Capstone Proposal

Intelligent Geofence System

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1. Understanding the Problem or the Need

The role of technology in emergency response, community safety, and the collection of digital evidence has grown rapidly over the past decade and continues to expand. Modern law enforcement increasingly depends on advanced computing tools - real-time data feeds, geospatial analytics, mobile alerting, and machine learning - to identify threats sooner, deploy resources more efficiently, and rescue people from critical, time-sensitive situations. As crime patterns evolve and communities expect faster, more accurate responses, the case for integrating advanced technology directly into the daily workflow of local emergency responders becomes stronger. Technology will continue to play a central role in modern law enforcement, and the agencies best positioned to protect their communities are those that adopt intelligent, data-driven systems for prevention, intervention, and post-incident analysis.

An area where this need is particularly urgent is the enforcement of civil and criminal protective orders. Protective orders are typically issued by courts to keep a restricted party away from a protected person's residence, place of work, or other defined locations. A paper order alone however, has increasingly been recognized as limited in capacity to aid in prevention or real time detection of a restricted party crossing the designated area. In certain more severe cases, the gap between an order being issued and a crossing being detected and acted on, can be the absence or presence of a timely emergency response and a life-saving aid.

In February 2026 the Federal Bureau of Investigation released a Special Report that cited key findings from the 2020–2024 study. The report lists statistics that are aimed to raise awareness of the scale of lethalities associated with domestic situations where protective orders alone are evidently not doing enough to prioritize safety of the protectees. The report states that between 2020–2024 there were over 11,000 homicides tied to cases of domestic relationship (FBI, 2026). That's approximately 2,866 per year on average. While the current laws in all states provide for protective order measures, some states are starting to realize that the paper orders

alone without assistive modern computer technology to enforce them, might not be providing sufficient protection.

Several states in the United States now have laws that allow or require courts to order geofence monitoring and notification technology systems for individuals subject to protection orders. While the specifics vary - some states make it mandatory for “high-risk” cases, while others leave it to the judge’s discretion - the trend has further accelerated recently with the development of “Victim Notification Technology,” which alerts the victim directly if the restricted party enters a restricted zone.

As of 2026, the following states are notable for their implementation or recent expansion of these programs. Washington State, one of the leaders in this area, utilizes the Electronic Monitoring with Victim Notification Technology (EMVNT) program. Courts can order geofence tracking that provides real-time alerts via mobile apps or text if a restrained party violates distance requirements. More recently, in 2026, Oklahoma passed legislation (SB 1325) requiring geofence monitoring for defendants in criminal cases designated as severe, including those with aggravating factors. Tennessee and North Carolina were early adopters of geofence tracking. Tennessee’s law allows judges to require geofence tracking as a condition of a protection order. Also referred to as “Debbie’s Law,” it is named after Debbie Sisco and Marie Varsos, a mother and daughter who in 2021 was issued a protective order in Tennessee. The law at the time did not institute a geofence tracking notification technology to go along with the order. Both passed away in the aftermath of an attack that took place during a protective order breach.

In Illinois, under the “Cindy Bischof Law,” judges can order geofence monitoring for those who violate orders of protection. And most recently, in March 2026, California introduced an amended bill SB 871, which establishes a continuous geofence monitoring program for high-risk offenders in order to provide real-time enforcement of domestic violence protective orders. This law would mandate local law enforcement to integrate geofencing technology into digital intelligence command centers and provide real-time alerts to dispatch when the restricted area

is being crossed. Instead of placing the burden on the person who is protected by the protective order to identify if the restricted party has entered their domicile — which can be difficult if the protected person is asleep or otherwise unconscious at the time when the breach of the restricted perimeter is occurring — the burden is instead removed from the protected person and placed on the law enforcement to respond when the geofencing technology detects a breach of the restricted area by the restricted party. A timely response by law enforcement can result in life-saving aid administered to the protected person that would otherwise be unavailable due to lack of real-time notification to the digital intelligence command center.

The newly introduced law SB 871 in the state of California would require that such systems are integrated with the local law enforcement. One of the main roadblocks with implementation of such systems are funding, technical proficiency, and access to tools. While there are some commercial solutions for geofence monitoring that exist on the software market, there are currently no complete non-profit solutions that would offer an out-of-the-box intelligent system to implement this on a scale that it would require in order to get this effort off the ground by local agencies. Furthermore, the existing solutions frequently incorporate outdated technology and don't offer advanced Machine Learning-based pattern recognition technology and other intelligent features that would improve the quality of data provided to the geofence monitoring protection system.

Without modernized, agency-integrated solutions, the consequences of inaction range from adverse to severe: missed opportunities for early intervention, increased burden on victims to self-monitor their own safety, ongoing reliance on paper orders that the offender can violate before any response is mobilized and preventable lethalities. The consequences extend beyond the protected person — they include family members, bystanders, responding officers, and the broader community that bears the social and economic cost of insufficient protection.

The proposal of this project constitutes building a geofence monitoring system that would utilize Machine Learning, Python, GeoPandas, Scikit-learn, PostGIS, Leaflet.js, and GPS data processing open source tools in order to create a custom built pattern recognition software that would administer geofence analytics of objects in real time. The front-end will consist of a web-based application portal. The user located at the digital intelligence command center at a local agency station would be able to log into an Admin Dashboard where they will be able to add new objects to track, set geofence locations and parameters, receive immediate alerts about geofence crossings or restricted areas, get reports and analysis of movement patterns, and review daily data insights. The aim is to fill the gap left by commercial vendors and outdated tools by providing an intelligent, modern, agency-deployable solution that can save lives.

2. Stakeholders

The stakeholders for this project include law enforcement agencies and protected persons (who hold active protective orders).

Law enforcement agencies stand to gain a real-time, intelligent alerting capability integrated into their digital intelligence command center. With this system in place, dispatchers and patrol officers receive immediate notification when a restricted party crosses into a protected zone, enabling proactive response instead of reactive investigation after an incident. Officers gain a reliable evidentiary record of movement patterns and violations that can support criminal charges, bail revocations, and risk-assessment decisions in court. Without such a system, agencies continue to rely on victim-initiated 911 calls, which are inherently delayed and often impossible when the protected person is unable to call (e.g., asleep, restrained, or incapacitated). The risk of inaction for law enforcement constitute preventable lethalities and exposure to liability in jurisdictions where statutes increasingly expect proactive enforcement.

Protected persons (who hold protective order) stand to gain an increased possibility of life-saving intervention even when they are unable to dial 911 — for example, when they are asleep, unconscious, or unaware that a protective order breach is taking place. The system shifts the burden of detection from the victim to the technology and to law enforcement, which is the explicit policy goal of every state statute referenced in Section 1. Potential concerns for this stakeholder group include onboarding processes and getting assistance from law enforcement. These concerns are addressed by the system design, role-based access, and an opt-in workflow administered by the agency.

The developer of this project will obtain experience working on a project that includes integration of machine learning, geospatial analytics, full-stack web development, and a deployable architecture aligned with a real public-safety use case. The developer will increase skills and experience in navigating client requirements, user acceptance testing, and the legal context that shapes how such systems must be built.

The agency (a local municipal law enforcement agency) will be able to conduct an early evaluation of an open, non-proprietary solution they can use as a reference architecture or as the basis for a procurement decision. The barrier to adoption — discussed in Section 1 as funding, technical proficiency, and access to tools — is directly reduced by a non-profit oriented system that does not lock the agency into a vendor contract.

Potential roadblocks to adoption include: integration with existing CAD/RMS (computer-aided dispatch and records management) systems used by the agency, the administration of GPS hardware for restricted parties (typically covered as a part of state statute administering the monitoring), training requirements for dispatchers and officers, and building or updating existing internal framework governing data retention. These issues are listed in order to raise awareness in advance so that feedback can be gathered further.

3. Environmental Scan

A review of statutory developments, academic literature, and existing commercial solutions asserts that location-based geofence monitoring for protective order enforcement is a recognized and expanding technology in the United States. Nevertheless, some gaps remain, particularly in machine-learning-enhanced pattern recognition and open, agency-deployable architectures.

Illinois was one of the earliest states to enact a statutory framework specifically for GPS monitoring of protective order respondents. The Cindy Bischof Law, named for a woman who was killed after previous repeated violations of order of protection by the restricted individual, The law authorizes courts to order monitoring as a condition of bail or probation for individuals charged with or convicted of violating an order of protection in a domestic violence case, and it establishes statewide standards for the Domestic Violence Surveillance Program (Illinois State Bar Association, 2019). Implementation in Cook County is operated through the Adult Probation Department's Home Confinement Unit, which uses GPS devices to enforce defined exclusion zones around victims' homes and workplaces (Circuit Court of Cook County, n.d.).

Operational data from Illinois, however, demonstrates that the existence of a monitoring statute does not by itself guarantee effective enforcement. A Chicago Sun-Times investigation found that 911 dispatchers were notified of nearly 12,000 breaches of safety zones in a single recent year, yet only a small number of those alerts resulted in arrests, with several arrests ultimately dismissed (Charles, 2021). The Sun-Times also reported that some monitored individuals appeared to repeatedly test their devices, generating multiple alerts in short periods — behavior consistent with attempts to identify gaps in coverage (Charles, 2021). This finding is relevant to the present project: it suggests that pure threshold-based geofencing produces a high volume of alerts without sufficient prioritization, and that machine-learning-based pattern

recognition could meaningfully improve triage by flagging repeated probing behavior, dwell time near a zone boundary, or trajectories consistent with approach rather than incidental transit.

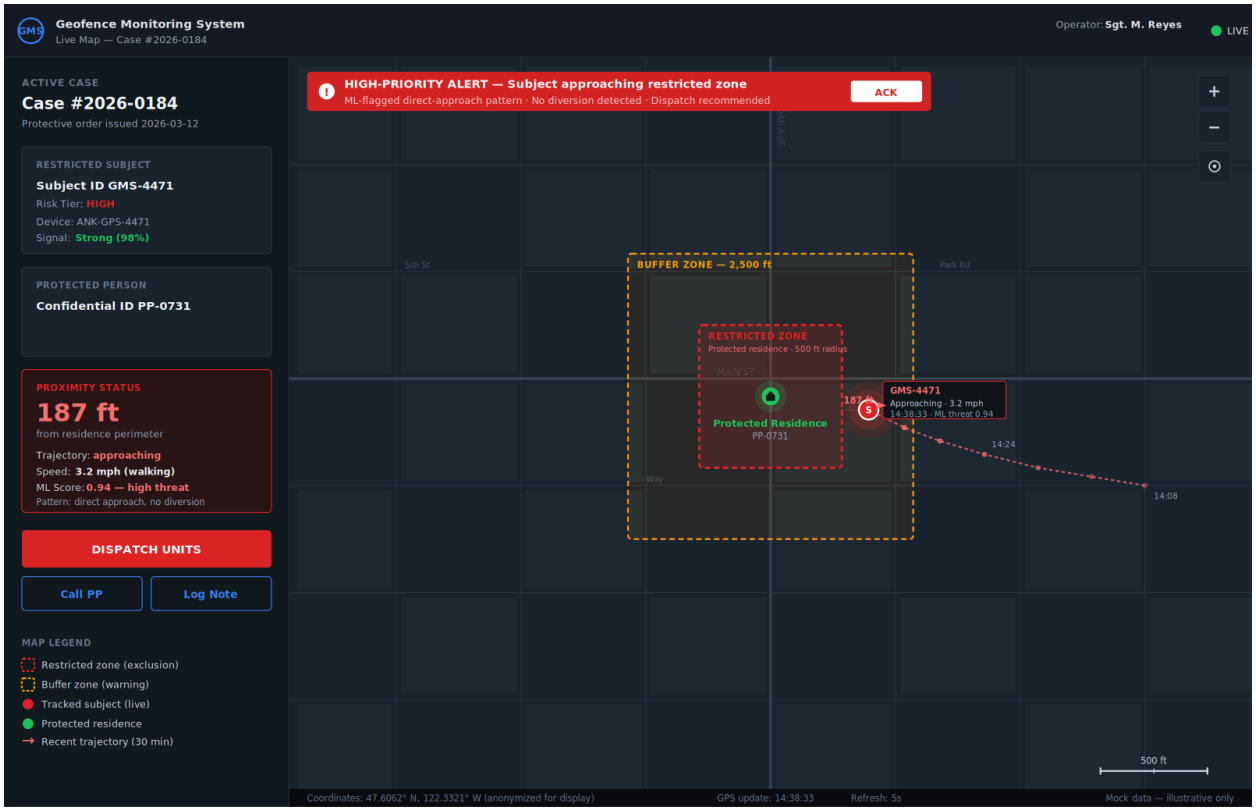
Academic literature on machine learning for geospatial trajectory analysis supports the proposed technical approach. In their work on anomaly-resilient geofencing in IoT environments, Mohamed, Shafea, and Abdelhakam (2026) demonstrated that a One-Class SVM classifier achieved 93.5% accuracy in filtering spurious signals before geofence evaluation, outperforming K-Nearest Neighbors (86.6%) and Isolation Forest (67.4%) on the same dataset. Scikit-learn provides production-ready implementations of all three algorithms (Pedregosa et al., 2011), which supports the project's choice of an open-source Python stack.

Existing commercial offerings in the protective-order monitoring space, which includes vendors such as BI Incorporated, SCRAM Systems, and Securus Monitoring Solutions, are functional but share several limitations relevant to this project. They are proprietary, license-fee based, and typically packaged with hardware contracts; they provide limited data to the agency's own analysts, potentially making integration with broader intelligence systems complicated. Furthermore, the pattern-recognition logic in alerting commonly appears as static rule-based. This may result in an alert-fatigue in agencies receiving large volumes of low-priority notifications, which can lead to important alerts being missed or deprioritized (Charles, 2021).

The environmental scan provides support for the existence of a gap that this project proposes to address. State statutes increasingly mandate or authorize geofence monitoring; the renewed support for these policies indicate that population may benefit from reducing lethal risk; and the academic literature emphasizes that machine-learning-based trajectory and anomaly analysis is a well-tested technique suited for improving the precision of alerts. What is currently missing is an open, agency-deployable system that combines real-time geofence enforcement, ML-based pattern recognition for alert prioritization, and a usable command-center dashboard — designed for adoption by local agencies that cannot easily afford proprietary vendors. This project is positioned to fill that gap.

4. Prototype and Planned Key Features

Dashboard View



Planned Key Features

Admin Dashboard. A web-based portal for the digital intelligence command center, with secure login, role-based access (administrator, dispatcher, supervisor), and a map-centric main view rendered via Leaflet.js.

Tracked Object Management. Create, edit, and deactivate tracked subjects (restricted parties), each linked to one or more protective orders, hardware identifiers, and protected persons.

Geofence Configuration. Define exclusion zones (e.g., home, workplace, school) as polygons or radius buffers around addresses, with configurable buffer/exclusion distances consistent with statutory frameworks (e.g., the 2,500-foot and 5,000-foot zones referenced in the Illinois model).

Real-Time Alerting. Immediate notifications in the dashboard when a tracked object crosses into a restricted zone, with priority scoring informed by the machine learning layer.

Machine Learning Pattern Recognition. Trajectory and anomaly analysis using Scikit-learn (Isolation Forest, One-Class SVM, and DBSCAN clustering on movement features) to distinguish incidental transit from intentional approach, identify repeated probing behavior near a boundary, and reduce alert fatigue.

Reports and Analytics. Daily and weekly reports of movement patterns, violations, response times, and case-level summaries suitable for use in court filings and bail-review hearings.

Audit Log. Tamper-evident logging of alerts, user actions, changes to a geofence configuration.

Evaluation Plan

Evaluation with measurable criteria: simulated geofence breach to dashboard alert under 5 seconds in a local test environment; classification performance of the ML alert-prioritization layer measured by precision, recall, and F1-score against a labeled set of simulated trajectories that include both genuine approach patterns and incidental transit; dashboard usability scored via a System Usability Scale questionnaire administered to test users; functional completeness measured against the feature list using a written user stories checklist; and qualitative feedback from a review session with an end user at the sponsoring local municipal agency.

5. Individual's Intended Contribution to the Project

Individual intended contribution by the developer is the design of the project architecture, particularly database design for PostgreSQL, integration of backend and front end, curation of custom pattern recognition software, user Dashboard design and user acceptance testing, research, documentation writing, professional communications with end users.

6. Final Deliverables

The anticipated final deliverables for this capstone project constitute a working web application and the supporting materials needed for evaluation and handoff.

The primary deliverable is a geofence monitoring web application that utilizes Machine Learning, Python, GeoPandas, Scikit-learn, PostGIS, Leaflet.js, and GPS data processing open-source tools to create a custom-built pattern recognition system that administers geofence analytics of objects in real time. The front end will consist of a web-based application portal. The user located at the digital intelligence command center at a local agency station will be able to log into an Admin Dashboard where they will be able to add new objects to track, set geofence locations and parameters, receive immediate alerts about geofence crossings or restricted areas, get reports and analysis of movement patterns, and review daily data insights.

Supporting documentation deliverables include: a database schema document covering the PostgreSQL/PostGIS structure; setup instructions; user documentation for dispatchers and administrators; a developer/integration document for the agency's technical staff; a written final report; and a set of test cases and a record of user acceptance testing results.

Client approval will be obtained by conducting a structured review session with end users at a local municipal agency. The session will demonstrate the application against the documented feature list, capture written feedback, and result in acknowledgement that the deliverables meet the requirements agreed upon at the start of the project.

Success criteria for the deliverables are: the application performs the full alert workflow end-to-end against simulated GPS streams without unrecovered errors; the ML pattern recognition layer is trained, persisted, and demonstrably integrated into the alert pipeline; the dashboard is usable by a non-technical reviewer upon completion of an orientation; and the agency reviewer signs off on the demonstration.

7. Approach / Methodology

The project will follow an Agile development process organized into weekly iterations. Each week will be broken down into tasks and user stories that capture both research activities (e.g., reviewing a specific state statute, evaluating a Python library, or gathering a GPS dataset for testing) and software development activities (e.g., building the database schema, implementing the alert microservice, or wiring the ML classifier into the alert pipeline). The Agile structure is chosen because it supports incremental delivery and frequent reassessment — both of which are essential given that this project combines unfamiliar elements (geospatial ML) with a domain (protective-order enforcement) where requirements must be validated against local frameworks and end-user expectations.

At the start of each weekly iteration, tasks and user stories will be entered into a task tracker. Each user story will follow the standard format “as a [role], I want [feature], so that [outcome]” pattern and will carry acceptance criteria. At the end of each week, a review brief will identify what was completed, what roadblocks were faced, and if anything needs to move into the next iteration. This cadence allows the project to process new findings and adjust on the go. For instance, when the pure threshold-based alerting produces a high volume of low-priority notifications, it can be re-tested and re-tuned to focus on specific patterns of interest.

Planned research activities include continued review of relevant state statutes, review of academic literature on trajectory anomaly detection, evaluation of open-source libraries (GeoPandas, Shapely, Scikit-learn, Leaflet.js), and informal conversations with the sponsoring agency representative to confirm operational assumptions. Development activities are organized around the four phases described in Section 8, each of which contains its own set of weekly user stories that lead to a defined milestone.

8. Timeline / Resources

The timeline is organized into four major phases (with milestones).

Phase	Focus	Key Activities	Resources
PHASE 1	Research and Development of Data Pipeline Backend (Database)	Database design; PostgreSQL setup; PostGIS extension installation and configuration; defining location data types and spatial indexes; data storage schema for tracked objects, geofences, alerts, and audit logs; ingestion endpoint for GPS streams.	PostgreSQL, PostGIS, Python, SQLAlchemy/GeoAlchemy, Git/GitHub, local development workstation.
PHASE 2	Machine Learning with Python — Data Pattern Processing and Analysis	Using GeoPandas, Scikit-learn, Python, and other tools to implement custom software for pattern recognition. Feature engineering on GPS streams (speed, heading, dwell, distance-to-boundary); training and evaluation of anomaly detection models; persistence of trained models; integration plan for the alert pipeline.	GeoPandas, Scikit-learn, Shapely, NumPy, Pandas, Jupyter for prototyping; sample/synthetic GPS datasets.
PHASE 3	Web Application with Flask / Python	Server configuration; building the user/Admin Dashboard; map rendering with Leaflet.js; geofence creation and editing interface; alert console; daily reports and movement analytics screens.	Flask, Jinja2, Leaflet.js, HTML/CSS/JavaScript, Bootstrap or comparable CSS framework, web server (gunicorn/nginx or development equivalent).
PHASE 4	Backend and Front-End Integration; UAT; Deployment; Documentation	Wire the ML pipeline into the live alert flow; end-to-end testing; user acceptance testing with the sponsoring agency; bug fixes and feature adjustments based on feedback; production-style deployment; final documentation (user guide, developer guide, final report).	Cloud or on-prem hosting environment, monitoring tools, documentation tooling (Markdown, draw.io for diagrams), test plan documents.

9. Testing Plan

The product will be tested for functionality and usability by executing user acceptance scenarios, gathering feedback, documenting test results, and making adjustments based on those results to address any bug fixes or add feature updates.

Functionality testing will be conducted by breaking down the functionality of each feature. An internal functionality check will test each documented feature against a written test plan: account login and role enforcement; creation, editing, and deactivation of tracked objects; geofence creation; ingestion of simulated GPS streams; correct triggering of alerts on boundary crossings; correct prioritization scoring from the Machine Learning layer; and correct generation of daily and weekly reports. Test cases will record expected and actual results, with identified defects logged and tracked for resolution. Integration testing will include the end-to-end workflow from GPS ingestion through alert display under representative load.

Usability testing will be conducted with a small group of representative end users at the local municipal agency. Users will be asked to complete a set of scenarios (e.g., “add a new tracked object and assign two geofences”, “respond to an incoming alert and view the trajectory leading up to the breach”, “generate a daily summary report for a specific case”) while a test facilitator observes and records issues, feedback and questions. The session will conclude with a short System Usability Scale (SUS) questionnaire and open-ended questions about clarity, terminology, and missing features. Results will be aggregated and fed back into the Agile backlog as user stories for the next iteration.

Acceptance criteria for the testing plan are: application feature passes functional test case; the Machine Learning prioritization layer reaches a defined precision/recall threshold on the labeled simulation set; usability testing yields a user usability score above the established threshold; the agency reviewer signs off that the system meets the requirements demonstrated.

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