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ENHANCED DATA TO DECISION ANALYTICS FOR FORCE PROTECTION & CBRNE SENSING IN MULTINATIONAL COALITIONS

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Outline

- Motivation
- Sensor Selection & Models
- Detection Algorithms
- Enhanced Data To Decision
- Conclusion

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Motivation

- Asymmetric threats including chemical and biological attacks represent a persistent obstacle to U.S. military operations, and those of our Coalition Partners.
- Sensor and surveillance systems possess the capacity to provide warnings and indicators on a point-by-point basis, however real-time actionable intelligence derived from the data remains a challenge for Commanders.
- The algorithms we are developing help address uncertainty and latency in the Military Decision Making Process.
- "The variety, origin and severity of these threats continues to grow while resources shrink. The DoD protects US Forces against weaponized CB agents and emerging threats using an integrated, layered defense and a risk informed approach. In order to strike a balance between risk and resources, the DoD integrates capabilities to the maximum extent"

Motivation 2

- As a low probability, high consequence event, CBRN detection must provide acceptable levels of protection and acceptable levels of cost.
- However, its simply not feasible to deploy capability to all areas of interest given most fielded, non-laboratory sensors are not 100% reliable no matter their cost and sophistication.
- Aside from the Probability of Detection (Pd), False alarm rates (FAR), and cost issues, once sensor information is being relayed, data inundation at the Command Post can lead to decision paralysis: in many cases binary alarmed/not alarmed sensor algorithms leads to a "cry wolf" syndrome causing operational elements to ignore alarming sensors.
- The situation is exacerbated when international, combined forces are deployed.

Integration Approach

SENTEL's extensive systems integration knowledge contributes to extensive, reliable and real-time-situation awareness enabling successful decision-making across a broad range of complex and dynamic environments.

Over 100 Devices Integrated

Mobile Options

Operations Centers

We produce situational awareness products capable of real time, multi-echelon communications across numerous C4ISR systems.

Utilizing numerous wired and wireless communications pathways including cross domain guards.

- Sensor Integration Successes: JUPITR, JTR-FED, RDR, RDR-WEB, HALO, Cerberus, CBP Mobile Surveillance Systems, Mobile Data Recorder, Joint Portal Shield, JBTDS
- Our mobile apps have been deployed in support of the Brazilian Army and JPEO CBD for Osan Air Base

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Biological Sensors

- We selected two commonly use versions of bioaerosol detectors: TACBIO and IBAC.
- Each detector contains multiple internal sensors; however, one key difference between the two are their excitation wavelengths.
- Both devices use laser-induced fluorescence to excite particles from the air with a specific wavelength of light (405 nm in the IBAC and 365 nm in the TACBIO).
- The lower excitation wavelength in the TACBIO sensor allows it to detect a larger set of biological warfare agents (BWAs).
- However, lower excitation wavelengths in general are associated with increased detection of interferent particles in the air, such as clay minerals leading to higher FARs.
- The amount of interferent particles detected is thus a complex variable: dependent upon wind speed introducing particles to general air flow, and also upon factors inherent to the device, such as excitation wavelength.

Biological Sensor Simulations

- We utilize meteorological inputs and augmented sensor characterization based on the operational environment which effectively increases sensor reliability by eliminating data variability caused by the environmental noise.
- Humidity is an environmental variable that can also affect biological sensor readings because light emission spectra of biological particles can change based on the moisture content of the sample.
- To create a consistent biological threat rating despite variable environmental conditions, we use a Bayesian analysis of the Mahalanobis distance

Biological Sensor Simulations

- The Mahalanobis distance is a way to generalize the distance that a multi-sensor reading would be from baseline activity.
- Multi-sensor readings from TACBIO and IBAC can be collected under normal conditions in a variety of environmental settings.
- In each different environmental setting, the means of all sensor readings and their covariance matrix can be computed.
- Using this data, we will compute the distance (D_M below) of each separate device from its baseline activity in that specific environmental setting.
- In the equations below, x is the sensor readings of the device at the current moment in time. μ is the average activity of the sensor baseline. N is the total number of sensors in the device and S is a covariance matrix of the

$$\vec{x} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{bmatrix} \qquad \vec{\mu} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_N \end{bmatrix}$$

$$D_{\mathrm{M}}(\vec{x}) = \sqrt{(\vec{x} - \vec{\mu})^T S^{-1} (\vec{x} - \vec{\mu})}$$

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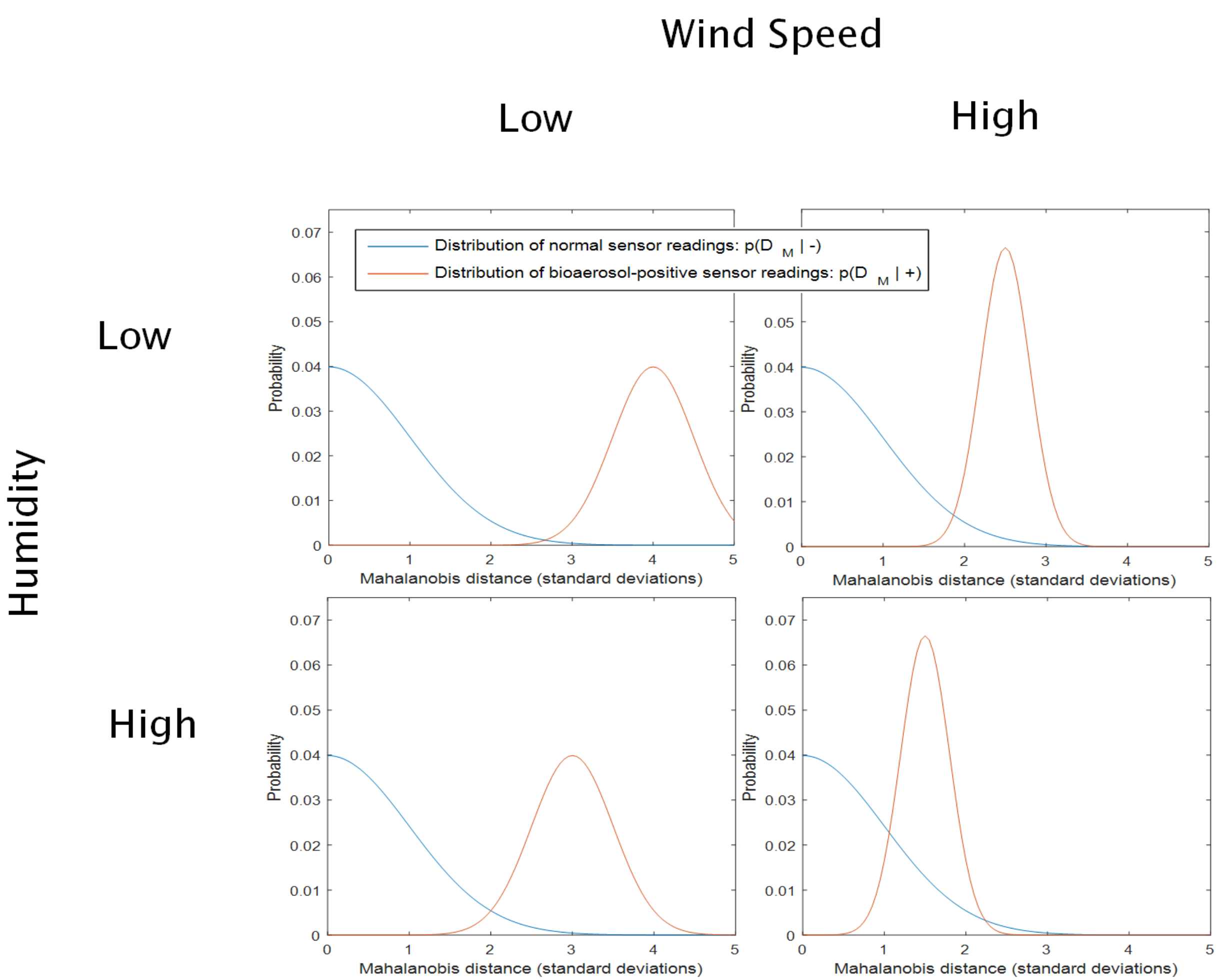
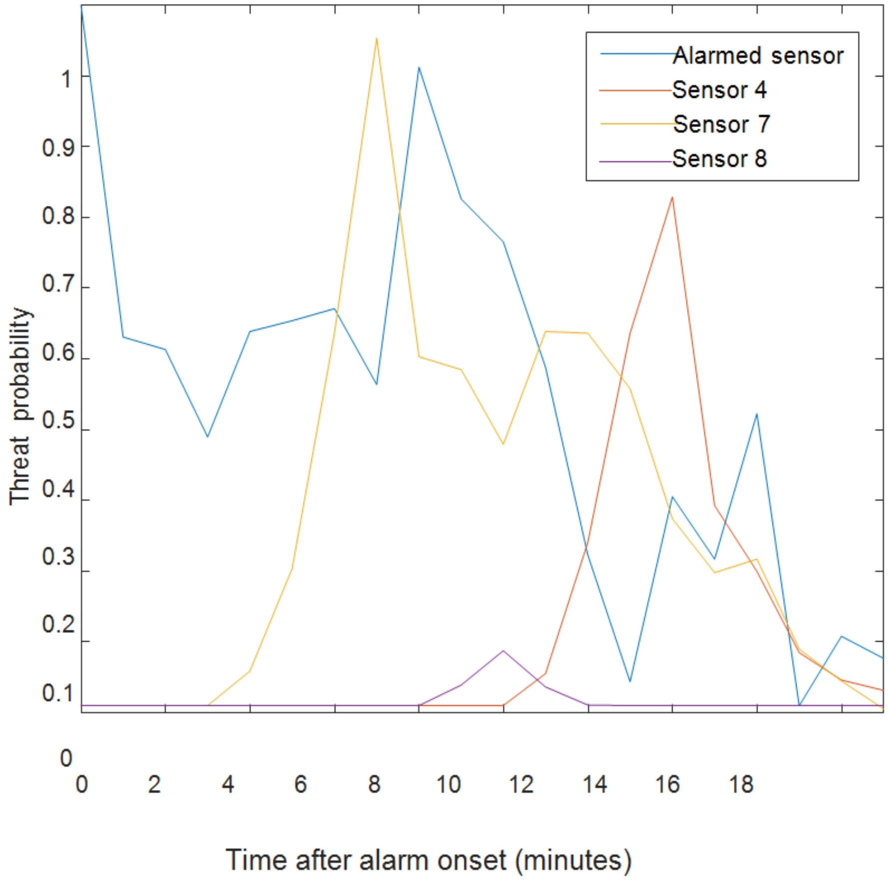
Example Characterization Of Bioaerosol Detectors Based On Meteorological Conditions

- **Humidity:** Light emission spectra of biological particles can change based on the moisture content of the sample. As bioaerosol detection devices measure light emission with different sensors, sensitivities, and algorithms, humidity can affect sensor readings differently across devices.
- **Wind Speed:** Wind speed introduces interferent particles into the air



Network-wide Analysis Of Geographically Distributed Sensors

- Its straightforward to calculate the certainty of sensor readings within a given individual detector using external wind speed and humidity information.
- Comparing different sensors at multiple locations is more complex, however.
- When comparing readings from multiple sensors, it is necessary to consider location, time, and wind velocity as well as the sensor readings themselves.
- When bioaerosol particles are detected at one location, it makes sense to compare sensor readings at downwind locations at future moments in time.
- Wind speed data is necessary information to determine how distant sensor readings should be for comparison purposes, and at which moments in time their readings should be compared.
- In the following example, an array of sensors detects a cloud of particles as it moves across a sensor array over a span of 19 minutes.
- Readings from a selected few of the sensors show that the peak of detection occurs at different times depending upon the location of the sensor.



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Detection Algorithm

- Use analytical methods that extract a single threat value from multiple sensor modalities.
  - Requires only limited training data to establish baseline
  - Correlations among different sensor readings
  - Separate statistical models generated for different metrological conditions. If background measurements that sensors take are dependent upon weather or time of day, modeling specificity will anticipate these changes by measuring the current environmental conditions.
- Track detected particles as they would be displaced by the wind and use the additional information collected by downwind sensors.
  - Simulate the movement of bioaerosols as they are moved by the wind over long time periods. Measurements from an upwind sensor are only compared with downwind measurements at the appropriate time points, as determined by wind velocity.
  - Information from other nearby sensors is taken into account by using local averaging that is weighted according to how far away sensors are from each other. Using information from multiple sources limits the effect of spurious alarm response signals.

We use Bayesian inference to compute the level of uncertainty in alarm signals, while taking readings from multiple time points, locations, and sensor modalities into account.

Simulation & Analysis

4D Atmospheric Simulation

- High fidelity micro scale meteorological simulation
- Realistic plume modeling to provide data for statistical analysis

Sensor Simulation

- Multiple sensor of various modalities placed in 4D atmospheric simulation
- Sensor response characterization and response influenced by weather information such as wind speed and humidity

Sensor Statistical Analysis

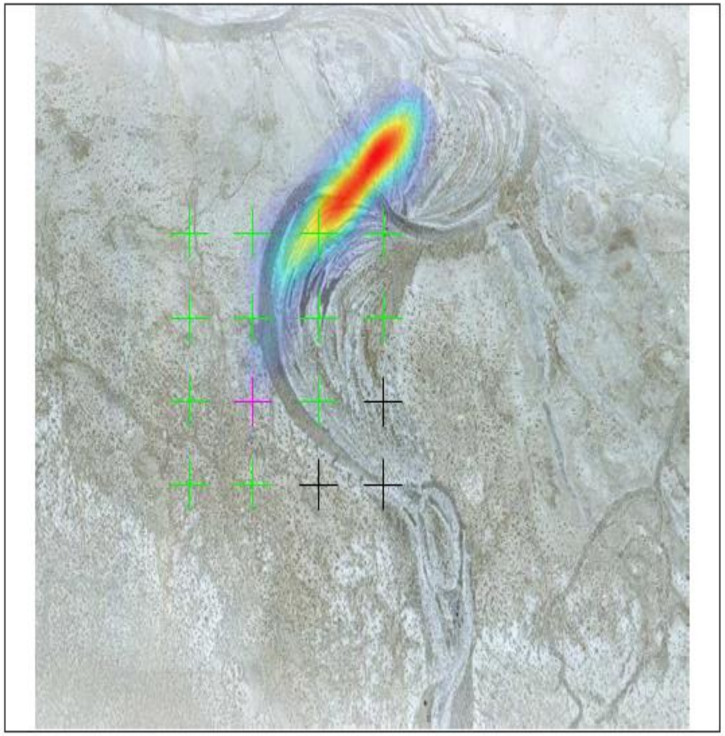
- Sensor baselines are established in the absents of agents
- Statistical analysis to identify deviations from baseline per sensor

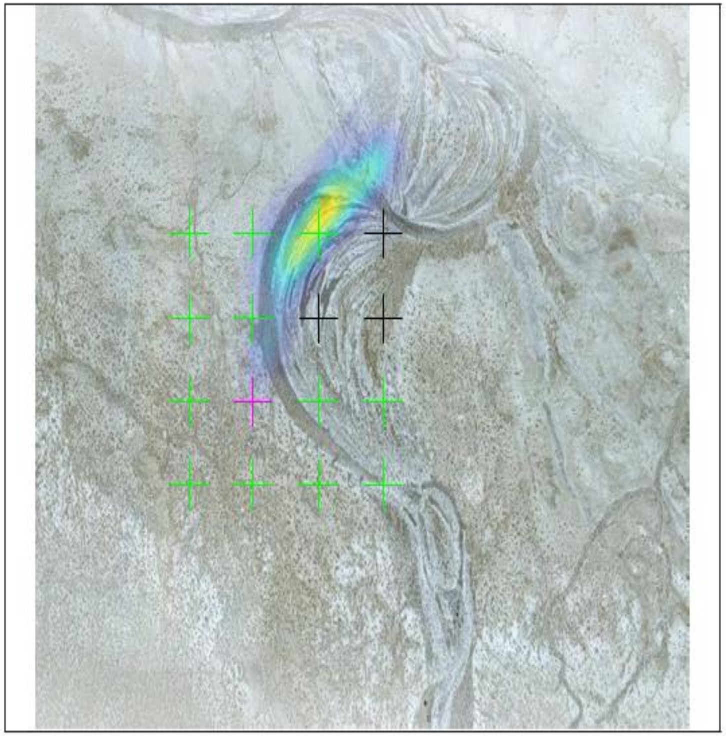
Network Statistical Analysis

- Statistical analysis to identify deviations from baseline network wide from multiple sensors and modalities

Bayesian Inference

- Compute the level of uncertainty in alarm signals, while taking readings from multiple time points, locations, and sensor modalities into account.





- The alarmed sensor is colored magenta. In this simulation, wind blows generally to the northeast, but shifts slightly during the course of the simulation. In a situation where the downwind sensors do not detect this threat (right), the threat level is relatively low. In a situation where the downwind sensors also detect this threat, the threat level is higher (left).
- In the left image, the threat probabilities of three bottom right sensors (colored black) have been adjusted to zero by the algorithms. This change has no impact on the probability of an alarm because these sensors are not downwind of the alarmed sensor, but add fidelity to the threat for the Commander.
- In the right image, three downwind sensors (in black) did not detect the threat so they have had their readings changed to zero to contradict the sensor readings of the alarmed sensor. As a result, the threat probability reported by the alarmed sensor is significantly diminished.

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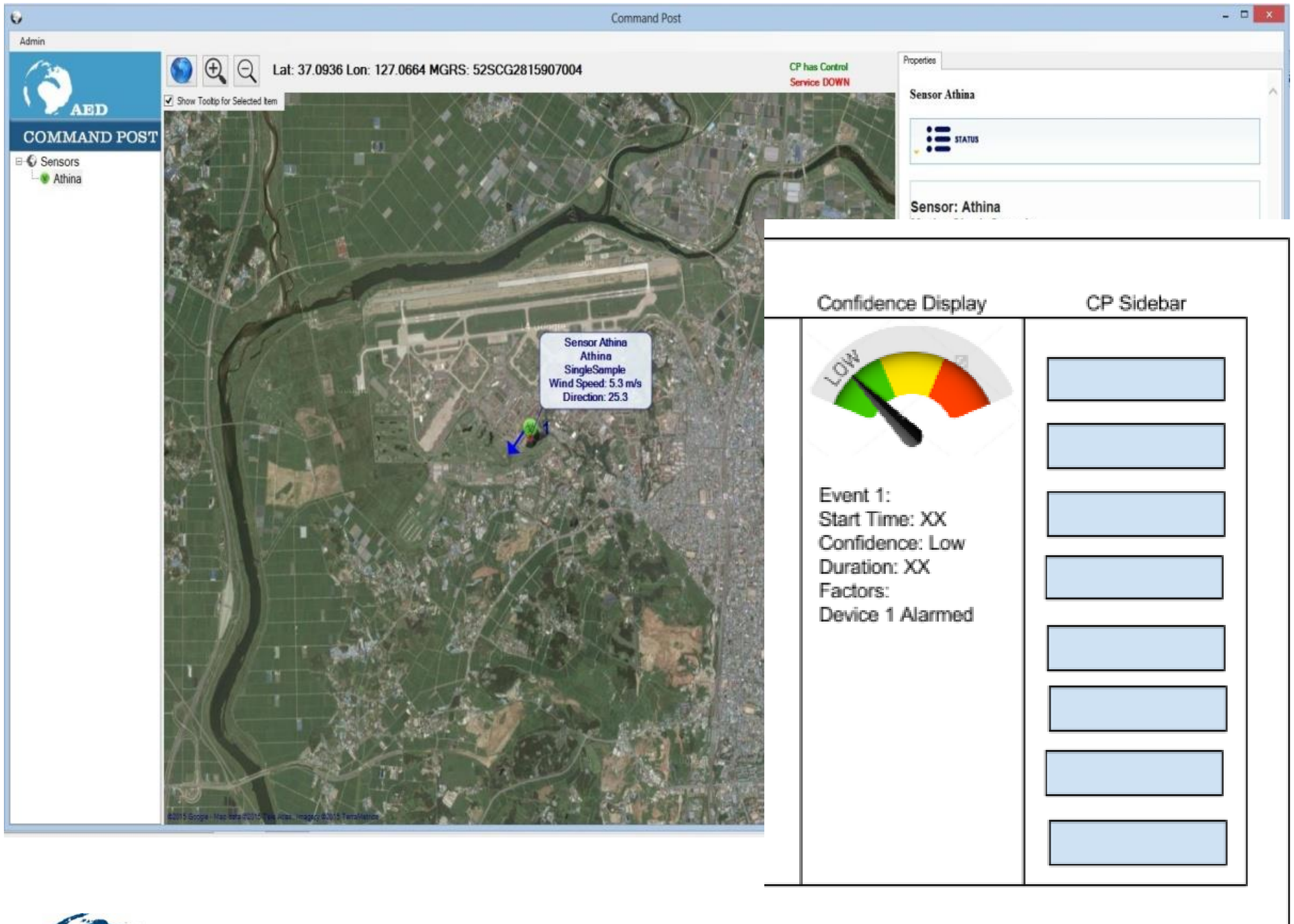
Enhanced Data To Decision



- Once the heats maps are created, automated course of action decisions can be implemented using whatever protocols are desired.
- In the previous example, Commanders could be automatically notified that certain alarming sensor are not reliable and the bioaersol threat is outside the location of deployed forces.
- This can be of critical importance when international responses require coordination.

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CONCLUSIONS

- Data to decision relies not only on better sensor technology but better analysis of all data available.
- Our solution is currently a layered approach to developing a comprehensive situational understanding from multiple sensors modalities placed at multiple locations.
- Early warning provided by a layered defence is made possible by giving decision makers not just binary alarm information but probabilities based on the fusion of all data.
- In our simulations, we increased the quality and precision of automated course of action (COA) decisions by characterizing individual sensor data based on environmental conditions and then combining all sensor data.

Questions?

Would you like to learn more? Please contact us:

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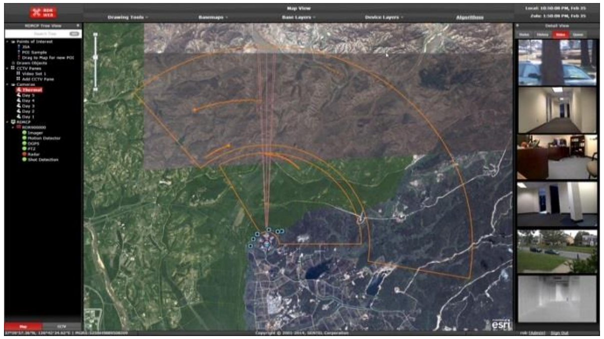
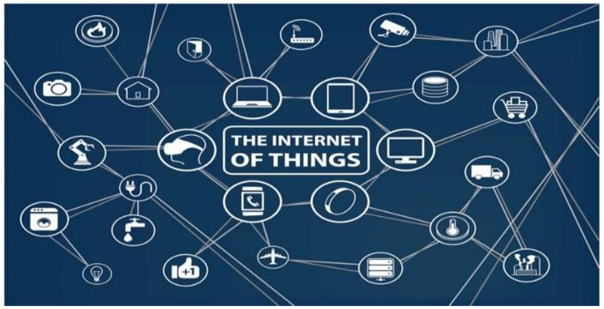
Force Protection Systems



Common Operational Picture

CBRN Systems

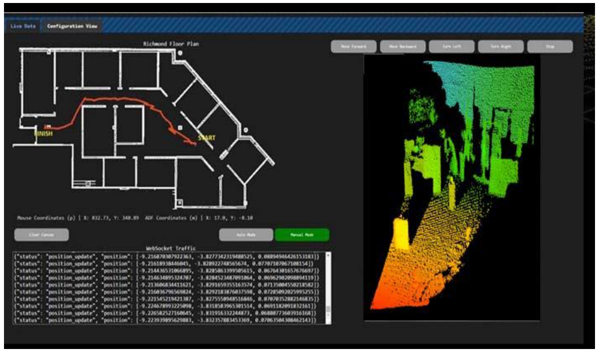


Internet of Things

Augmented Reality

Software Development

Algorithm Development



Autonomous Navigation

All Threats Integration

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Precision & Excellence . . . Engineering solutions for complex challenges

SENTEL integrates disparate systems to provide information, based on real-time *observations,* to *orient* and organize thoughts about potential threat situations, substantiating confidence in our *decisions* about when and how to *act*.

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