

SENTRY Research Project Portfolio

OUR DEPARTMENT OF HOMELAND SECURITY CENTER OF EXCELLENCE RESEARCH STRUCTURE AND PROJECT IMPACTS



Soft Target Engineering
to Neutralize the
Threat Reality

Supporting DHS Research Priorities

SENTRY research aligns with DHS primary priorities: securing and managing air, land, and maritime borders, and expediting lawful trade and travel. It also supports secondary research priorities of threat characterization, detection, and mitigation, as well as emergency response and critical infrastructure for public safety.

Our Research

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places (STCPs) to four fundamental research areas, culminating in our vision of the **Virtual Sentry Framework** (VSF). The Framework aims to provide real-time decision support systems enabling actionable situational awareness leading to more effective threat assessment, preparedness, mitigation, and response for STCPs.

Fundamental Research Areas

Real-Time
Management of
Threat Detection
and Mitigation



Programs

- *Real-Time Management of Adaptive Surveillance and Mitigation*
- *Real-Time Video Surveillance for Threat Detection and Mitigation*
- *An Artificial Intelligence-Driven Threat Detection and Real-Time Visualization System in Crowded Places*
- *End-to-End Graph-Agnostic Real-Time Evacuation Routing to Protect Soft Targets During Active-Shooter Scenarios*

Advanced Sensing
Technologies for
Threat Awareness



- *Multi-Sensor Threat Assessment Platforms: Digital Dog Nose*
- *Multi-Sensor Threat Assessment Platforms: Mid-Infrared Laser-Based Sensors*
- *Radar Stand-Off Detection of Concealed Threats on Moving People*
- *Protection of Soft Targets and Crowded Places Using Aerial/Ground Agents*

Threat Risk
Assessment,
Prediction, and
Deterrence



- *Machine Intelligence for Effective Threat Deterrence and Risk Mitigation at Soft Targets and Crowded Places*
- *Protecting Soft Targets: a Game-Theoretic Framework for Multitarget, Multi-Layer Defense Against Strategic Attackers*
- *Modeling and Behavior Analysis to Assess Public Space Safety and Protect Soft Targets against Active Shooter Attacks*

Layered Security
Architectural
Design and
Simulation



- *Architectural Design Research: Integrating Security in the Public Realm*
- *Dynamic Digital Twins for Secure and Smart Civic Space*
- *Real-Time Crowd and Attacker Forecasting for Risk Assessment and Threat Mitigation*
- *Impact of Architectural Design on Emergency Behavior and Response During Active Shooter Incidents*



REAL-TIME MANAGEMENT OF ADAPTIVE SURVEILLANCE AND MITIGATION



Soft Target Engineering
to Neutralize the
Threat Reality

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

A DEPARTMENT OF HOMELAND SECURITY (DHS) CENTER OF EXCELLENCE LED BY NORTHEASTERN UNIVERSITY

Real-Time Management of Threat Detection and Mitigation Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Real-Time Management of Adaptive Surveillance and Mitigation Project** falls within the **Real-Time Management of Threat Detection and Mitigation Research Area**. The research area leverages data and information to develop decision support systems for enhanced and timely protection of soft targets and crowded places in a real-time, operational capacity.

PROBLEM

This project addresses the critical need for decision-support systems that effectively use multimodal sensors to help decision-makers identify threats, predict crowd behavior, and suggest strategies to influence and guide crowds to safety.

SOLUTION

The primary objective is to develop a new class of real-time decision-support systems to advise decision-makers on effective mitigation strategies and likely outcomes. These systems will help enable threat detection in dynamic situations, allowing decision-makers at several levels to explore what-if scenarios and select appropriate actions.



Accomplishments

Real-Time Crowd Guidance

Developed a framework and associated software to generate real-time crowd-guiding strategies in complex environments, even with partial information about physical surroundings and the locations of potential threats. To complement this framework, researchers developed tools to assess the safety of these strategies.

Safety Assessment and Sensor Integration

Created tools to assess the safety of these guiding strategies, measuring in terms of the likelihood that resulting trajectories will enter unsafe areas.

Delay-Aware Safety Evaluation

Established a practical framework to evaluate the safety of these strategies while accounting for time delays, including sensor lags, time needed to convey information to relevant parties, and crowd reaction times.

Practical Applications

These models and algorithms can be integrated into SENTRY's **Virtual Sentry Framework** or existing Security Operation Centers for operational application in various soft target settings, including schools, surface transportation sites, malls, and stadia. When utilized by first responders to conduct risk mitigation strategies and to model human responses in emergency situations, these tools can assist Customs and Border Protection, the Cybersecurity and Infrastructure Security Agency, the United States Secret Service, and the Transportation Security Administration in the Department of Homeland Security Science and Technology Directorate priority of emergency response and public safety.

Collaborations

The project works closely with:

- **Customs and Border Protection Command Center, Long Beach** -to gather suggestions for desired technologies and potential opportunities for testing prototype algorithms.
- **SENTRY's Real-Time Video Surveillance for Threat Detection and Mitigation Project** - to develop tools that combine data from multiple sensors into a single video sequence, analyzed to reveal interactions between persons of interest and predict their future locations.
- **SENTRY's Dynamic Digital Twins for Secure and Smart Civic Space Project** - to help validate findings and explore potential applications to the Virtual Sentry Framework.

Publications & Presentations

[Adaptive Layered Surveillance Systems](#) *Mario Sznaier, Milad Siami, Stacy Marsella, David Castañón, and Richard John* - Presented on April 12, 2023

[On The Disclosure Of Defensive Posture: Adversarial Belief Dormation And Target Selection Decisions](#) *Kyle Hunt, Sule Güney, Jun Zhuang and Richard John* - Published in Production and Operations Management, December, 2024

[Dynamic Network Flow Optimization for Task Scheduling in PTZ Camera Surveillance Systems](#) *Jared Miller, Tianyu Dai and Mario Sznaier* - Published at the 6th International Conference on Artificial Intelligence, Robotics, and Control, May, 2025

[Learning Enabled Real Time Strategies for Safely Avoiding an Active Shooter in Unknown Environments](#) *Mario Sznaier and Milad Siami* - Presented on February 19, 2025

[Behavioral Validation for a Game-Theoretic Model of Attacker Strategic Decisions, Signaling, and Deterrence in Multi-Layer Security for Soft Targets](#) *Kevin Kapadia, Ian Unson, Katie Byrd, Jun Zhuang, and Richard John* - Published in Risk Analysis, February 2025

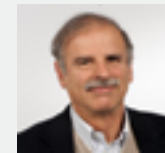
[Hear Something, Say Something: Perceived Threat as a Mediator of Concerning Behavior and Reporting Intention for School Staff, Parents, and Recent Students](#) *Kevin Kapadia, Katie Byrd, and Richard John* - Published in Journal of Risk Research, March 2025

Project Leaders

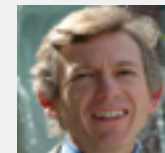
Principal Investigators



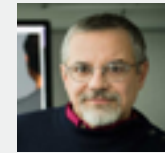
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REAL-TIME VIDEO SURVEILLANCE FOR THREAT DETECTION AND MITIGATION



Soft Target Engineering
to Neutralize the
Threat Reality

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

A DEPARTMENT OF HOMELAND SECURITY (DHS) CENTER OF EXCELLENCE LED BY NORTHEASTERN UNIVERSITY

Real-Time Management of Threat Detection and Mitigation Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Real-Time Video Surveillance for Threat Detection and Mitigation Project** falls within the **Real-Time Management of Threat Detection and Mitigation Research Area**. The research area leverages data and information to develop decision support systems for enhanced and timely protection of soft targets and crowded places in a real-time, operational capacity.

PROBLEM

This project aims to tackle the challenges associated with automatically analyzing videos from extensive camera networks in crowded environments. Existing computer vision algorithms struggle to understand typical human behaviors, identify specific people or objects, and recognize actions from various camera angles.

SOLUTION

The proposed solution is to create new computer vision algorithms that can learn typical patterns in videos based on time, spot specific people or objects across cameras, and recognize actions from different camera angles.

Accomplishments

Publicly Distributed Computer Vision Algorithms for Action Recognition

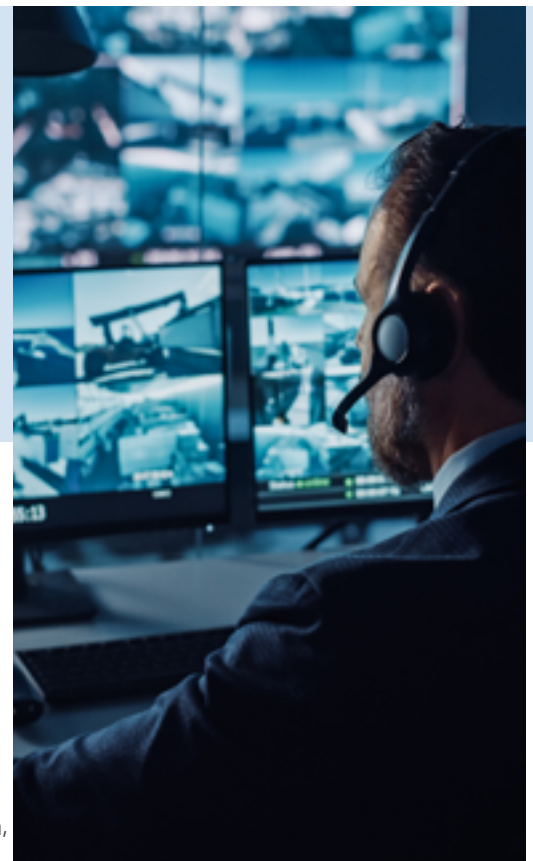
SENTRY's nine computer vision algorithms for action recognition and segmentation and video temporal super-resolution are publicly available and have been downloaded by the computer vision community to improve the performance and accuracy of action recognition solutions.

Novel Anomaly Detection Dataset Created

Developed and released an innovative video anomaly detection dataset featuring comprehensive annotations that encompass flight schedules, regional activity patterns, and crowd metrics, in partnership with Albany International Airport. This dataset will help advance tools in real-time crowd anomaly prediction and detection, giving those responsible for security more time to respond to threat events.

Advancing Capabilities in Person and Action Detection

Attained state-of-the-art performance of finding a specific person in a video and long-term tracking, setting new benchmarks in the field. This new approach's impressive accuracy rate exceeding 95% was achieved by implementing a cutting-edge Multiview detection and tracking algorithm, significantly improving detection reliability. The team engineered a sophisticated multi-agent action recognition model capable of accurately identifying a diverse range of actions, including but not limited to "punch/slap," "giving something," and "kicking," enhancing overall situational awareness and response capabilities.





Practical Applications

SENTRY's video analytic tools can help to identify unusual or suspicious actions of crowds and individuals or track bad actors across camera views in real time. Video-based solutions are key components of many safety and security installations. The software SENTRY has developed can be applied to existing camera systems in various soft target settings. These tools will help support Department of Homeland Security Components in a broad capacity. Transportation Security Administration's operational mission of safeguarding all four general modes of land-based transportation by identifying potential threat events, Cybersecurity and Infrastructure Security Agency's priority of school safety, Customs and Border Protection's mission priorities of countering terrorism and securing the border, the Department of Homeland Security Science & Technology research priority of public safety, and the United States Secret Service priority of securing public places are just a few areas that will benefit from the software developed by SENTRY.

Collaborations

The project works closely with:

- **SENTRY's Stadium Security and Surface Transportation Partners** - to discuss needs, tour facilities and establish a roadmap to test and refine algorithms in live environments.
- **Albany International Airport** - for providing real world data resulting in the creation of SENTRY's novel video anomaly detection dataset.
- **University of Notre Dame** - established a pathway for data exchange and field testing.
- **Axis Communications and MappedIn** - to support the integration of these solutions with their products, partnering with Industry to bring tools to the market.

Publications & Presentations

Real Time Video Surveillance for Threat Detection and Mitigation

Richard Radke, Octavia Camps, Henry Medeiros, Zhengye Yang, Yuexi Zhang, and Dan Luo - Presented on April 12, 2023

Inferring Relational Potentials in Interacting Systems

Armand Comas, Yilun Du, Christian Fernandez, Sandesh Ghimire, Mario Sznaiier, Joshua B. Tenenbaum, and Octavia Camps

- Presented at the International Conference on Machine Learning (ICML), July 2023

Efficient Identification of Error-in-Variables Switched Systems Using a

Riemannian Embedding

Mario Sznaiier, Xikang Zhang, and Octavia Camps -

Published in IEEE Transactions on Automatic Control, February 2024

Context Aware Video Anomaly Detection in Long-Term Datasets

Zhengye Yang and Richard Radke - Published in the 2024 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops, June 2024

Identifying the Dynamics of Interacting Objects with Applications

to Scene Understanding and Video Temporal Manipulation

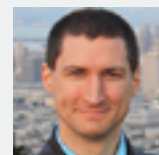
Armand Comas, Christian Fernandez, Sandesh Ghimire, Haolin Li, Octavia Camps, Mario Sznaiier - Published in IFAC-PapersOnLine, July 2024

Detecting Contextual Anomalies by Discovering Consistent Spatial

Regions

Zhengye Yang and Richard Radke - Presented at the 2025 Winter Conference of Applications on Computer Vision, March 2025

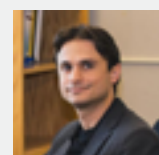
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AN ARTIFICIAL INTELLIGENCE-DRIVEN THREAT DETECTION AND REAL-TIME VISUALIZATION SYSTEM IN CROWDED PLACES



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Real-Time Management of Threat Detection and Mitigation Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **An Artificial Intelligence-Driven Threat Detection and Real-Time Visualization System in Crowded Places Project** falls within the **Real-Time Management of Threat Detection and Mitigation Research Area**. The research area leverages data and information to develop decision support systems for enhanced and timely protection of soft targets and crowded places in a real-time, operational capacity.

PROBLEM

This project addresses the challenge of timely threat detection in crowded public places by developing human-in-the-loop gun detection solutions. The proposed solution will improve emergency response times and resource allocation by integrating AI-driven detection with real-time visualization capabilities.

SOLUTION

The project aims to improve the efficiency of law enforcement and emergency services by providing real-time threat detection (particularly for detecting guns in videos and marking the corresponding videos as anomaly) and response recommendations through a visualization dashboard.



Accomplishments

AI-Driven Gun Detection Software

Developed AI-based advanced gun detection software integrated into a comprehensive visualization dashboard. The system not only reports when a gun is detected within a video network, it also provides first responders with a location and map identifying where the gun has been located supporting a fast and accurate response. This software is open-source, promoting transparency and collaboration between research, industry, and government communities.

Highly Accurate Detection Rates while Maintaining Privacy

This tool significantly improves the accuracy of existing gun detection technologies. Notably, our approach achieves high accuracy (up to ~99%) on a synthetic dataset and up to ~92% accuracy on a real-world shooting dataset, while also precisely localizing the gun within video frames and accurately identifying the timeframe of gun appearance. By specifically addressing gun detection problem, our method outperforms state-of-the-art action recognition methods, demonstrating its effectiveness and potential for real-world applications. In addition, we are also working to integrate differential privacy (DP) within our proposed gun detection method and analyzing the privacy utility trade-off in the proposed AI-based threat detection method.



Accomplishments Continued

Patent Secured with Royalty-Free Licensing to DHS

Obtained a patent for the tool, which is owned by Florida International University, with a royalty-free perpetual license granted to the Department of Homeland Security and to the Northeastern University for use by SENTRY.

Practical Applications

These tools can support various Department of Homeland Security priorities, including the Cybersecurity and Infrastructure Security Agency's focus on school safety, the Science and Technology Directorate's emphasis on public safety, Customs and Border Protection's directive of securing borders and ports of entry, and the Secret Service's mission to secure public spaces. Different components of the Department of Homeland Security and soft target venues can use this software to enhance their existing camera systems for gun threat detection and response.

Collaborations

The project works closely with:

- **University of Notre Dame**- established a pathway for data exchange and field testing.
- **United States Secret Service**- to review the product and discuss potential applications and brainstorm on new features and capabilities to be added.
- **Axis Communications and MappedIn** - to support the integration of these solutions with their products, partnering with industry to bring tools to the market.
- **SENTRY Practitioner Advisory Board** - to provide recommendations and insights to tailor the decision support tool to specific end-users' needs.

Publications & Presentations

An AI-Driven Threat Detection and Real-Time Visualization System in Crowded Places M. Hadi Amini, Badhan Chandra Das, and Liwei Ding - Presented at the SENTRY Practitioner Advisory Board Meeting, January 2025

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END-TO-END GRAPH-AGNOSTIC REAL-TIME EVACUATION ROUTING TO PROTECT SOFT TARGETS DURING ACTIVE-SHOOTER SCENARIOS



Soft Target Engineering to Neutralize the Threat Reality

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Real-Time Management of Threat Detection and Mitigation Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **End-to-End Graph-Agnostic Real-Time Evacuation Routing to Protect Soft Targets During Active-Shooter Scenarios Project** falls within the **Real-Time Management of Threat Detection and Mitigation Research Area**. The research area leverages data and information to develop decision support systems for enhanced and timely protection of soft targets and crowded places in a real-time, operational capacity.

PROBLEM

This project aims to tackle the challenge of ineffective decision-making during active shooter incidents in public places, such as schools. Life-threatening mistakes occur when crucial evacuation decisions are made with incomplete or flawed information during high-stress situations.

SOLUTION

The primary objective is to develop an end-to-end, real-time public guidance and advisory tool to improve crisis decision-making capabilities for indoor environments.



Accomplishments

Digital Twin Simulation Company Established

ASTERS Inc (a Delaware C-corporation) is an early-stage startup that spun out of the work done for SENTRY. The company aims to build Agentic-AI based Digital Twin simulations for Homeland Security applications. With the rapid developments happening in the spatial intelligence and Agentic AI space, the time is ripe to build on top of these solutions focused on solving some of the Homeland Security challenges. The company aims to focus on both AI Research and software development. ASTERS Inc has been accepted into the University of Chicago Transform AI accelerator (cohort 4), which comes with \$325K compute credits and \$25K cash investment along with mentorship from leading academics, industry, and corporate partners.

Critical Components of Real-time Routing Product Developed

A low-latency database pipeline for data exchange between Unreal Engine and SENTRY's optimal routing algorithm has been established, allowing real-time information updates in the simulation. Customizable Non-player Character (NPC) movement protocol using waypoints has been established, where parameters such as the speed of each NPC can be tuned.

A workflow for streaming real-time video footage from virtual IP-based cameras inside the simulated environment of a school building, that can be fed into Computer Vision algorithms has been created.



Accomplishments Continued

Testing and Validating for Quality

Conducted extensive testing for discrete-event simulations that incorporate actuatable doors, specifically for access control during active shooter scenarios. This includes evaluating additional parameters and layouts to improve responsiveness, reliability, and speed.

Practical Applications

Digital twin environments created with the capability for broadcasting multiple camera streams from inside the game environment will mimic real security cameras in terms of resolution, depth-of-field, focal length, angle of view and can be placed in user-selected locations inside the digital environment. This simulated space will be populated with one (or more) shooters moving through the environment, carrying weapons of various types, as well as non-playing characters whose behavior can be controlled using a dynamically updating database.

The system includes custom routing and planning software that will have situational awareness and will lead the NPCs to safety through optimized route selection. The shooter(s) as well as the NPCs will look and behave naturally, meaning, the camera streams can be analyzed by shooter detection algorithms for expedited and continuous monitoring.

This multi-level digital twin framework will enable the verification and effectiveness of systems for accurately identifying shooters in various situations and the effectiveness of mitigation strategies (optimized routing, dynamic lock-downs, reconfigurable architectural components, etc.).

These tools can be utilized by Department of Homeland Security components and soft target security stakeholders both for risk analysis and planning as well as in a real-time capacity to provide effective and responsive evacuation guidance during active shooter events. The work of this project can support the Cybersecurity and Infrastructure Security Agency's priority of school safety and securing critical infrastructure by providing a usable and tested tool to guide and safely evacuate schools and other venues during an active shooter attack. The tool has also received interest from the Transportation Security Administration and the Secret Service for its potential applications in other soft target spaces.

Collaborations

The project works closely with:

- **Guardian Centers**- for potential use as a simulation testbed.
- **Cambridge Consultants**- for potential collaboration using AI agents in simulation. In the process of discussing the integration of an industry-leading API that gives AI agents in synthetic digital environments the ability to have multimodal perception and reasoning.

Publications & Presentations

End-to-End Graph-Agnostic Real-Time Evacuation Routing to Protect Soft Targets During Active-Shooter Scenarios *Subhadeep Chakraborty* - Presented at the SENTRY Practitioner Advisory Board Meeting, September 2024

Optimizing Risk in Active-Shooter Scenarios by Controlling Automatic Doors *Anirudh Ramesh and Subhadeep Chakraborty* - Presented at the Society for Risk Analysis Annual Meeting, December 2024

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MULTI-SENSOR THREAT ASSESSMENT PLATFORMS: DIGITAL DOG NOSE

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

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Advanced Sensing Technologies for Threat Awareness Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Multi-Sensor Threat Assessment Platforms: Digital Dog Nose Project** falls within the **Advanced Sensing Technologies for Threat Awareness Research Area**. The research area is focused on developing new and advanced sensor technologies for detecting concealed threats in a crowd.

PROBLEM

This project aims to tackle a significant gap in the Department of Homeland Security's capabilities for continuous threat detection. Specifically, it addresses the challenge of developing vapor detection systems that can operate without fatigue and can track a threat signature to its source, unlike trained canines, which require rest and ongoing training.

SOLUTION

The primary objective is to develop a portable vapor sensor system capable of continuous operation without human intervention to detect and track threats, such as explosives and gun oils, in densely populated areas.



Accomplishments

Unmatched Sensitivity in Vapor Detection – Digital Dog Nose

A novel vapor sensor utilizing an array of thermodynamic sensors that can be drone-mounted, carried, or discreetly placed. The Digital Dog Nose efficiently detects and communicates threats, outperforming canine handlers. The device features unmatched sensitivity under parts per quadrillion (ppq) levels, weighs less than 10 mg, consumes low power at less than 150 mW, and offers real-time, continuous detection with precise differentiation and identification, while being platform agnostic and tunable for various target compounds, including explosives, narcotics, and gun oils.

Design of High Flowrate Vapor Sensor

To assure vapor gets to the Digital Dog Nose, a high throughput vapor sensor capable of exceeding 750 Cubic Feet per Minute flowrates for continuous threat screening was developed. This apparatus doubles vapor acquisition at standoff distances of 4-6 inches and significantly enhances vapor throughput through compressed air amplification. The team is conducting ongoing experiments to further increase standoff distances.

Accomplishments Continued

Groundbreaking Patents and Inventions

Secured a utility patent for foundational Digital Dog Nose technology, exclusively licensed to Trace Sensing Technologies for integration into its product lines. Trace Sensing, a startup emerged from SENTRY, has been granted four additional patents on vapor sensing technology. Their invention disclosure on optimizing escape routes during active shooter scenarios indicates over 50% reduction in casualties during discrete event simulations.

Spin-off Company - Trace Sensing Technologies

Trace Sensing Technologies, founded by Drs. Peter Ricci and Otto Gregory, is focused on commercializing its thermodynamic vapor sensor technology for healthcare, security, and defense. A direct result of SENTRY-funded research, Trace Sensing Technologies is developing a sensor platform for detecting breath biomarkers related to diseases affecting millions in the US. The company has several preclinical studies underway and is exploring defense and security opportunities with Homeland Security stakeholders such as the Office of Countering Weapons of Mass Destruction and Customs and Border Protection.

Chemical Threat Detection Dataset

SENTRY has established a comprehensive threat identification dataset with over 150 unique fingerprints for various threat compounds. This includes explosives, narcotics, gun oils, known precursors (e.g., acetone, hydrogen peroxide), and common interferents (e.g., deodorant, perfume). This dataset supports the development of the Digital Dog Nose, ensuring real-time threat detection across multiple applications.

Practical Applications

The Digital Dog Nose is a versatile and portable vapor detection system that can be utilized in various environments, such as borders, ports of entry, stadiums, and train stations. This device can effectively identify vapors to detect the presence of firearms, explosives, and narcotics, making it invaluable for agencies like the Transportation Security Administration, Customs and Border Protection, United States Coast Guard, and other components of the Department of Homeland Security. Its compact design allows for easy integration into existing screening processes and entry points. Mounted on a drone to serve as a mobile sensor, this tool can support several priorities within the Department of Homeland Security, including efforts by the Science & Technology Directorate and the Office of Countering Weapons of Mass Destruction, particularly in the areas of threat characterization and detection.

Collaborations

The project works closely with:

- **SENTRY's School Security Stakeholders**- engaged with Lincoln Rhode Island Public School District to identify a use case and potential pilot.
- **The University of Notre Dame** - partnering with stadium security and other SENTRY teams to incorporate the Digital Dog Nose into the Virtual Sentry Framework Infrastructure for testing at Notre Dame Stadium.

Publications & Presentations

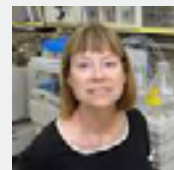
Developing A Novel Small-Scale Test to Predict Explosivity Justin Hunter, James Smith, and Jimmie Oxley - Published in Propellants, Explosives, Pyrotechnics, August 2022

Seeking Forensic Evidence of Preparation Routes to 2,4,6-Trinitrophenol Taylor Busby, James Smith, and Jimmie Oxley - Published in Journal of Energetic Materials, February 2023

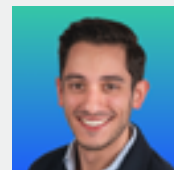
RDX Red Gum: A High Performance Pressable Formulation Taylor Busby, Robert Ichiyama, James Smith, and Jimmie Oxley - Published in Journal of Energetic Materials, April 2023

The Digital Dog Nose™ Peter Ricci, Jimmie Oxley, and Otto Gregory - Presented on April 12, 2023

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Soft Target Engineering
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RADAR STAND-OFF DETECTION OF CONCEALED THREATS ON MOVING PEOPLE

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

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Advanced Sensing Technologies for Threat Awareness Research Area

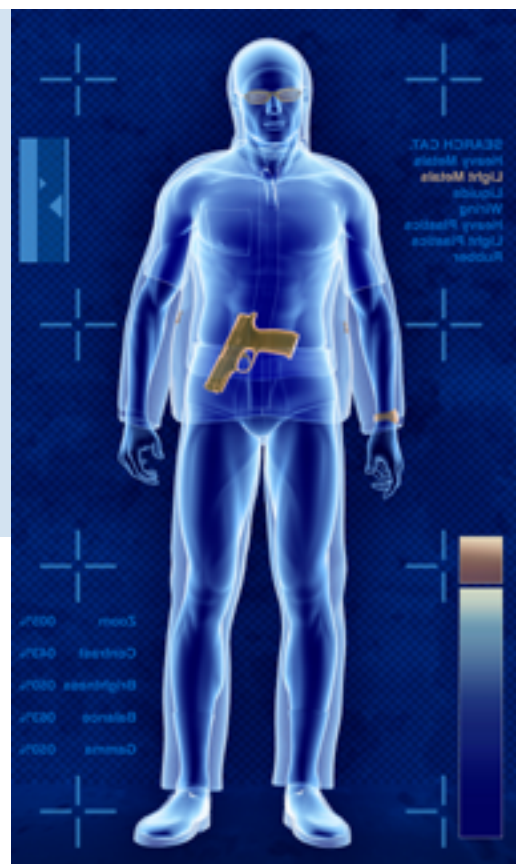
SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Radar Stand-off Detection of Concealed Threats on Moving People Project** falls within the **Advanced Sensing Technologies for Threat Awareness Research Area**. The research area is focused on developing new and advanced sensor technologies for detecting concealed threats in a crowd.

PROBLEM

This project aims to address the challenge of detecting large concealed metallic weapons, such as rifles, on individuals in crowded environments from a distance, discreetly, and cost-effectively. Traditional security methods often struggle with early detection in dynamic, crowded spaces, making it difficult to identify threats before they become an immediate danger.

SOLUTION

The project is focused on developing an effective radar design to detect concealed weapon threats in crowded environments. The aim is to create, test, and deploy a network of advanced stationary multibeam antennas. These antennas will use video tracking and imaging enhanced by artificial intelligence techniques to detect and distinguish concealed threats on individuals in crowded spaces.



Accomplishments

Cross-Sectional Body Imaging Dataset

Created a comprehensive dataset for cross-sectional model-based body imaging, analyzing the impact of metal weapon targets positioned at various locations on the body, in scenarios involving static multibeam antennas and approaching pedestrians, whether alone or in small groups.

Innovative Antenna Design and Patent Disclosure

Designed an innovative Luneburg lens/reflector array hybrid, focusing on enhancing signal reception and transmission capabilities. Engineered a custom cradle antenna mount, specifically tailored to secure and stabilize the hybrid system while ensuring ease of installation and maintenance. Conducted extensive research and testing to optimize performance, leading to improvements in both efficiency and reliability. Culminated in the submission of a patent disclosure to protect intellectual property, thereby safeguarding the unique aspects of the design and functionality for potential future developments.



Practical Applications

This stand-off detector is capable of identifying concealed weapons on moving people from a distance. Practical applications include installing the device at perimeters or entryways of soft targets to detect concealed weapons before a perpetrator enters a facility. This tool supports priorities of the Department of Homeland Security Science and Technology Directorate and Customs and Border Protection in securing borders, the United States Secret Service in protecting key locations, and the Cybersecurity and Infrastructure Security Agency in safeguarding schools.

Collaborations

The project works closely with:

- **SENTRY's Real-Time Management of Adaptive Surveillance and Mitigation project**- to coordinate video tracking with radar.
- **SENTRY's Protecting Soft Targets: a Game-Theoretic Framework for Multitarget, Multi-Layer Defense Against Strategic Attackers project and the Dynamic Digital Twins for Secure and Smart Civic Space project** - to provide data that will be needed to improve their tools.
- **MatrixSpace Inc.**- working collaboratively with SENTRY Industry Advisory Board member, MatrixSpace, to pair the Luneburg lens with their radar.

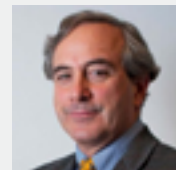
Publications & Presentations

[Stationary & Aerial Based Radar Detection of Concealed Threats](#) Mahshid Asri, Ann Morgenthaler, and Carey Rappaport - Presented on April 12, 2023

[Stationary and Aerial Based RF/Radar Detection of Concealed Threats and Anomalous Communications](#) Christopher Wahl, Dr. Jonathan Chisum, Dr. Scott Howard, and Dr. Bertrand Hochwald - Presented on April 12, 2023

[Pixel-Wise Localization of Concealed Objects on Millimeter-Wave Radar Images Using Deep Learning](#) Mahshid Asri, Rahul Chowdhury, Allison Care, David Femi Lamptey, Ann Morgenthaler, and Octavia Camps- Published in IEEE Transactions on Radar Systems, October 2024

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Soft Target Engineering
to Neutralize the
Threat Reality

PROTECTION OF SOFT TARGETS AND CROWDED PLACES USING AERIAL/GROUND AGENTS

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

A DEPARTMENT OF HOMELAND SECURITY (DHS) CENTER OF EXCELLENCE LED BY NORTHEASTERN UNIVERSITY

Advanced Sensing Technologies for Threat Awareness Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Protection of Soft Targets and Crowded Places Using Aerial/Ground Agents Project** falls within the **Advanced Sensing Technologies for Threat Awareness Research Area**. The research area is focused on developing new and advanced sensor technologies for detecting concealed threats in a crowd.

PROBLEM

This project aims to tackle the inefficiencies of current soft target security systems such as high costs and limited adaptability to new and emerging threats. These inefficiencies overwhelm human operators, resulting in delayed incident response times.

SOLUTION

The project proposes the creation of a new real-time semi-autonomous system that uses drones and ground robots equipped with various sensors to identify, report, and as a result, reduce threats in crowded areas with minimal human involvement. The focus is on learning about development, testing, and experimental evaluation techniques to improve the system for deploying teams of moving robots and drones capable of navigating different environments for better risk assessment and response to evolving threats.

Accomplishments

Real-Time Multi-Modal Dataset for UAS Threat Detection

Developed a comprehensive data set incorporating real-time multi-modal data and sensor fusion techniques for enhanced Unmanned Aerial Systems (UAS) threat detection in crowded environments.

Successful Field Test of Unmanned Aerial Systems for Threat Detection

Tested and validated SENTRY unmanned aerial systems at Northeastern's Kostas Research Institute (KRI) to ensure their effectiveness in protecting soft targets and crowded places through advanced threat detection. Transitioning from laboratory testing to real-world validation at KRI's indoor and outdoor UAS facilities is critical in delivering this system to DHS components.

Demonstration of GPS-Denied, Video-Denied, Drone Navigation

Successfully navigated a drone without GPS or camera assistance using the Radar Inertial Odometry system, showcasing its ability to operate in foggy or smoky conditions. Out of 12 tests, the system only missed detecting one person and maintained a zero false alarm rate. This demonstration confirmed the drone's capabilities in creating indoor maps, recognizing human figures, and locating exits in low-visibility scenarios.





Accomplishments Continued

Counter-UAS Scenario: Threat Drone Detected and Autonomously Intercepted

Executed a scenario involving an attacking drone approaching a critical target. Ground based radar effectively detected the incoming threat, while the system successfully parsed and tracked the attacking drone, coordinating with a defending drone that autonomously intercepted it.

Practical Applications

This technology can be used to autonomously detect drones, even in the absence of GPS video imagery, and in certain circumstances, radio frequency signals. This allows for usage both indoors and outdoors and in foggy or smoky conditions. The autonomous nature of this system creates resource efficiency, augmenting security personnel's capabilities and improving response time. This work directly supports the priority of developing new technologies to counter unmanned aircraft systems, which is a priority for the United States Coast Guard, the Transportation Security Administration, and Customs and Border Protection.

Collaborations

The project works closely with:

- **Transportation Security Administration** - discussions on how the system may be leveraged in support of their mission objectives related to securing soft targets.
- **National Sports Stadium** - met with stadium security stakeholders to demonstrate system capabilities and ideate on real-world application potential.
- **Kostas Research Institute** - testing the proposed framework to evaluate the technology's capability for enhancing situational awareness and mitigation strategies in real-world environments.
- **MatrixSpace Inc.**- collaborating with this SENTRY Industry Advisory Board member to integrate the project's multimodal sensor payloads into their radar products.

Publications & Presentations

Protection of Soft Targets and Crowded Places Using Aerial/Ground

Agents Jose Martinez Lorenzo, Yutao Jing, and Chang Wang- Presented at the SENTRY Practitioner Advisory Board Meeting, March 2025

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Soft Target Engineering
to Neutralize the
Threat Reality

MACHINE INTELLIGENCE FOR EFFECTIVE THREAT DETERRENCE AND RISK MITIGATION

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

A DEPARTMENT OF HOMELAND SECURITY (DHS) CENTER OF EXCELLENCE LED BY NORTHEASTERN UNIVERSITY

Threat Risk Assessment, Prediction, and Deterrence Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Machine Intelligence for Effective Threat Deterrence and Risk Mitigation at Soft Targets and Crowded Places Project** falls within the **Threat Risk Assessment, Prediction, and Deterrence Research Area**. The research area aims to develop AI-driven tools to facilitate strategic and tactical security planning which are capable of assessing risk, and intelligently predicting or deterring potential threats within soft targets and crowded spaces.

PROBLEM

This project addresses the challenge of effectively deterring threats and mitigating cascading risks at soft targets and crowded places, such as urban transportation systems. Specifically, the project seeks to define and quantify threat deterrence strategies across entire transportation systems, not just a specific station or area. Historically, this has not been easy due to the complex, interconnected nature of transportation networks.

SOLUTION

The proposed solution is to create data-driven models to understand how potential threats and prepared defenses interact across a system. These models will pinpoint where security resources are needed most to keep the entire transportation network safe.

Accomplishments

Development of Network Risk Modeling and Simulation Capability

Developed a robust network risk modeling and simulation capability designed to assess threat risks and deterrence strategies for soft transportation infrastructures, specifically for rail systems. This capability informs resource allocation decisions effectively and includes the development of spatial overlays of rail network features alongside dynamic heatmaps indicating time-varying station attractiveness predictions.

AI-Driven Network Risk Modeling for Rail Transit Completed

Conducted a proof-of-concept analysis on the Boston urban rail network (Massachusetts Bay Transportation Authority - MBTA) utilizing a comprehensive software platform that encompasses three interconnected modules: (1) machine learning with graphs - for target attractiveness prediction, (2) network failure simulation - to simulate cascading network failure sequences for what-if scenario analysis, and (3) network resource optimization - for risk-informed network resource allocation.





Accomplishments Continued

Leadership in Dissemination of Research Findings

Organized, chaired, and presented findings at a technical symposium titled “Soft Target Security and Deterrence for Infrastructure Networks” at the 2024 Society for Risk Analysis (SRA) Annual Meeting in Austin, TX. The Society for Risk Analysis is the world’s leading authority on risk science and its applications. SRA empowers professionals, decision makers and the public with the science and tools of risk analysis to better assess, manage, govern and communicate risk.

Practical Applications

Graph convolutional networks can effectively allocate scarce defensive resources for securing soft targets. This has been modeled on urban rail networks and can be used in other soft targets as well. These tools can be utilized by the Transportation Security Administration to evaluate risk and effectively allocate resources to secure surface transportation, by the Cybersecurity and Infrastructure Security Agency’s National Risk Management Center for planning and preparedness and by the Federal Emergency Management Agency for disaster response. This work directly supports the Department of Homeland Security’s research priorities of developing tools to mitigate threats, secure critical infrastructure, expedite safe travel, and improve emergency response.

Collaborations

The project works closely with:

- **The Transportation Security Administration**- worked alongside surface operation leadership to secure potential partnerships.
- **Cybersecurity and Infrastructure Security Agency National Risk Management Center** - for knowledge sharing and emergency preparedness.
- **The Massachusetts Bay Transportation Authority** - to conduct a proof-of-concept analysis using its urban rail network.

Publications & Presentations

[Robustness of Urban Coastal Rail Network under Projected Future Floods](#)

Ashis Kumar Pal, Puja Das, Nishant Yadav, and Auroop R. Ganguly - Presented at the 2022 Fragile Earth Workshop of the AI for Good Foundation, ACM Knowledge Discovery and Data Mining (KDD) Conference, August 2022

[Resilience of Urban Rail Transit Networks under Compound Natural and Opportunistic Failures](#)

Jack R. Watson, Samrat Chatterjee, and Auroop Ganguly- Published in the 2022 IEEE International Symposium on Technologies for Homeland Security (HST), November 2022

[Machine Intelligence for Effective Threat Deterrence and Risk Mitigation at Soft Targets and Crowded Places: Focus on Urban Surface Transit Systems](#)

Auroop Ganguly, Samrat Chatterjee, Rishi Sahastrabuddhe, Puja Das, AshisPal, and Jack Watson - Presented on April 12, 2023

[A Graph Neural Network Approach for Analyzing Urban Rail Transit System Threat Deterrence](#)

Samrat Chatterjee - Presented on November 14, 2024

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Soft Target Engineering
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A GAME-THEORETIC FRAMEWORK FOR MULTI-TARGET, MULTI-LAYER DEFENSE AGAINST STRATEGIC ATTACKERS

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

A DEPARTMENT OF HOMELAND SECURITY (DHS) CENTER OF EXCELLENCE LED BY NORTHEASTERN UNIVERSITY

Threat Risk Assessment, Prediction, and Deterrence Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Protecting Soft Targets: a Game-Theoretic Framework for Multi-Target, Multi-Layer Defense Against Strategic Attackers Project** falls within the **Threat Risk Assessment, Prediction, and Deterrence Research Area**. The research area aims to develop AI-driven tools to facilitate strategic and tactical security planning which are capable of assessing risk, and intelligently predicting or deterring potential threats within soft targets and crowded spaces.

PROBLEM

This project addresses the significant gap in how agencies and stakeholders allocate resources to defend against threats to soft targets, as current methods often rely on intuition and outdated practices rather than data-driven strategies. Current practices lead to inefficiencies in deploying countermeasures and increase the vulnerability of soft targets to strategic attacks.

SOLUTION

The primary objective is to develop game-theoretic models, which strategically predict how humans will act and make decisions based on several factors. These models aid organizations in optimizing the allocation of security resources against strategic attackers based on these predictive models, which incorporate stakeholder-informed parameters and data, offering a tool for better decision-making and resource distribution to defend soft targets.

Accomplishments

User-Focused Tools for Defensive Resource Allocation

Delivered user-friendly game-theoretic defensive resource allocation models through a Graphical User Interface, informed by feedback from Department of Homeland Security stakeholders and extensive academic research, accumulating 480 downloads to date.

Strategic Attacker Datasets and Analysis Delivered

Several datasets and analysis of understanding strategic attackers' behaviors and decision-making processes have been delivered to the U.S. public, as well as businesses, organizations, and institutions that want to reduce the risk of terrorism and crime to the individuals that patronize them.

Development of Prototype Risk Assessment Tools for Schools

Created an alpha version prototype risk assessment tool for visualizing student movement, now seeking feedback from stakeholders including campus police departments. The team has also developed an adversarial risk analysis model tailored to a specific soft target case study in the space of surface transportation and stadia.





Accomplishments Continued

Experimental Validation of Game-Theoretic Models

Conducted human-subject experiments to validate the game-theoretic model, ensuring its practical applicability. Initiated the design of a study to gather data on adversaries examined through a game-theoretic reinforcement model.

Practical Applications

The alpha version of the risk assessment tool for visualizing student movement is already being tested and used by University at Buffalo Police. They are using the tool to improve their operational response and resource allocations. These tools align with Department of Homeland Security's research priorities of developing tools for emergency preparedness and leveraging AI to mitigate threats. This work is in direct alignment with Cybersecurity and Infrastructure Security Agency's National Risk Management Center mission providing actionable risk analysis to drive secure and resilient critical infrastructure for the American people. The Transportation Security Administration, the Cybersecurity and Infrastructure Security Agency, the United States Coast Guard, and Customs and Border Protection would benefit from the Game Theory models that can assist these agencies in resource allocation problems across multiple layers of security for multiple targets.

Collaborations

The project works closely with:

- **SENTRY's Stadium Security Case Study** - to collaborate with soft target venue stakeholders, including Buffalo Bills Security, Amherst police, local school district and local houses of worship.
- **University at Buffalo Athletics** - to receive feedback on GUI that displays resource allocation solutions.
- **SENTRY Projects** - Collaborated with the Adaptive Layered Surveillance Systems: Design, Management and Decision Support for Threat Detection and Mitigation project, the Machine Intelligence for Effective Threat Deterrence and Risk Mitigation at Soft Targets and Crowded Places project, the Dynamic Digital Twin for Secure and Smart Civic Spaces project, and the Real-Time Crowd and Attacker Forecasting for Risk Assessment and Threat Mitigation project.

Publications & Presentations

[Protecting Soft Targets \(ProSoT\): A Game-theoretic Framework for Multi-target, Multi-layer Defense against Strategic Attackers](#)

Jun Zhuang and Richard John - Presented on April 12, 2023

[Behavioral Validation for a Game-Theoretic Model of Attacker Strategic Decisions, Signaling, and Deterrence in Multi-Layer Security for Soft Targets](#)

Kevin Kapadia, Ian Unson, Katie Byrd, Jun Zhuang, and Richard John - Published in Risk Analysis, February 2025

[Perceived Effectiveness and Intrusiveness of School Security Countermeasures Among Parents, Students, and Staff](#)

Katie Byrd, Kevin Kapadia, and Richard John - Published in Environment Systems and Decisions, February 2025

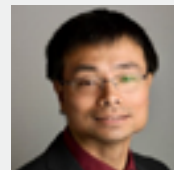
[Hear Something, Say Something: Perceived Threat as a Mediator of Concerning Behavior and Reporting Intention for School Staff, Parents, and Recent Students](#)

Kevin Kapadia, Katie Byrd, and Richard John - Published in Journal of Risk Research, March 2025

[Balancing Security and Inconvenience: Perceptions of Countermeasures in U.S. Commercial Facilities](#)

Katie Byrd, Kevin Kapadia, Adam Rose, and Richard John - Published in Risk Sciences, April 2025

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MODELING AND BEHAVIOR ANALYSIS TO ASSESS PUBLIC SPACE SAFETY AND PROTECT SOFT TARGETS AGAINST ACTIVE SHOOTER ATTACKS



Soft Target Engineering
to Neutralize the
Threat Reality

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

A DEPARTMENT OF HOMELAND SECURITY (DHS) CENTER OF EXCELLENCE LED BY NORTHEASTERN UNIVERSITY

Threat Risk Assessment, Prediction, and Deterrence Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Modeling and Behavior Analysis to Assess Public Space Safety and Protect Soft Targets Against Active Shooter Attacks Project** falls within the **Threat Risk Assessment, Prediction, and Deterrence Research Area**. The research area aims to develop AI-driven tools to facilitate strategic and tactical security planning which are capable of assessing risk, and intelligently predicting or deterring potential threats within soft targets and crowded spaces.

PROBLEM

Attacks in public spaces have increased alarmingly over the past decade and raised a serious security concern in public safety. However, the knowledge on attack detection and civilian response strategy under such violence is very limited. Such a lack of understanding hinders the development of effective training modules, building assessments, response, and mitigation strategies (for both civilians and law enforcement officers) for such events, which are highly unpredictable.

SOLUTION

This study performed human-subject experiments in a controlled environment to understand how an individual behaves in an active shooter attack to learn from these behavioral responses (via human response trajectory). Using this data, an inverse reinforcement learning algorithm has been developed into an interactive software with a customizable user interface. This software can be utilized to extend the knowledge from a laboratory setting (e.g., classrooms, empty rooms, and hallways) to a realistic environment and can simulate individual behavior under new circumstances such as physical surroundings (e.g., room size, entryway position, entryway size), number of shooters, position of shooters, firearm effective range, and the field of view. This can be used to plan for response and mitigation strategies for active shooter events.



Accomplishments

Interactive Environment Simulation Tool

Developed interactive software with a customizable user interface that enables the creation of diverse building environments and offers advanced output visualization features. This tool can be utilized by DHS and security stakeholders to visualize movement patterns, areas at risk and safe zones to assist in response and mitigation strategies for active shooter events.



Accomplishments Continued

Algorithm Developed for Building Resilience

Created a tailored inverse reinforcement learning algorithm to analyze the resilience of building configurations in the context of an active shooter attack, currently operating with synthetic data. This algorithm is used to process the information of the interactive simulation tool, which can inform security stakeholders in planning response and exit strategies to active shooter events.

Trajectory Dataset Created for Active Shooter Scenarios

Worked with local police and university to collect data of person movement and response during an active shooter simulation drill. These data were compiled into a comprehensive dataset of human subject trajectories gathered during active shooter scenarios in schools. The dataset enhances the assessment tool's accuracy and is available for use by DHS components.

Practical Applications

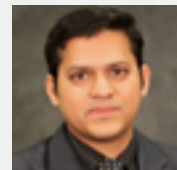
By providing interactive configurations and environments to simulate scenarios specific to a soft target venue, this tool allows stakeholders, including the Department of Homeland Security and law enforcement agencies, to assess and optimize safety protocols to better respond to active shooter incidents. Aligned with the Administration's priority of making America safer, these tools can be provided to schools and churches through Cybersecurity and Infrastructure Security Agency's schoolsafety.gov and the Department of Homeland Security Center for Faith-Based and Neighborhood Partnerships to assist in planning and preparedness. Because of its customizable structure, the tool can also be leveraged by Department of Homeland Security Components for planning the security of other soft targets like ports of entry (Customs and Border Protection), train stations (Transportation Security Administration) and physical infrastructure (Cybersecurity and Infrastructure Security Agency), supporting mission priorities of keeping the American public safe, secure, and resilient.

Collaborations

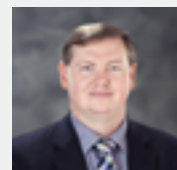
The project works closely with:

- **Starkville Police Department** - contributes to the execution of active shooter exercises to collect human subject data for the project. The department plans to work with the team to provide operational feedback on the tool to assure a tool that is fitting the needs of first responders and security stakeholders.

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**Soft Target Engineering
to Neutralize the
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ARCHITECTURAL DESIGN: INTEGRATING SECURITY IN THE PUBLIC REALM

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

A DEPARTMENT OF HOMELAND SECURITY (DHS) CENTER OF EXCELLENCE LED BY NORTHEASTERN UNIVERSITY

Layered Security Architectural Design and Simulation Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Architectural Design Research: Integrating Security in the Public Realm Project** falls within the **Layered Security Architectural Design and Simulation Research Area**. The research area aims to generate principles and protocols for designs that enhance passive security features and enable augmentation with active surveillance and mitigation capabilities.

PROBLEM

This project addresses the challenge of using building design to improve security in soft targets and crowded places without turning the location into a "hard target", fortified with oppressive security measures. This research aims to enhance human safety while preserving open and welcoming environments by identifying cost-effective and humane design strategies inherent to the design of public places.

SOLUTION

The primary objective is to develop new protocols for the physical assessment and design of safer public spaces, such as schools or transportation hubs. The developed guidelines will help building designers make smart decisions about design—using the layout of a space to allow or inhibit movement and designing for visibility by people and sensors—to make the space less vulnerable to threats without making them closed off or feel intimidating.



Accomplishments

Guidance for School Decision Makers to Support Safety and Security through Building Design

Developed evidence-based guidance for school decision-makers to support safety and security through thoughtful building design. This peer-reviewed product is based on interviews with designers, literature reviews, and incident report analysis. The team is currently developing similar guidance for surface transportation venues.

Architectural Prototypes of Common K-12 Schools to Facilitate Security Simulations

The school architectural models are available for use. The models have been used by SENTRY's Impact of Architectural Design on Emergency Behavior and Response During Active Shooter Incidents project team for simulations of school shootings and SENTRY's Real-Time Management of Adaptive Surveillance and Mitigation project team have used the models for additional simulation applications.



Accomplishments Continued

Supporting Federal and Global Efforts in School Safety

Delivered a comprehensive bibliography of school security resources to the Cybersecurity and Infrastructure Security Agency. Provided an expert briefing to the United Nations Office of Counter-Terrorism Global Network on "Protecting Educational Institutions and other Learning Spaces against Terrorist Attacks" Partnered with the Cybersecurity and Infrastructure Security Agency's School Safety Task Force as subject matter experts in the development of recommendations and guidelines for school security and safety.

Practical Applications

Venue managers, designers and construction teams for various soft targets can use SENTRY developed guidance and tools to take action in their specific context to improve security through architectural design. These tools can also be used to understand how to deploy technologies to maximize effectiveness. The deliverables of this project fully support the Cybersecurity and Infrastructure Security Agency's mission to strengthen the safety and security of K-12 schools across the country. Future outputs focused on other venues like public transportation, stadiums, and outdoor spaces, will support DHS's research priority of public safety and the US Secret Service mission of safeguarding places and securing events.

Collaborations

The project works closely with:

- **SENTRY School Security and Stadium Case Studies** - participated in site visits and listening sessions, including Northwestern University's new stadium.
- **SENTRY's Impact of Architectural Design on Emergency Behavior and Response During Active Shooter Incidents Project**- offered models of four common K-12 school layouts for simulations of school shootings.
- **SENTRY's Real-Time Management of Adaptive Surveillance and Mitigation Project** - shared a prototype for additional simulation applications.
- **CISA School Safety Task Force**- provided evidence-based tools, subject matter expert support, and knowledge products in support of School Safety.

Publications & Presentations

[Architectural Design for Protecting Soft Targets](#)

David Fannon - Presented on May 3, 2022

[Coding Built Environment's Effect on Incidents of Mass Shootings in Schools Using Public Records](#)

Vaani Aggarwal, Michelle Laboy, David Fannon, and Peter Wiederspahn - Presented on April 12, 2023

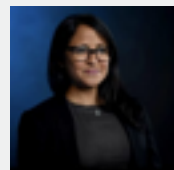
[Layered Security in K-12 Schools: Transparency as Security](#)

Michelle Laboy, David Fannon, and Peter Wiederspahn - Presented on November 3, 2023

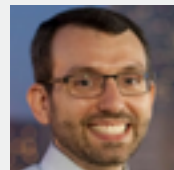
[SENTRY Soft Target Security Series - Evidence-Based Security Design for Positive School Environments](#)

Michelle Laboy - Presented on November 6, 2024

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Soft Target Engineering
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DYNAMIC DIGITAL TWINS FOR SECURE AND SMART CIVIC SPACE

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

A DEPARTMENT OF HOMELAND SECURITY (DHS) CENTER OF EXCELLENCE LED BY NORTHEASTERN UNIVERSITY

Layered Security Architectural Design and Simulation Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Dynamic Digital Twins for Secure and Smart Civic Space Project** falls within the **Layered Security Architectural Design and Simulation Research Area**. The research area aims to generate principles and protocols for designs that enhance passive security features and enable augmentation with active surveillance and mitigation capabilities.

PROBLEM

This project addresses the lack of effective digital twin technology for identifying and mitigating security risks at soft targets and crowded places. The challenges to making digital twins, which are virtual representations of physical assets, environments or systems that can be used to simulate their behavior to better understand how they work, include data integration issues, limited real-time monitoring, lack of human digital twin teaming, and high costs.

SOLUTION

The primary objective is to design, experiment with, and evaluate scalable and effective methods for creating dynamic digital twins of soft targets and crowded places that enhance security by monitoring environments in real-time, predicting threats, and integrating crowd behavior models to mitigate vulnerabilities.



Accomplishments

Dynamic Digital Twins Delivered

A digital twin of the New Jersey Hoboken Terminal is now capable of monitoring crowd movements in real time across multiple cameras, providing valuable data to analyze crowd behavior. Additionally, it can simulate various threats, including flooding events and malicious attacks, which significantly broadens the range of scenarios that can be evaluated within a digital twin environment.

Digital twins of New Jersey Secaucus Station enable real-time monitoring and simulation of crowd management during various scenarios, including predicting hot spots based on crowd size and train schedules. This functionality has led New Jersey Transit to request the development of a digital twin for Newark Penn Station, supporting its renovation ahead of the 2026 World Cup.



Accomplishments Continued

Real-time 3D Mapping using AI and a Robot Dog

A large language model has been integrated into a robot dog platform to facilitate multi-modal interaction between the human operator, the digital twin, and robotic systems. The system is designed to accelerate digital twin development and includes a security feature localization system, can be used to rapidly characterize the spatial structure of the crowded places, as well as update the dynamic contents (such as temporary objects) in the digital twin environment.

Practical Applications

Digital twins provide powerful platforms for exploring what-if scenarios, thereby improving decision making for crisis management. Dynamic digital twins have great value in addressing security challenges for various soft target venue types, such as school, transportation hubs and stadia. The digital twins developed as part of this effort align with the Department of Homeland Security's research priority of emergency preparedness and response. Specifically, the Cybersecurity and Infrastructure Security Agency objective to provide actionable risk analysis to drive secure and resilient critical infrastructure for the American people. The development of an accelerated digital twin development strategy with AI and a robot dog could greatly enhance US Secret Service's capabilities in safeguarding places and securing events.

Collaborations

The project works closely with:

- **2026 NYNJ World Cup Host Committee** - supported efforts specific to crowd management and facilitated dialog between NJ Transit and TSA about 2026 FIFA World Cup planning.
- **SENTRY's Stadium and Passenger-based Transportation Case Studies** - joint crowd observation sessions during Copa America games with NJ Transit and MetLife Stadium security team. Conducted a site visit at the Prudential Center, NJ Performing Arts Center.
- **NJ Transit Agencies** - met bi-weekly with Hoboken Terminal, and Secaucus Junction Station on digital twin development and testing.
- **NJ Public Safety & Emergency Response Agencies** - worked with NJ State Police, including the bomb squad, NJ Office of Homeland Security & Preparedness and the Seaside Heights Police Department.
- **Transportation Security Administration Surface Operations** - foster engagement with surface transit facilities.
- **Cybersecurity and Infrastructure Security Agency. Infrastructure Securities Division** - to support security and engagement with public spaces and places of worship.

Publications & Presentations

[A route optimization model based on building semantics, human factors, and user constraints to enable personalized travel in complex public facilities](#) Zhaojing Wang, Yi Yu, Cecilia Feeley, Samantha Herrick, Hao, Hu, Jie Gong - Published on January 2022

[Dynamic Digital Twins for Secure and Smart Civic Spaces](#) Jie Gong, Mubbassir Kapadia, Jing Jin and Fred Roberts - Presented on April 12, 2023

[SENTRY Soft Target Security Series - Dynamic Digital Twins for Secure and Smart Civic Space](#) Jie Gong, Mubbassir Kapadia, Peter Jin and Fred Roberts - Presented on November 6, 2024

[Risk Assessment for Integrated Cyber and Physical Attacks on Stadiums and Transportation Systems](#) Fred Roberts - Presented on November 14, 2024

[Microscopic Driver Behavioral Fundamental Diagram Analysis Using Computer Vision Techniques: Implications for Human Driving Responses to Visual Stimuli](#) Bowen Geng and Peter J. Jin. Published in Transportation Research Record, February 2025.

[Roadside CCTV Traffic Sensor Coverage and Spatial Accuracy Analysis with Line-of-Sight Simulation over 3D Digital Surface Mode.](#) Yi Ge, Peter J. Jin, Tianya T. Zhang, and Anjiang Chen. Published in Transportation Research Record, February 2025.

Project Leaders

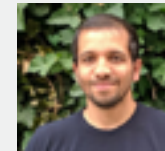
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REAL-TIME CROWD AND ATTACKER FORECASTING FOR RISK ASSESSMENT AND THREAT MITIGATION



Soft Target Engineering
to Neutralize the
Threat Reality

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

A DEPARTMENT OF HOMELAND SECURITY (DHS) CENTER OF EXCELLENCE LED BY NORTHEASTERN UNIVERSITY

Layered Security Architectural Design and Simulation Research Area

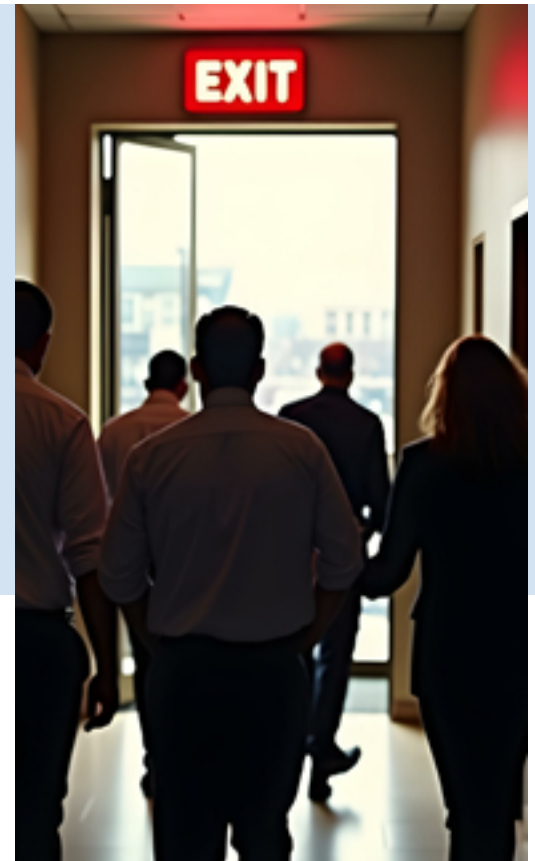
SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Real-Time Crowd and Attacker Forecasting for Risk Assessment and Threat Mitigation Project** falls within the **Layered Security Architectural Design and Simulation Research Area**. The research area aims to generate principles and protocols for designs that enhance passive security features and enable augmentation with active surveillance and mitigation capabilities.

PROBLEM

This project aims to address the challenges posed by architectural design changes during the design phase and post-occupancy, which can significantly alter how crowds behave during emergencies. Changes in building layout, exit placements, and overall design can lead to confusion, bottlenecks, or even panic during evacuations, increasing risk during disasters. Current tools are inadequate for evaluating the impact of alternative architectural design features or physical alterations to existing structures on crowd flow.

SOLUTION

The primary objective is to integrate human behavior modeling with architectural design and analysis using digital twins, which are virtual models of physical locations, environments, or systems. This integrated approach will more effectively guide the design and modifications of buildings to influence, promote, and enhance the desired crowd behavior during emergencies, such as active shooter scenarios and bomb threats.



Accomplishments

Advanced Crowd Simulation Software

Developed high performance, cross-platform crowd simulation software capable of handling over 60,000 individuals in real time, offering unprecedented speeds and scalability that surpass current industry standards for both normal and evacuation scenarios. This software can be customized to be used for various soft targets and crowded places.

Integration of Dynamic Digital Twin with Crowd Simulation Software

Established a semi-automated pipeline to integrate SENTRY's Dynamic Digital Twin infrastructure model into the Real-Time Crowd and Attacker Forecasting for Risk Assessment and Threat Mitigation crowd simulation framework.

Using Real World Data to Deliver the Most Accurate Tool

Used video analytics to process over 80GB of real-world footage collected from 14 locations within the stadium during a college football event. The team detailed pedestrian trajectories to calibrate the crowd simulation model ensuring a realistic baseline for behavior modeling.

Accomplishments Continued

Threat Analysis and Mitigation Strategy Framework

Developed an innovative line-of-sight (LOS) simulation framework that effectively identifies potential threat areas from firearms and projectiles, as well as the coverage areas of strategically deployed safety personnel. This tool aids security decisionmakers in assessing vulnerabilities and establishing proactive response strategies.

Practical Applications

The simulation and mitigation strategy tools developed will be used as the basis of effective threat deterrence, risk assessment, and site architecture design for soft targets. The line-of-sight simulation capabilities offer valuable resources for 3D modeling platforms such as SkyeBrowse, Pix4D, and DroneDeploy. These tools assist in evaluating the security vulnerabilities of public venues and event layouts related to active shooter scenarios, drone attacks, and explosives.

The integration of real-time crowd simulation and digital twin technologies enhances security planning, enabling informed decisions regarding coverage and patrol routes during public events like marathons, festivals, and political gatherings. Soft Target Security Decision Makers and U.S. Department of Homeland Security Components like the Federal Emergency Management Agency, the Cybersecurity and Infrastructure Security Agency, the Transportation Security Administration, and the United States Secret Service can leverage these tools to plan for threat events and emergency planning. The real-time capabilities of these tools can be leveraged by these same agencies to disrupt and mitigate the threat of terrorists and catastrophic events.

Collaborations

The project works closely with:

- **Rutgers Police and Emergency Response Team** - for data collection of the stadium infrastructure and during Rutgers football events. Includes several rounds of interview questions about realistic evacuation scenarios and infrastructure changes for consideration in crowd simulation modeling.
- **FIFA World Cup 2026 MetLife Stadium** - discussion with state and local agencies on the planning and preparation, including transit planning, for FIFA World Cup 2026 Games and Final Game to be played at MetLife stadium.
- **New Jersey Transit**- discussion to expand work to support Secaucus-Meadowland Transitway Rail and bus services.
- **NJ Office of Homeland Security and Preparedness**- explored the data needs and modeling needs with local police and Emergency Response Team in Seaside, NJ for creating digital twins for planned events, including a Polar Plunge.
- **Six Flags Theme Park Security** - reached out to the team for potential collaboration.

Publications & Presentations

[Hash-based Gaussian Mixture Model \(HGMM\) for Roadside LiDAR Smart Infrastructure Applications](#) *Tianya Terry Zhang, Yi Ge, Anjiang Chen, Mina Sartipi, and Peter J. Jin* - Published in IEEE Transaction on Intelligent Transportation Systems, October 2024

[SENTRY Soft Target Security Series - Real-Time Crowd and Attacker Forecasting for Risk Assessment](#) *Peter Jin* - Presented on November 6, 2024

[Risk Assessment for Integrated Cyber and Physical Attacks on Stadiums and Transportation Systems](#) *Fred Roberts* - Presented on November 14, 2024

Project Leaders

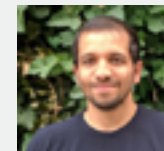
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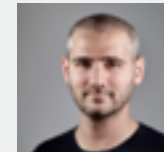
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Soft Target Engineering
to Neutralize the
Threat Reality

IMPACT OF ARCHITECTURAL DESIGN ON EMERGENCY BEHAVIOR DURING ACTIVE SHOOTER INCIDENTS

SOFT TARGET ENGINEERING TO NEUTRALIZE THE THREAT REALITY (SENTRY)

A DEPARTMENT OF HOMELAND SECURITY (DHS) CENTER OF EXCELLENCE LED BY NORTHEASTERN UNIVERSITY

Layered Security Architectural Design and Simulation Research Area

SENTRY's research structure ties the technical challenges of protecting soft targets and crowded places to four fundamental research areas. The **Impact of Architectural Design on Emergency Behavior and Response During Active Shooter Incidents Project** falls within the **Layered Security Architectural Design and Simulation Research Area**. The research area aims to generate principles and protocols for designs that enhance passive security features and enable augmentation with active surveillance and mitigation capabilities.

PROBLEM

This project seeks to understand how architectural design affects human behavior during emergencies, particularly during active shooter incidents. Using the information realized from analyzing human behavior in emergencies specifically related to architectural design elements, this research will address knowledge gaps in current crowd simulation tools, which fail to capture the complexity of human behavior in these critical situations.

SOLUTION

The primary objective is to assess the influence of architectural design on emergency behavior during active shooter incidents, ultimately creating a decision-support tool for improving safety practices, policy guidelines, and architectural standards across diverse building types.

Accomplishments

Reinforcement Learning Based Model Development

Developed a reinforcement learning based model that accurately simulates citizen and shooter behavior, currently in the training phase with 30 million training steps for each prototype to enhance performance and reliability.

Scenario Design and Diversification

Created over 100 different simulation scenarios created by modifying building characteristics such as occupancy rates, lockdown procedures, proportion of locked doors and door widths, utilizing the specialized crowd simulation platform, MassMotion.

Integration of Architectural Models into Simulation

Integrated four building information models from SENTRY's Architectural Design Research: Integrating Security in the Public Realm Project into the simulation environment, enhancing the realism and applicability of simulations.





Practical Applications

The development of a data-driven, agent-based simulation model has applications in a variety of soft target and built environments, extending beyond schools to include other critical infrastructure spaces such as offices, transportation hubs, and arenas. This research informs the design and emergency response strategies of a wide range of public spaces vulnerable to Active Shooter Incidents. What will be transitioned includes a decision-support tool that helps stakeholders understand and apply the insights gained from the model to enhance emergency preparedness and response. This tool supports key Department of Homeland Security operational priorities including emergency response, public safety and the Cybersecurity and Infrastructure Security Agency's priority of managing risk and enhancing resilience through exercises, planning and preparedness activities. In addition, this tool's relevance to the United States Secret Service's mission of ensuring the security of key facilities and major, national events by providing a tool to enable precise and responsive security design and planning is clear.

Collaborations

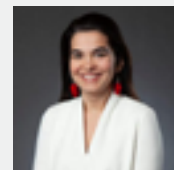
The project works closely with:

- **ARUP, Inc MassMotion Software**- integration with this crowd simulation software helps assess evacuation strategies, improve wayfinding, and enhance the overall safety and efficiency of built environments. By integrating our tool with software widely used by designers, engineers, and planners to analyze occupant movement and optimize space utilization, a clear path to transition of this work is established. It helps assess evacuation strategies, improve wayfinding, and enhance the overall safety and efficiency of built environments.
- **University of Southern California Campus Safety and Security**- engages with key campus safety stakeholders through a complementary NSF-funded project, including the police department, threat assessment teams, and first responders. This collaboration aims to improve safety strategies and inform decision-making processes.
- **SENTRY's Architectural Design Research: Integrating Security in the Public Realm Project** - leverages the project's architectural models to evaluate the impact of security focused design on school safety during simulated active shooter incidents and provide those findings to the general public.

Publications & Presentations

Enhancing Building Safety Design for Active Shooter Incidents: Exploration of Building Exit Parameters using Reinforcement Learning-Based Simulations Ruying Liu, Wanjing Wu, Burcin Becerik-Gerber, and Gale Lucas - Published at the 31st EG-ICE International Workshop on Intelligent Computing in Engineering, July 2024

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