and [Correctional] Officers to resolve them as appropriate. The Monitoring Center [was] also responsible for contacting victims" when needed.

In agencies with Probation and Parole missions, GPS monitoring can serve as a sanctioning tool within a client's supervision program, since the additional freedom-of-movement afforded by these devices in comparison to traditional RF-based systems can be viewed as a reward for good behavior. For example, at the time of Brown's et al. study, the Court Services and Offender Supervision Agency (CSOSA) of the District of Columbia typically used GPS for short-time-span monitoring of high-risk sex-offenders, domestic violence perpetrators, and substance abusers. The New Mexico Corrections Department's Probation and Parole Division also used GPS systems to monitor several categories of high-risk offenders. While more recent information on the use of these practices by these agencies was not available, the Massachusetts Probation Service expanded its EM program in 2005 to include the monitoring of sex offenders by GPS bracelets (Reference [32]), and MDOC has the option of imposing EM on any felony offender as a sanction for violation behavior.

Nevertheless, GPS-supervision programs embody a certain amount of risk, particularly when used to oversee individuals accused of violent crimes. Florida broadened its early RF-based house-arrest program in 1997 by permitting active GPS monitoring of offenders released into the community. As that program evolved, both active and passive systems were used increasingly to

track sex offenders and violent criminals, but the use of passive systems was terminated in 2006 because of cost considerations (Reference [33]). After a shooting by an actively-monitored pretrial defendant, a judge suspended the further use of GPS systems in Orange County in 2013 for individuals charged with violent crimes or who were on bail (Reference [34]).

4.1 High-Risk Use-Cases: Monitoring Sex and Gang Offenders in California

CDCR began a pilot program in San Diego in 2005 to test the utility of GPS technology for monitoring high-risk sex offenders that were on parole; its success prompted them to expand the program across the state. The full statewide program was completed in 2008 after phasing in 4,800 GPS monitoring units, which is nearly three times the 1,800 units used by Florida—the state with the second-greatest number of such devices at that time (Reference [35]). The generally positive experiences among parole agents with CDCR's sex-offender tracking program generated interest in applying the same technology to other offender categories in California. In March 2006, the CDCR's Division of Adult Parole Operations (DAPO) entered into a partnership with the City of San Bernardino to implement a pilot project to track the movements of known gang members, which was later expanded over a wider expanse of that state. Today, California has "chosen to use electronic monitoring as a significant tool in the supervising parole agent's toolbox." GPS-based systems are used to track all sex offenders under parole supervision, high risk gang offenders, a few high-notoriety cases, and participants in community-based reentry facilities. Approximately 260 case-carrying parole agents monitor that state's GPS program, which electronically monitors approximately 6,900 individuals, with about 6,400 of them being tracked by GPS systems (Reference [18]).

A quasi-experimental evaluation was conducted by Gies et al. (Reference [3]) of CDCR's statewide program to monitor High-Risk Gang Offenders (HRGOs), based on data from all HRGOs released from prison and residing in California between March 2006 and October 2009 in jurisdictions monitored by six specialized gang parole units[8]. Seven hundred eighty four (784) subjects were assessed who were equally divided according to their pretreatment risk characteristics between a group placed on GPS monitoring and a control group of matched offenders with similar backgrounds. The program's effectiveness was evaluated using an intent-to-treat approach with two main outcomes: non-compliance (i.e., the offender violated the conditions of his/her parole) and recidivism (i.e., the offender was arrested for committing a new crime). However, unlike California's GPS program for monitoring sex offenders where each subject was monitored continuously, a wide spread exists in the number of days that individual gang offenders were placed under GPS supervision.

Unlike early programs that envisioned GPS monitoring as an opportunity to provide feedback to offenders and facilitate rehabilitation, Gies et al.'s assessment suggests that the CDCR used GPS as part of a gang suppression program, where GPS monitoring offered an added level of surveillance. In contrast to gang programs based on prevention and intervention, suppression programs use the full force of the law through policing, prosecution and incarceration to

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[8] These six jurisdictions were the City of Los Angeles and the counties of Fresno, Los Angeles, Riverside, Sacramento and San Bernardino.

influence the behavior of gang members and deter criminal activities by increasing the certainty, severity and swiftness that they will be placed back into custody for any transgression. This interpretation was supported by finding that the odds of committing a technical or non-technical violation were greater among the GPS-monitored group than those in the control group, although the former were less likely to be rearrested overall or for violent crimes (Reference [17]). This apparent contradiction was rationalized by noting that one of the most common gang suppression approaches utilizes special gang probation and parole caseloads with more stringent revocation rules for gang members. In this approach, parole violations and a parole board are used in lieu of an arrest and traditional court proceedings (i.e., "back-end sentencing") to return GPS-monitored gang-member violators back into custody (Reference [3]).

The findings from the California studies are important because they suggest that GPS technology might serve multiple crime prevention purposes, depending on a program's goals and structural design. "Specifically, GPS can be used as a traditional deterrent mechanism, a focused deterrent tactic or a treatment enhancement provision" (Reference [17]). Although CDCR had the capacity to utilize their GPS monitoring program more broadly for crime scene correlation and to increase its insight into gang-related activities by conducting micro-level social network analysis (SNA), it did not exploit those capabilities at the time. Data indicating the locations of individual gang members and SNA revelation of ties among gangs can improve knowledge of gang territorial changes and facilitate the removal of key gang leaders (Reference [36]). These data also might be useful for determining whether discernable patterns exist in offender habits before the commission of violent or criminal acts, which have predictive value.

In spite of its apparent value, legal challenges have arisen in some states to the use of GPS-monitoring of community-released offenders. For example, the New Jersey Supreme Court ruled in September 2014 that offenders cannot be subjected to such monitoring if their crime occurred before the law authorizing that approach went into effect (Reference [37]). As a result, more than 100 individuals in New Jersey who had already served their sentences and were being monitored by GPS technology as of that time were potentially subject to being removed from that state's program.

4.2 Supervising Low-Risk Non-Violent Offenders

In addition to its use for monitoring violent offenders, GPS-based systems also contribute to reducing prison over-crowding by enabling community-release alternatives to incarceration for non-violent offenders that do not compromise public safety. For example, the Colorado Department of Corrections uses location-based tracking to monitor suitable members of its ISP-I population, who are "usually progressing from a Community Corrections Center, who have displayed positive behaviors and are within a specified timeframe of a parole eligibility date." Similarly, GPS technology assists in supervising YOS Phase III Inmates. Individuals sentenced to the YOS system, rather than prison, "are allowed to re-enter the community as the last portion of the step-down process." Currently, 1,869 of the 12,300 offenders supervised by the Parole division are on some form of electronic monitoring (see Table 2–1). Approximately one-half (i.e., ~100) of CDOC's officers have at least a few offenders in this category (Reference [20]).

The Oklahoma Department of Corrections (ODOC) currently monitors approximately 755 clients by GPS-based technology, which includes some sex offenders and parolees. The major segment of that population comprises non-violent and a small contingent of DUI[9] inmates (Reference [21]). These continuously-monitored inmates are allowed to return to their respective communities to begin a supervised reintegration process, and with the assistance of officers, to participate in community based treatment and support programs. Drake indicated in mid-2014 that Oklahoma's program uses a passive system with alert notifications made the following day through a written report (Reference [27]). In 2013, it was reported that each Probation and Parole Officer (PPO) in Oklahoma supervised as many as 49 offenders daily (the average was 4.03) and reviewed up to 45,350 GPS data points (an average of 1,336) over that time period. The basic monitoring tasks comprised watching for indications of a low battery in the unit, alerts signaling motion but no GPS, strap removals or tampers, an inability to connect to the monitoring center, and zone infractions (Reference [9]). Monitored individuals are not allowed to leave the state while under GPS supervision.

Eligibility for this program is restricted to non-violent offenders that are serving a sentence of 5 years or less and whose initial placement is not higher than the minimum security level. Alternatively, non-violent offenders also qualify if they have no more than 11 months left to serve, have an approved home offer with the ability to remain in that home for at least 90 days, and who are currently assigned to a halfway house, community correctional center, or community work center. Offenders that have been convicted of a violent offense or who have escaped from a penal institution within the previous 10 years are ineligible for the program, as are offenders that have outstanding felony warrants from another jurisdiction or who have been denied parole within the previous 12 months. In particular, offenders that have been convicted of drug trafficking or racketeering activity or of a sex offense that would require them to be registered as a sex offender upon release are ineligible as are those that have a domestic abuse protective order against them or who have violated such an order. Anyone that has ever been removed from the GPS program is also ineligible (Reference [38]).

4.3 Facilitating Crime Scene Attribution

GPS monitoring technology can enable the automation of crime-scene analyses by allowing crime data from cooperating law enforcement agencies to be cross-referenced with the mapped location histories of tracked offenders. At the time Brown's et al. study was published in 2007, the movement path of a client typically could be played back, and some mapping products also indicated the client's speed and direction. In addition, the locations of exclusion zones were shown. In some cases, these zones could be defined by dragging a mouse over the relevant area on a map, but none of the interviewed agencies were actively using mapping software to visually correlate the locations of crime scenes with client tracks. One of the biggest challenges to achieving automated correlation between law enforcement data and community corrections data was achieving seamless access to both datasets from a single software system. Data collection and reporting systems often employed incompatible data formats and were accessible over different secure networks (Reference [7]).

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[9] DUI is an abbreviation for Driving Under the Influence.

Over the intervening decade tracking and mapping capabilities have improved, and several correctional agencies now use the tracking data collected by their electronic monitoring systems to conduct automated crime-scene analyses. For example, California's DAPO collaborates with local law enforcement agencies by providing access to their GPS database and conducting crime analyses to identify or eliminate GPS-monitored offenders as suspects in criminal activity. The offender-tracking systems operated by ODOC and MDOC also permit such automated analyses to be performed. Other respondents to the RT&E Center's questionnaire rely largely on some form of manual analysis to accomplish that task, and legal barriers exist to such programs in at least one of the states (Colorado).

The crime analysis software used by CDOC resides on a system that is separate from their EM vendor's Web-based product. Agencies interested in benefiting from those capabilities would normally have to provide appropriate crime geo-location and time data to the state for manual comparison. Although "[s]ome integration has been made with the Denver Police Department, ATF, and the vendor … to provide automated searches in relation to GPS locations of gunshots,"[10] CDOC has not expanded their collaborative efforts in this regard primarily because of legal concerns. Other agencies have requested blanket access to CDOC's geo-location data, but "under the advice of the Attorney General's Office in reviewing recent legislation regarding the sharing of geo-location data, we have determined that the data flow would have to be such that the agency provide their crime scene data to us and we will provide information back regarding any matches" (Reference [20]). Noting that there is no database to draw information from, Denver's Pretrial Services concurred that crime scene analysis can only "be performed manually using data provided by 3rd parties (e.g., detectives investigating cases, the news, etc.)." After plugging in the address, date, and time of a crime, Denver can then determine if any of their defendants were in the vicinity (Reference [24]).

5. INCREASING THE EFFICIENCY OF OFFENDER MONITORING

Several hardware and software improvement goals have been suggested over the last decade to increase the efficiency of GPS-based offender monitoring systems, including reliably and accurately tracking clients indoors, underground (e.g., in subways), during poor weather conditions, and within multi-story buildings. Since many of these goals exceed the capabilities of stand-alone GPS systems, integrated systems utilizing supplemental technologies will be required. Automated processing and alerting algorithms that more fully exploit gathered data by focusing an agent's attention on events requiring investigation (e.g., on violation reports or unusual tracks) or providing intelligence on offender habits (e.g., on offender stops and congregations) would be a force-multiplier (References [9] and [24]).

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[10] ATF is an acronym for Alcohol, Tobacco, and Firearms.

Techniques that substantially reduce the number of location points that PPOs must review daily would be highly beneficial in any setting. Several were identified during the summer 2006 interviews conducted by Brown et al.:

- Set detailed, irregularly-shaped zones that would allow an agency to monitor only those areas under its jurisdiction;

- Set warm zones around hot zones, to provide some leeway for client movements;

- Efficiently apply established zones to more than one client (e.g., the locations of schools and day-care centers to all sex offenders being monitored);

- Distinguish among directions of travel;

- Visually differentiate data points obtained for a client on different days;

- Incorporate finer-grained map-location data, and more frequent map updates;

- More comprehensively report and analyze the data to establish patterns and trends among offender movements.

However, at the time those authors conducted their study, the "types and volume of data that [could already] be integrated with maps [were] so large, and the techniques for producing high-quality overlaid graphical displays [were] so complex, that it [was] no longer economically feasible to develop software from scratch." A movement was underway to customize commercial off-the-shelf (COTS) components to produce domain-specific solutions, and mapping displays were envisioned on a wider variety of portable hardware platforms, such as smart phones and personal digital assistants (PDAs). Seamless integration with archived satellite imagery was also expected (Reference [7]).

5.1 TRACKS: A Prototype Geo-spatial Analytics Toolkit

The University of Oklahoma (OU) and ODOC partnered with NIJ in 2010 to develop a prototype geospatial toolkit (Reference [9]) with the goal of making GPS data more useful in community supervision by largely automating the production of corrections-actionable knowledge[11]. Because various data formats and a wide variety of proprietary algorithms existed at the time, a vendor-neutral processor design was adopted that utilized raw data. Following its initial development, the toolkit (called TRACKS) underwent Web-enabled beta testing with ODOC and by several state and local agencies that participate in NIJ's offender-monitoring Technology Working Group (TWG)[12] to assess its performance.

The use-cases developed by OU to guide their interactions with ODOC and other correctional partners during that beta testing addressed three objectives: (1) evaluating the then-current ODOC GPS program to determine data and functional requirements and expectations for space-time track analysis, (2) developing analytic tools to address identified needs, and (3) identifying

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[11] This partnership was initiated under NIJ Award No. 2010-DE-BX-K005.

[12] Beta testing was conducted in three phases, representing Web-based interactions of various stakeholder groups with the developmental Toolkit: OU and NIJ; ODOC (involving several jurisdictions in Oklahoma); and other state-level stakeholders from outside of Oklahoma that are represented on the TWG.

inmate characteristics and GPS movement patterns to improve eligibility criteria used to recruit participants for the (early release) program (Reference [39]). The functional requirements and expectations for space-time track analysis during that testing were to reduce the daily review workload and determine how TRACKS could be used for other monitoring needs, with a focus on ease-of-use, user friendliness, and the effectiveness of displays and outputs (Reference [40]). By comparing daily movements, TRACKS could identify new movement patterns by indicating where offenders go, the route they took to get there, how long they stayed, and whether they were in spatial-temporal proximity to other offenders or locations where crimes had been committed. The patterns resident in heat-maps generated from those data could additionally reveal potential social networks among offenders (Reference [41]).

The architecture and design of TRACKS were predicated on needs identified by correctional officers in the field based on user surveys, job shadowing, focus groups, and interviews with PPOs in Oklahoma[13]. Because OU was advised not to duplicate existing vendor capabilities, most of the new tools were conceptualized to provide features that were not available in the software implemented by ODOC's current vendor. OU sought information on whether the functions provided by those tools were desirable and whether their designs were easy to use. Prototyping efforts continued until at least mid-2014 related to the development of Web applications, PPO review and administrator tools, and determining appropriate monitoring settings. The University's Center for Spatial Analysis also planned to scale-up its computing capabilities to improve the system's computational efficiency and response time, and to assess its security (Reference [9]).

The prototype TRACKS system was configured to overlay offender movements on a map of the local environment, which were associated with entries in a listing of offenders on the same screen. The existence and severity of alerts generated either by the vendor or by TRACKS analyses also were indicated on-screen in a color-coded tabular format (see Figure 5–1). A PPO could select and review the track of any specific offender, and either retrieve additional information or approve that track before proceeding to the next individual. The stops made by an offender could be geo-contextualized by superposing them on archived satellite imagery, which indicated the types of terrain or buildings present at those locations, and by viewing an inset box showing the date of the stop, the times when the stop began and ended, and its duration. Tracks and stops from offenders with approved behaviors were excluded from future analysis-generated alerts for the chosen time period.

Customized monitoring preferences could be set for each offender to indicate whether he or she stopped at a night club, a gun store, a casino, or some other type of pre-set location. When suspicious stops were found, the system could be queried to determine if the offender made such stops on other days of that week or on a particular day every week. Furthermore, the type of alarms that the system provides also could be set for each offender (e.g., a strap violation, zone violation, time deviation, or bracelet gone). By linking to law enforcement databases, the locations of particular types of (color-coded) crimes could be overlaid on a map of the local

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[13] User needs were assessed by surveying 55 officers to gauge their views on the system then in use in Oklahoma, by shadowing 38 officers as they conducted their jobs to assess how they used that system (e.g., how and if they viewed the GPS points, and how they addressed violations), and by conducting focus groups comprising 44 officers to probe their views on the value and utility of the candidate set of new tools being considered for use in TRACKS.

environment along with the space-time tracks of offenders monitored by the PPO for potential correlation. The color-coded representations of the locations and durations of these stops also could be used to identify potential social networks (Reference [9]).
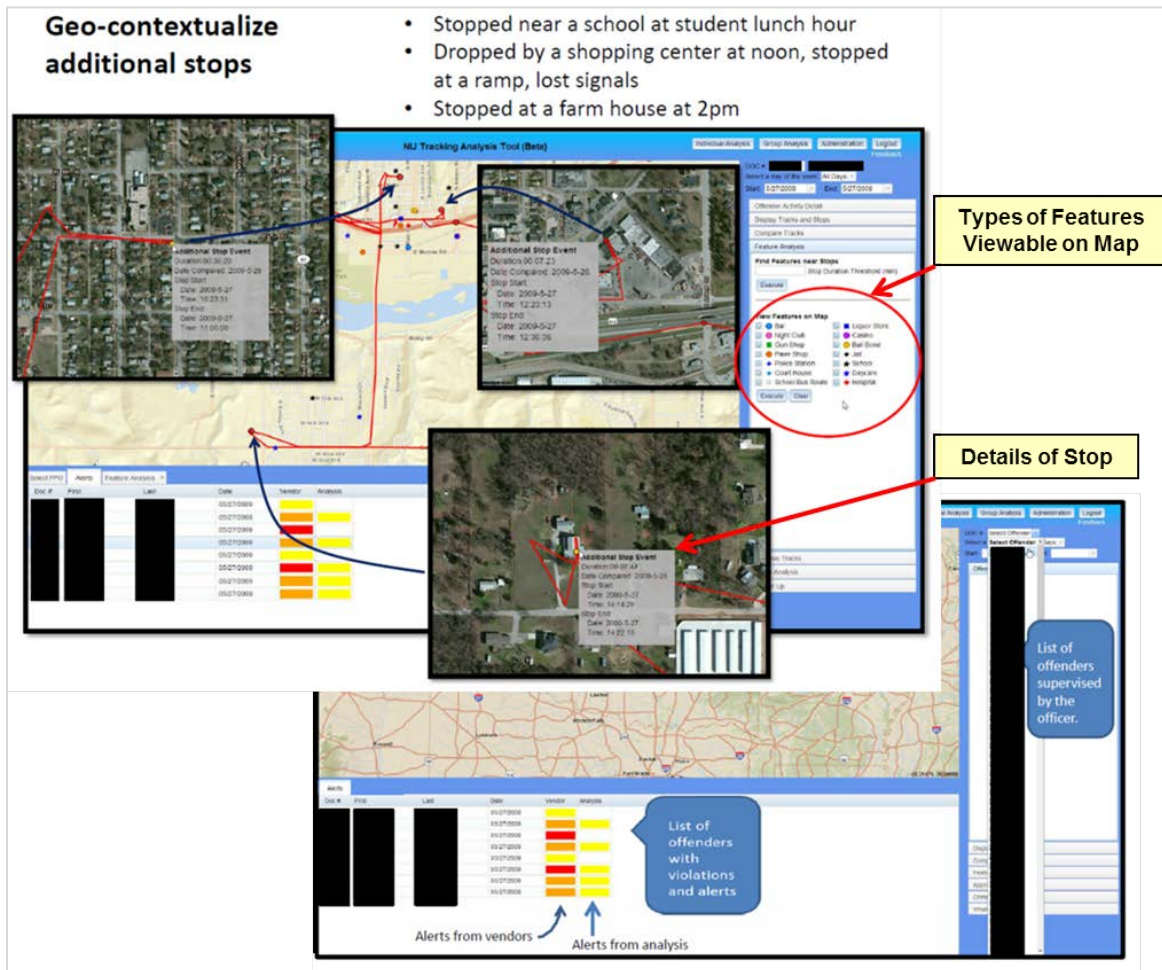
(Adapted from Reference [9])

Figure 5–1: Geo-Contextualizing the Space-Time Movements of Selected Offenders Based on Automated Alerts from the Prototype TRACKS System

This approach has been used by Nara et al. (Reference [42]) to examine whether patterns in spatial-temporal data could be exploited to identify behavioral groups that were more likely to succeed (or fail) as participants in early-release offender monitoring programs. Patterns found in data mined from 2,614 offenders in ODOC's GPS monitoring program over a 678-day period from March 2009 to January 2011 were classified based on their geometric and semantic properties. These case files, which resulted in the generation of 343,694 daily tracks, were separated into four classes, comprising offenders that: (1) showed no unsanctioned behavior; (2) had limited involvement in unsanctioned behavior; (3) had significant involvement in unsanctioned behavior but who remained in the program; and (4) that failed the program.

The raw GPS data were used to compute values for several geometric quantities describing aspects of daily offender tracks and to perform social network analyses, which were combined with client demographic profiles to perform unsupervised classification using self-organizing maps. These maps addressed the presence of offenders at particular points and times, the distance traveled between events, path complexity and directionality, demographics (e.g., ethnicity and gender), the number of potential social interaction links and variability in social interaction durations. While explanations were not embedded in Nara's et al. viewgraph presentation to aid in interpreting those results, Reference [42] concluded that several interesting patterns were found, which were undergoing validation. OU planned to extend the Self-Organizing Map approach by assessing the closeness of an offender to crimes and specific features, and by applying Sequential Pattern Analysis to the results[14], but there is no indication that this research was completed before NIJ withdrew its support for the program in the latter part of 2014.

The RT&E Center at the Johns Hopkins University Applied Physics Laboratory (JHU/APL) was tasked earlier that year to produce a plan for conducting operational testing of the anticipated government-off-the shelf (GOTS) version of TRACKS in another jurisdiction during 2015. The plan for distributing that system following its validation was still being developed at the time[15], but the most likely scenario was for criminal justice agencies to access it over Web-based links under an open-source (free) license from NIJ. However, the Center's efforts were re-baselined following the curtailment of OU's program. The preliminary recommendations developed by the Center as part of that tasking are summarized in Appendix B.

5.2 Analytics Capabilities of Commercially-available Software

To identify current analytical options for deriving actionable information from the burgeoning volume of GPS tracking data, NIJ subsequently tasked the RT&E Center to conduct a market survey of commercially-available products/systems suitable for use in electronically monitoring community-released offenders. Six companies responded to the associated RFI that was issued by NIJ in the Federal Register (Reference [10]). Their responses were analyzed by the Center and compared to an estimate of the capabilities of a seventh vendor's product, which were synthesized from information on that company's Web site (Reference [43]) and insights provided by correctional departments that use that firm's services (References [21] and [23]). The results are summarized in Table 5-1 (Reference [19]).

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[14] Sequential Pattern Analysis is a data mining approach concerned with identifying statistically-relevant patterns among time-sequenced data elements.

[15] Three distribution alternatives were under consideration as of the summer of 2013. The user would: (1) download installation packages; (2) upload data and use TRACKS' embedded Web-based capabilities under service agreements; or (3) work with OU to integrate TRACKS into the their software systems (Reference [9]).

Johns Hopkins Applied Physics Laboratory

Table 5–1: Analytic Capabilities of Commercially-available Offender Monitoring Products

Topic (Response: Yes or No)	SAS Institute	FMS	Track Group	Satellite Tracking of People	BI	Uncharted Software	3M Electronic Monitoring
Geospatial analysis	NR*	NR	Yes	NR	NR	NR	No
Track individual offenders	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Track groups of offenders	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Offender stop-analysis/drill-down capabilities	Yes	Maybe/Yes	Yes	Yes	Yes/Mouse	Yes	Yes
Offender association monitoring	Yes	Yes	Yes	Yes	No (future)	Yes	Yes
Entity resolution	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Identify patterns of activity	Yes	Yes	Yes	Yes	No (future)	Yes	NR
Visually distinguish client data points by day	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Victim monitoring	Yes	Yes	Yes	Yes	Yes	Yes	NR
Geocontextualize habits on imagery	NR	NR	Yes	NR	NR	NR	Yes
Geocoding/reverse geocoding	Yes	No	Yes	Yes	Yes	Yes	Yes
Provide both aerial and street views	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Overlay points-of-interest on maps/imagery	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Conduct geographic profiling	Yes	No	Yes	No	Yes	Yes	NR
Heat maps	Yes	No	Yes	No	No (future)	Yes	NR
Social network analysis	Yes	Yes	No	Yes	No (future)	Yes	No
Automated crime-scene correlation	NR	No	Yes	Yes	Yes	NR	Yes
Requires separate analysis of each jurisdiction	No	No	No	No	No	No	No
Requires separate analysis of each offender	No	No	No	No	No	No	No
Evaluates multiple jurisdictions/offenders	Yes	Possibly	Yes	Yes	Yes	Yes	Yes
User-specified time/distance thresholds	Yes	Yes/No	Yes	Yes	Yes	Yes	Yes
Hover over points for more information	Yes	Yes	Yes	No	No	Yes	Yes
Identify possible travel routes after a crime	Yes	Possibly	Yes	No	Yes	Yes	Yes
Automatic creation of offender watch lists	Yes	No	Yes	No	No	No	No
Caseload management planning by a PPO	NR	No	Yes	Yes	NR	NR	Yes
Allows curfews to be defined	Yes	No	Yes	Yes	NR	No	Yes
Supports creation of global zones	Yes	No	Yes	Yes	Yes	No	Yes
Supports creation of free-form zones	Yes	No	Yes	Yes	Yes	Yes	Yes
Configure zones as regular/arbitrary polygons	Yes	No	Yes	Yes	Yes	Yes	Yes
Customize monitoring parameters to individuals	Yes	No	Yes	Yes	Yes	No	Yes
Apply established zones to multiple clients	Yes	No	Yes	Yes	Yes	Yes	Yes
Create zone templates for offender classes	Yes	No	Yes	Yes	Yes	No	Yes
Permits definition of mobile restriction zones	Yes	No	Yes	Yes	No	No	Yes
Allows warm zones to be set around hot zones	Yes	No	Yes	Yes	NR	No	NR
Review tracking points/approve behavior	Yes	No	Yes	Yes	Yes	Yes	Yes
Automated alerting/event escalation	Yes	No	Yes	Yes	Yes	Yes	Yes
Provides basic predictive modeling	NR	No	Yes	Yes	NR	NR	No
Prediction of offender behavioral trends	Yes	No	Yes	No	No (future)	Visualization	No
Prediction of community monitoring candidates	Yes	No	Yes	No	No (future)	Pattern Eval.	No
Provides next-event forecasting	Yes	No	Yes	No	No (future)	No	No
Computes statistical significance of predictions	Yes	No	Yes	No	No (future)	No	NR
Able to identify serial offender anchor points	Yes	No	Yes	Yes	Yes	No	NR
Additional capabilities not covered above	See text	NR	NR	No	See text	See text	See text
Dates of Information (2015)	9/25, 10/5	9/16, 9/17	10/6, 10/9	9/23, 9/24	10/2, 10/5	9/29, 10/1	9/29

(From Reference [19])

* NR means "No Response; Mouse means "Mouseover"

The seven products identified by the market survey are offered under various business arrangements by: (1) companies that currently provide integrated offender-monitoring services to correctional customers (BI, STOP, 3M), (2) an industry-leader in big-data predictive analytics (SAS), and (3) vendors offering products that have been successfully applied to criminal justice and other applications (Track Group[16], FMS, Uncharted Software). Some of these analytics solutions are part of integrated monitoring systems and some represent stand-alone analytical engines. While none offer all of the capabilities that were under investigation in the TRACKS program, many of those features are available today, and the potential exists for incorporating more advanced analytics in the future.

5.3 Current Role of Analytics in Community Monitoring Systems

Space-time analyses of the temporal data sequences provided by GPS monitoring systems enable the discovery of patterns in the movements and stops of individual offenders, but the ability to draw valid inferences requires the analysis of large volumes of reliable data. Without extensive automation, data mining is not very practical in the corrections community. Agencies have their own objectives that are usually more immediate in nature, and each vendor also has its own processing algorithms, which are treated as intellectual property (Reference [27]). Overall price and responsiveness to individual agency requirements were identified by the departments responding to the RT&E Center's questionnaire as the predominant factors when selecting current EM vendors and systems. Those replies suggested that analytics were not generally an important factor in the competitive bidding process.

California was the only respondent that indicated analytics represented one of its bid discriminators. Development of a "Point Pattern Analysis" (PPA) feature was required by CDCR/DAPO in any procured mapping tool to visually distinguish locations where an offender spent designated periods of time. Going forward, DAPO is exploring other uses of analytical software in addition to PPA. In Maryland "DPSCS has been more focused on the value of electronic monitoring as a containment tool and hasn't really explored the analytics aspect to any great degree" (Reference [22]). In addition to cost, ODOC noted that its principal evaluation criteria were the offender population to be monitored, the performance of equipment in rural areas, and program set-up and implementation issues. However, their current system is 15 years old, and "[a]s analysis technology progresses and becomes more user-friendly, that feature would become more of a consideration" in any replacement systems that are contemplated (Reference [21]).

Although analytics did not drive EM vendor selection, the monitoring systems in use by the responding state-level agencies are capable of identifying patterns of activity for individual offenders, including stop analysis and association/congregation monitoring, although CDCR hasn't implemented the latter feature yet program-wide. Several also permit groups of offenders to be monitored, but none provide social network analyses or predictions of offender behavioral trends, good candidates for community monitoring, or next-event forecasting. Each of the

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[16] For example, the INTELLITRACK system being developed by the Track Group is predicated on the icuSUITE product originally developed for law enforcement applications by G2 Research in Canada (Reference [44]), which comprises a set of "intelligent tracking" tools that are similar to those that were under development for use in TRACKS (Reference [45]). G2 Research was acquired by the Track Group in 2014.

responding departments conducts crime scene analyses, but that function is automated only in the products operated by ODOC, MDOC, and CDCR. While those systems and the manual approach used in Colorado can perform such analyses by comparing the locations of all offenders monitored by a particular PPO with criminal events across multiple jurisdictions, the identification of possible travel routes after the commission of a crime generally requires an officer to manually map the alternatives.

Each department/agency indicated that its offender monitoring software provides easily understandable information that permits individuals to view all content permitted by their roles, permissions and information technology devices. However, only the products operated by MDOC and Maryland's DPSCS support caseload management planning. Denver's Pretrial Services noted that it "does not have automated tools that permit PPO's to more efficiently organize their monitoring routes and reduce their case-loads by assessing offender movements directly from the system, which might otherwise preclude the need to investigate some apparently suspicious behaviors" (Reference [24]). CDCR's system also does not offer that capability. Nevertheless, all of the systems allow curfews and free-form polygonal zones to be established, and monitoring parameters can be customized to individual offenders. Established zones can be applied to more than one client, and with the exception of Maryland's DPSCS and MDOC, zone templates can be created for various offender classes. Only three of the responding departments had the capability to implement mobile restriction zones (Colorado, Oklahoma and California), although CDCR does not exercise either that capability or their ability to customize monitoring parameters to individual offenders. None of the departments have software that automatically creates and updates offender watch lists.

All six agencies have the capability to overlay points-of-interest on maps and imagery, and the five state-level systems support geocoding and reverse geocoding. However, only ODOC and MDOC indicated they could geo-contextualize offender habits on those maps and images. The systems operated by or on-behalf of CDOC, ODOC, Maryland DPSCS, and MDOC allow PPOs to review tracking points and approve acceptable behavior. California does not, and Denver indicated that it does not currently have the staffing to allow them to complete fieldwork. "Officers do track behavior to determine the reason for violations, but it is not automated and the … courts make the determination as to whether or not a defendant has a good 'excuse' for not following his/her court ordered curfew or other requirements" (Reference [24]). Each system permits automated configuration of logged events as alerts when appropriate, and implementation of event escalation procedures.

6. OPERATIONAL IMPACT OF GPS MONITORING

The International Association of Chiefs of Police has identified four main benefits and four main issues regarding the use of GPS systems for community supervision (Reference [3]):

- Benefits: (1) Flexibility (it can be tailored to individual offenders, offering an alternative to incarceration); (2) Reintegration (it promotes compliance with the conditions of supervision and treatment); (3) Control (it provides the ability to track individuals and quickly respond to violations); and (4) Investigation (it provides accurate location information that is useful for crime scene correlation).

- Issues: (1) Limited empirical support (studies of the impact of GPS on recidivism show mixed results); (2) Increased officer workload; (3) False sense of security (false negatives and positives do occur); and (4) Legal and liability concerns (courts have not decided how to handle challenges related to GPS use, or what happens if a Department fails to respond to an alert or the equipment fails and a crime is committed).

Although many agencies believe that GPS monitoring provides a deterrent, the extent to which it alters client behavior is not yet known. For example, Brown et al. asked several agencies to quantify their experience with using GPS to assist in client supervision. After segregating the responses according to the role of the respondent (e.g., officers, technicians, monitors, supervisors, and planners), the overwhelming perception was that GPS positively impacts that ability. At the same time, the respondents indicated that use of GPS makes it harder for them to perform their jobs. GPS monitoring raises new concerns for an agency in terms of its responsibilities and obligations to victims. Location data provide the opportunity for agencies to better supervise their clients, but the availability of tracking points implies an obligation to act upon those data. Failure to do so may result in unwanted or unexpected liability. (Reference [7]).

Nevertheless, evaluations of the effectiveness of GPS use in community supervision are rare, and generally poorly designed and executed. Gies et al. (Reference [3]) pointed out that little research existed as of 2013 on the use of GPS technology as a tool for deterring criminal behavior by removing serious and violent offenders from the streets. Their study of California's high-risk gang offenders concluded that the main benefit of augmenting back-end sentencing by GPS surveillance appeared to be the potential for increased public safety. The main detriments were the increased cost and caseload demands, including the costs associated with returning these offenders to custody.

Studies of program effectiveness conducted by individual agencies often suffer from a lack of viable metrics for measuring effectiveness, which can result from a lack of time to focus on such matters or from unrealistic expectations based on an inadequate understanding of the technologies employed. One jurisdiction may use offender monitoring technology to reduce institutional overcrowding, while another may use it to enhance supervision of their highest risk offenders. If the objective in the latter case is to enhance public safety,… success could be measured by "the number of leads [obtained] from crime scene correlation or a comparison of [the number] of new crimes in the monitored population to a sample population that is not monitored." Other programs seeking to reduce domestic violence could develop useful metrics based on "the number of early warning alerts sent to [potential] victims resulting in the

avoidance of participant-victim encounters" or the demonstration that "fewer re-victimization incidents (occurred) when compared to a time period when the technology was not used" (Reference [6]).

Early advocates of EM believed that such tools could increase manageable case-loads although experience has suggested the opposite. Workload issues can be impacted strongly by the chosen technology and monitoring approach. Determining effective caseloads can be challenging during program start-up due to the steep learning curve. Officers must monitor the equipment, respond to alerts (many of which can be false), and teach offenders how the equipment works. For example, after assessing its operations in the early 2000s, FDOC recommended that the maximum caseload burden for supervisors diminish from 25:1 when EM was not used to 22:1 when RF supervision was appropriate. Further reductions of those maxima to 17:1 and 8:1 were recommended when monitoring community-released offenders by active and passive GPS techniques, respectively (Reference [46]). The use of vendor-operated monitoring centers to screen GPS-generated events is used by several states to reduce their agent's caseload burdens. For example, during the 2001-2007 period covered by their research, Bales et al. (Reference [47]) noted that FDOC's use of that approach "resulted in a significantly more efficient EM program and diminished the workload of supervising officers (in) dealing with non-emergency" alerts, enabling them to spend more time on activities related to directly monitoring offenders in the community.

The EM data acquired today by most of the correctional departments queried by the RT&E Center are stored at vendor-operated data centers (e.g., CDCR, CDOC, ODOC) or on vendor Web sites (MDOC, Denver Pretrial Services), but those data are analyzed to produce actionable information in a variety of ways. For example, in California, alerts are triaged by the vendor's monitoring center to distinguish those requiring immediate notification of the parole agent from those that can be handled by the vendor's staff prior to agent involvement. DAPO agents review those data when investigating crimes or after being alerted by the vendor, and supervising agents routinely review data each work day (Reference [18]). The data system utilized by CDOC's EM vendor is integrated with the system maintained by their case management vendor, which uses parameters established by CDOC for alert handling and escalation. Actionable alerts are "transferred to CDOC's Command Post for dispatch to officers. The Command Post then tracks the response to the alert to assure the proper response (arrest, warrant, repair) occurs" (Reference [20]).

In Michigan, the Department of Corrections' uses a vendor to provide Web-based data from out-of-state servers, but alerts are managed by a state-employee call center. When alerts occur, staff members obtain information regarding their cause and attempt to bring the client back into compliance (Reference [23]). The electronic monitoring data supporting Denver Pretrial Services also are stored on vendor Web sites, although a separate internal database is maintained for pretrial management. The received data are analyzed internally on a daily basis to determine patterns of activity and whether violations have occurred, but the vendor's staff is available to assist with data interpretation as needed. In contrast, Maryland stores all of their electronic monitoring information in a data center run by DPSCS (Reference [22]).

7. COST CONSIDERATIONS

Several criteria commonly used to evaluate GPS systems were summarized by Brown et al. (Reference [7]), including performance- and design-related items such as GPS accuracy and reliability, signal acquisition time, the unit size and number of components, battery life, durability and its resistance to tampering. In addition, the amount of client feedback and victim alerting capabilities offered, and the type and capabilities of vendor software (e.g., Web access, high-quality maps, the ability to specify inclusion and exclusion zones) are frequently used for this purpose. Importantly, these criteria also included the system's cost and affordability, which can depend on the objectives of the underlying program and the vendor's ability to administer client-participation fees. Some states (e.g., Wisconsin) have found that offender tracking is much more costly than anticipated because expenses associated with monitoring are easily underestimated. Additional employee compensation, and the cost of vehicles, office space and administrative overhead are often overlooked (Reference [5]).

According to the Vera Institute of Justice, surveys completed by corrections departments in 40 states indicated that the yearly cost for keeping an inmate imprisoned varies between about $13,000 and $59,000 (Reference [48]). However, several assessments have found that the costs resulting from adopting GPS-based monitoring alternatives are much less. For example, Payne et al. (Reference [2]) cited an estimated cost of $9,000 per year for monitoring sex-offenders by GPS techniques, although the actual costs presented in that reference in Tennessee and Iowa were $3,846 and $4,800 annually[17]. Gies et al. (Reference [3]) found that the cost of California's GPS monitoring program for high-risk gang offenders was $21.20 per day per parolee, which equates to $7,738 per year for each client. The cost of traditional supervision was even less, totaling $7.20 per day (or only $2,628 annually) for each individual.

DeMichele and Payne (Reference [4]), citing a 2005 source, indicated that the average daily costs for passive and active GPS monitoring were about $5 and $9 (i.e., about $1,800 and $3,240 yearly), respectively. These costs are comparable to those cited by Brown et al. in 2007 when combining the expenses of GPS equipment and vendor services into one figure[18], and by Nara et al. (Reference [42])[19]. While care must be taken to ensure that these comparisons are based on costs that are computed in a consistent way, each of these annual expense levels are considerably smaller than the cost per incarcerated inmate shown in Yellin's graphic (Reference [48]). For example, for California, the latter is approximately $46,000 yearly.

Roman et al. (Reference [49]) recently broadened the process of estimating program costs to conducting cost-benefit analyses, including the effects of uncertainty, for forecasting the effectiveness of electronically-monitored probation programs in the District of Columbia in comparison to standard techniques. Bayesian simulations were used to estimate probabilities of

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[17] It is not clear that these estimated and actual costs can be compared on an equal footing. In a separate correspondence, Payne (Reference [16]) noted "that the difference is that the higher estimate [probably] factors in workloads while the lower does not."

[18] Those authors reported that daily costs per client ranged between about $6 and $10 for active monitoring, and between about $4 and $6 for passive monitoring.

[19] The average daily cost per client for GPS-based supervision was reported to be about $5–$10 (i.e., approximately $1,825 to $3,650 per year).

the program's impact, predicated on the estimated annual range of expenses to operate an EM system and the range of savings from reduced recidivism. While EM comprises both RF and GPS technologies, the adopted costs were based on equipment and monitoring costs associated solely with GPS systems. Data from many previous research studies were combined with District of Columbia-specific case-processing statistics and implementation costs to develop the predicted outcomes. In particular, the cost assumed for GPS monitoring of a parolee was $8 per day, which is consistent with then-current costs in the District of Columbia and estimates provided in Bales et al. (Reference [47]). The cost of equipment used in their simulations ranged from $1 to $12 per day for each offender, since equipment costs vary greatly across GPS programs. These figures generally indicate that there is a significant economic motivation to developing community monitoring programs that safely deter negative behaviors.

Offenders are often required to pay a portion of these costs. For example, offenders assigned to the ODOC program are required to pay the Department a monitoring fee of up to $5.50 per day for passive monitoring, or $13.50 per day for active monitoring, not to exceed $300 per month. GPS monitoring technology was judged to provide a cost effective alternative to incarceration, and each placement in that program was estimated to save ODOC approximately $16,000 per year (Reference [38]). Drake (Reference [27]) cited a similar figure, indicating that costs are passed from agencies to offenders when feasible, with some offenders paying about $270 per month.

8. SUMMARY, ISSUES, AND RECOMMENDATIONS

The use of GPS monitoring systems in community corrections has become more widespread over the past 15 years as many state and local jurisdictions faced directives to implement that technology as a condition for client release, but a wide variation occurs in the applications for these systems and in the degree to which they have been successfully implemented. An early 2009 review of state codes found that 46 states and the District of Columbia had some type of legislation governing usage of electronic monitoring, which primarily focused on tracking sex offenders. Location-based tracking is also used today for intensively supervising high-risk parolees, developing confinement alternatives for low-risk criminals to facilitate their re-entry into society and alleviate jail overcrowding, and monitoring pre-trial defendants. Active and passive GPS systems track gang members and domestic abusers, monitor habitual burglars, alert former victims when offenders are released from custody, and locate truant students. Furthermore, GPS technology has great potential for facilitating automated crime-scene analyses by allowing crime scene data collected by cooperating law enforcement agencies to be cross-referenced with the location history of all offenders being monitored, and for conducting intelligence-rich social network analyses.

While the temporal data obtained from GPS monitoring systems provide additional opportunities for exploring patterns of activity through the application of space-time analytics, the benefits and the limitations inherent in their use must be carefully weighed against an agency's objectives and desired outcomes when deciding whether and how to implement such a program. Benefits include the ability to tailor the monitoring approach to individual offenders, providing an alternative to incarceration by reintegrating individuals into the community, and the ability to maintain situational control by enabling officers to quickly respond to violations. The findings

from the California studies summarized in Reference [17] suggest that GPS technology might serve multiple crime prevention purposes, depending on a program's goals and structural design. Nevertheless, there has been a paucity of research directed toward rigorously assessing the impact of electronic monitoring on reducing recidivism, and additional issues arise regarding liability concerns, increased officer workload, and the potential development of a false sense of security caused by false negative and positive tracking points. While the potential exists for improving long-term outcomes by implementing EM within an overall strategy of behavioral modification, one study that used risk and needs factors to statistically-match treated offenders with those not receiving treatment found that the efficacy of using EM supplemented by treatment depends on the offender's risk level (Reference [29]).

In general, previous studies have found clear cost advantages to using GPS monitoring relative to more traditional approaches to supervision, but only one study performed a quantitative cost-benefit analysis. Nevertheless, none of the evaluated systems were developed in accordance with standards, and system improvements are needed to reliably and accurately track clients indoors, underground (e.g., in subways), during poor weather conditions, and in urban canyons (including in "altitude" to reveal their locations in multi-story buildings). Multi-technology approaches will be necessary to address many of those issues, since GPS receivers require an unobstructed view of the sky to function properly. The accuracy of the derived position can be affected by several factors, such as the angular altitudes and spacing in the sky of the satellites and by timing errors that arise when the signal reflects off tall buildings or rugged terrain before reaching the receiver.

8.1 Agency-identified Analytics Capability Needs

To reduce agency workloads, many correctional agencies have contracted with commercial vendors to acquire, store and monitor their offender location data. Although the analytical capabilities of those firms and their products do not appear to have strongly influenced correctional agency selection decisions to date, the roles envisioned for analytics by the correctional agencies contacted during the recent analytics market survey varied according to their perceived missions. For example, Maryland noted that their focus to date "has been on efficiently operating an electronic tracking program that contributes to the effective containment of particular types of offenders. We have not yet turned our focus to the analytic capabilities of the system" (Reference [22]).

Of those agencies that have, CDOC stressed the importance of using predictive analytics to model offender behavior to help decide whether early intervention is warranted to prevent the commission of a crime (Reference [20]). Denver Pretrial Services also emphasized the importance of behavior prediction, and of "automating crime scene correlation by gaining access to an appropriate database" (Reference [24]), and MDOC agreed that crime scene correlation and pattern recognition can help solve crimes (Reference [23]). CDCR identified three areas where additional analytic capabilities would be beneficial: offender association monitoring; the ability to identify which new data are the most important to map based on approved protocols and algorithms; and acquiring quickly and easily interpretable reporting options that identify any new locations frequented by an offender (Reference [18]).

8.2 Enhanced Roles for Advanced Analytics in Corrections

Analytic tools comprising various combinations of statistical analysis procedures, data and text mining, and predictive modeling can be mission enabling through the discovery of hidden behavioral patterns and the prediction of future outcomes. The massive amounts of space-time data provided by location-aware devices provide new opportunities for exploitation by trajectory analysis, trajectory mining and mobile-object modeling, and such approaches have resulted in the development of useful statistical and computational methods for identifying clusters and outliers in these types of datasets. However, those approaches explore individual tracks over time or collective tracks within a confined area. Semantic enrichment can be used to contextualize trajectory segments with behavioral characteristics, but space-time analytical methods simplify the complexity of those data into elements and structures that more usefully capture the embedded information (Reference [8]).

During development of the TRACKS program, OU began to examine whether patterns in spatial-temporal data could be exploited to identify behavioral groups that were more likely to succeed (or fail) as participants in early-release offender monitoring programs. Although results were not reported, predictive analytics offers the potential for improving community supervision outcomes and enabling more efficient investment and deployment of resources. In addition, the potential for using raw GPS data to compute several geometric-related metrics describing aspects of daily offender tracks and for performing social network analyses were investigated. Those products were combined with client demographic profiles to perform unsupervised classification using self-organizing maps, addressing the presence of offenders at particular points and times, the distance traveled between events, path complexity and directionality, the number of potential social interaction links, and variability in social interaction durations. Several interesting patterns were found, and OU planned to extend the Self-Organizing Map approach by assessing the closeness of an offender to crimes and specific features, and by applying Sequential Pattern Analysis to the results.

Since OU's program terminated prematurely, the results of these research efforts were not elaborated publically, and it is difficult to evaluate the potential of many of those approaches. However, the design goals for TRACKS and those investigations served to identify many of the topics included in the RT&E Center's market survey of the analytics features offered by commercially-available products suitable for use in offender-tracking applications. Each of the responding vendors was invited to extend the list of topics addressed in Table 5–1 by identifying any additional areas where its advanced analytics capabilities could enhance the effectiveness of community supervision. In its response, the SAS Institute identified four types of assessments provided by its products (Reference [50]):

1. Automated model development: By building and retraining hundreds of predictive models addressing multiple instantiations of particular types of events, and automatically picking the best model for each, significant amounts of time can be saved when searching for emerging or previously undetected patterns within vast amounts of data;

2.   Sentiment Analysis: An offender's rhetoric can be automatically extracted in real-time or over a period of time from social media and other written communications for evaluation by a combination of statistical modeling and rule-based natural language processing techniques to provide insight/scoring on whether that rhetoric might turn into actions;

3.   Adaptive Self-learning: Implementation of a closed-loop, integrated, adaptive monitoring and tracking environment for the dynamic discovery and management of movement patterns by evasive offenders;

4.   Adaptive Case Management: Changing conditions and new information can be analyzed and scored continuously allowing case workflows to be updated automatically.

While many of these techniques may have substantial promise if developed further to meet specific agency objectives, the press of daily business in correctional settings makes it unlikely that there will be a strong customer "pull" to leverage this development. Agencies will benefit most from improvements to those analytics techniques that they already understand and value. While market forces may create a vendor "push" for extending current analytics capabilities, significant advances in realizing the potential of advanced analytics techniques will likely require vendor research and development, possibly in partnership with academia, which is catalyzed by government sponsorship.

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APPENDIX A. ABBREVIATIONS AND ACRONYMS

ATF	Alcohol, Tobacco, and Firearms
CARAS	Colorado Actuarial Risk Assessment Score
CDCR	California Department of Corrections and Rehabilitation
CDOC	Colorado Department of Corrections
COTS	Commercial Off-the-Shelf
CSOSA	Court Services and Offender Supervision Agency
DAPO	Division of Adult Parole Operations (California)
DPSCS	Department of Public Safety and Correctional Services (Maryland)
DUI	Driving Under the Influence
EM	Electronic Monitoring
FDOC	Florida Department of Corrections
GAO	Government Accountability Office
GOTS	Government Off-the-Shelf
GPS	Global Positioning System
HRGO	High-Risk Gang Offender
ISP-I	Intensive Supervision Program-Inmates (Colorado)
ISP-P	Intensive Supervision Program-Parolees (Colorado)
JHU/APL	Johns Hopkins University Applied Physics Laboratory
MDOC	Michigan Department of Corrections
NIJ	National Institute of Justice
NR	Not Reported or No Response
ODOC	Oklahoma Department of Corrections
OU	University of Oklahoma
PDA	Personal Digital Assistant
PPA	Point Pattern Analysis
PPO	Probation and Parole Officer
RF	Radio Frequency
RFI	Request for Information

RT&E Center	National Criminal Justice Technology Research, Test & Evaluation Center
SNA	Social Network Analysis
TWG	Technology Working Group
VPI	Violence Prevention Initiative
YOS	Youthful Offender System (Colorado)

APPENDIX B. RECOMMENDATIONS FOR OPERATIONAL TESTING OF TRACKS

The development of TRACKS began in 2010 with the goal of reducing the workload of correctional officers engaged in GPS-based offender monitoring by implementing automated analysis and alerting functions that were not dependent on proprietary vendor algorithms or data structures. Based on this expectation, the results from many of the previous studies summarized in this paper, and the limited documentation available to the NIJ RT&E Center on the development of TRACKS, the Center developed the following conclusions and recommendations at the end of 2014:

- TRACKS offers the potential for considerably enhancing the value of GPS-based offender monitoring in community supervision, and the development of that system should be completed if possible.

- Before a decision can be made to undertake that task, it is crucial to understand the state of the system that has been or will be delivered to NIJ, and what documentation is available regarding its hardware and software architectures, its implementation strategy, and the scope of and results obtained during the operational testing conducted to date.

  – What additional changes did University of Oklahoma (OU) plan to make to the system based on the results from the previous beta testing, or the additional heat-map research and algorithm development activities that were underway?

  – How difficult would it be to continue making and complete those changes?

  – What was OU's view at the time funding was curtailed of the critical issues with that system?

  – How difficult would it be without OU's guidance to tailor the geo-referenced graphics embedded in TRACKS to new locations appropriate to another agency's mission?

- Prototyping efforts continued up until at least the end of 2014, and OU planned to scale up its computing capabilities to improve the system's computational efficiency and response time, and to assess its security.

  – The prototyping activities entailed the development of Web applications, probation and parole officer review tools, administrator tools, and determining appropriate monitoring settings. The status and importance of these activities must be determined.

  – An assessment of the cyber-security of TRACKS is crucial for ensuring data integrity and maintaining the chain-of-custody necessary for using the derived results in evidentiary proceedings. If such an assessment has not been done, one must be completed before a Web-based TRACKS system could be implemented in practice. If such an assessment has been completed, it is important to understand those results to gauge their continued relevance to evolving cyber threats.

- Because TRACKS was developed to address the passive monitoring needs of Oklahoma Department of Corrections (ODOC), its value and applicability would be enhanced if it could be adapted for use in both active and passive modes.

    – How difficult would it be to adapt TRACKS for use in active monitoring?

    – Would additional systems engineering studies be necessary to augment its design?

- If the system is functional in its current state or its development can be completed relatively easily without the guidance of OU, the previously planned operational testing should occur.

    – The partnering agency selected should have a different mission from those evaluated already in order to test the robustness and extendibility of TRACKS.

    – Because TRACKS was used to monitor low-risk offenders during the ODOC focused beta testing, the new evaluation should occur in a high-risk environment that potentially utilizes active tracking.

- The distribution model being pursued by OU for implementing the government off-the-shelf version of TRACKS appears to have been based on allowing criminal justice agencies to access that product over Web-based links under an open-source free license from NIJ, although three distribution alternatives were still under consideration as of the summer of 2013.

    – In those models, the user would download installation packages; upload data and use the embedded Web-based capabilities of TRACKS under service agreements; or OU would work with individual vendors to integrate TRACKS into their software systems.

    – The benefits and drawbacks of each of these approaches should be compared to confirm the best choice from a user's perspective.