AI-Augmented Bandwidth-Scaled Methods in Cyber Security for Remote Surveillance Applications

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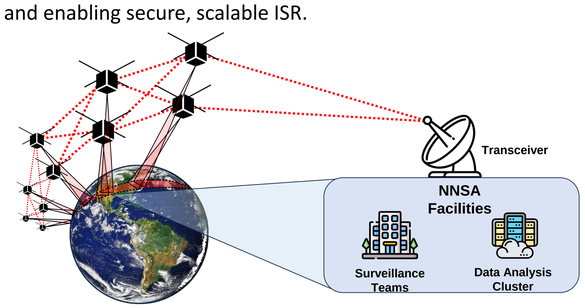
Abstract

Surveillance platforms for Intelligence, Surveillance, and Reconnaissance (ISR) of nuclear facilities face stringent downlink constraints and heightened cybersecurity risk when transmitting raw imagery. We integrate a lightweight autoencoder onboard a multispectral sensor payload—implemented on analog processors—to compress multi-band frames into compact, encrypted latent codes. This encoding reduces data volume and inherently obfuscates pixel-level information as a model-derived encryption layer. Ground stations decode these latent representations and perform final anomaly detection on nuclear signatures, decoupling heavy analytics from the spaceborne node and enabling secure, scalable ISR.



METHODS

Autonomous Anomaly Detection and Classification: AI models were trained using convolutional neural networks (CNNs) to autonomously detect and classify anomalies, reducing human workload and enhancing ISR capabilities for continuous monitoring.

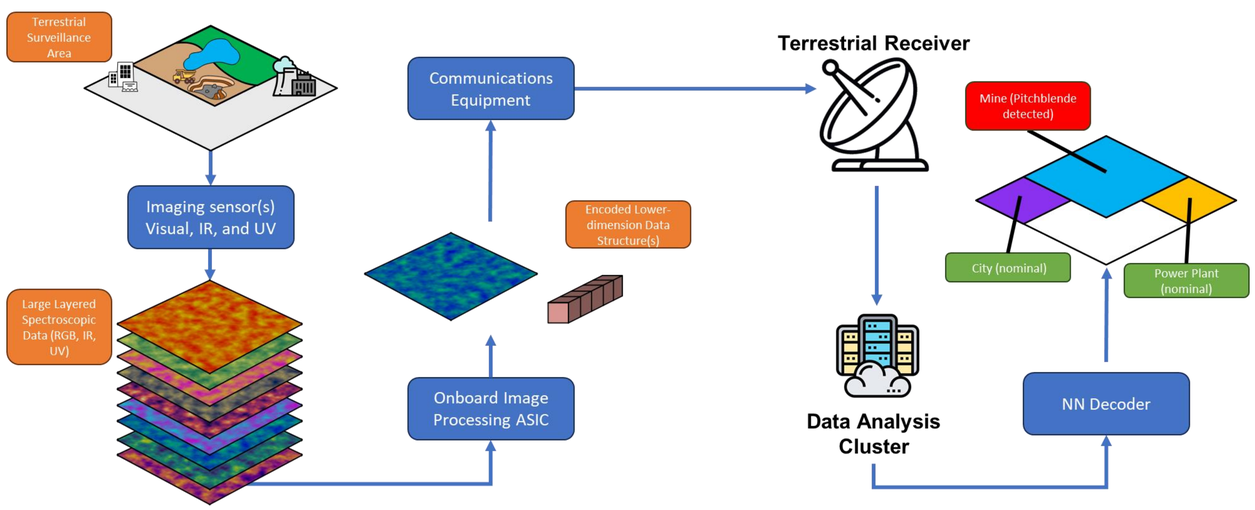
Synthetic Data Generation: Synthetic datasets were created with spectral signatures across visual, IR, UV, and Vis-NIR spectra to train AI models under conditions impractical for real-time collection, ensuring robust system preparation.

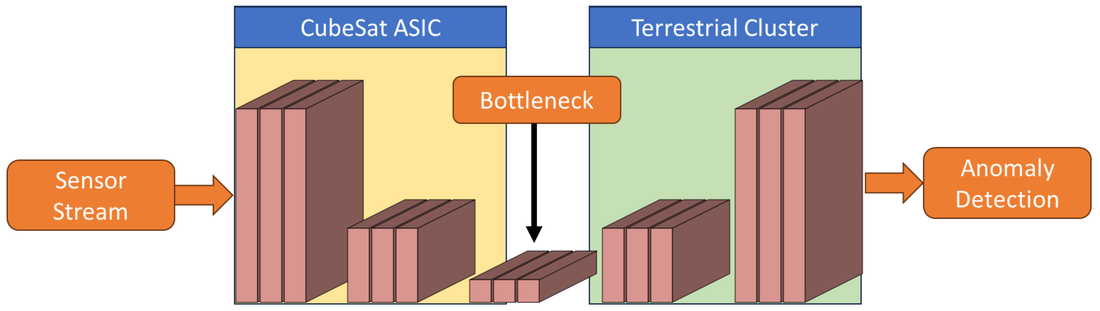
Signature Characterization: The dataset was enriched with attributes such as intensity and size to emulate hyperspectral sensor measurements, enhancing the accuracy of anomaly detection.

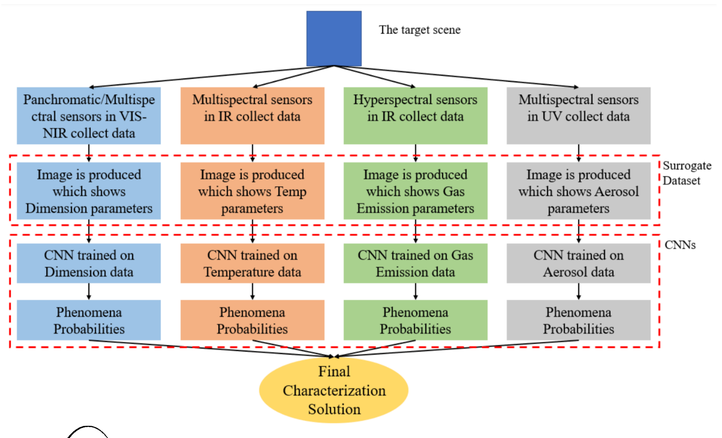
Hardware Design: The satellite constellation was designed with high-resolution sensors and modular low-SWAP components, balancing cost-effectiveness with targeted ISR capabilities to meet mission requirements.

RESULTS

The CubeSat platform demonstrated effective autonomous anomaly detection using low-resolution imagery, with precision and recall rates between 89.7% to 99.9%. Initial testing confirmed the platform's ISR capability to detect anomalies using secondary optical signatures, providing a foundation for rapid response in large-scale defense operations. Surrogate datasets and AI integration significantly improved anomaly detection accuracy, reducing the risk of false positives during monitoring activities.







DISCUSSION

Enhanced ISR Capabilities: The AI-enabled satellite platform delivers autonomous, persistent ISR (Intelligence, Surveillance, Reconnaissance) for localized anomaly detection, reducing human error and enabling rapid threat response—key for nuclear security and early threat identification.

Operational Versatility: Though focused on nuclear security, the platform is adaptable for multiple mission sets, including environmental monitoring and disaster response, offering rapid re-tasking to address emergent threats across defense operations.

Challenges and Future Work:

- **Sensor Sensitivity:** Enhancing sensor capabilities to detect lower-signature anomalies.
- **Real-World Validation:** Field deployment to validate operational readiness, including integration with high-resolution sensors for applications like microreactor security.
- **Onboard Processing:** Upgrading onboard analytics to reduce data latency, ensuring actionable intelligence reaches the warfighter in real time.

Acknowledgements

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Publications

M. M. Mendoza, "Multi-modal global surveillance methodology for predictive and on-demand characterization of localized processes using cube satellite platforms," M.S. thesis, Dept. Nuclear Eng., Texas A&M Univ., College Station, TX, USA, 2021

M. A. Avalos, "Deep-learning based event identification for reliable monitoring of nuclear facilities," M.S. thesis, Dept. Nuclear Eng., Texas A&M Univ., College Station, TX, USA, Dec. 2023.

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