WHITE PAPER

INTEGRATED SENSING AND COMMUNICATIONS (ISAC):

UNLOCKING THE DUAL USE OF WIRELESS INFRASTRUCTURE FOR NATIONAL DEFENSE AND SITUATIONAL AWARENESS

CREATED BY: ENGINEERS AT TIAMI NETWORKS, A LEADER IN ISAC

Executive Summary

As modern battlefields and contested domains grow increasingly complex and data-driven, the United States Department of Defense (DoD) is investing in technologies that are capable of delivering more functionality with fewer resources. Integrated Sensing and Communications (ISAC) is one such paradigm - a next-generation approach that merges radio-based sensing and data transmission into a unified hardware and spectrum architecture. By enabling communications infrastructure to perform dual roles, ISAC offers a path to operational efficiency, enhanced spectrum utilization, and increased battlefield survivability.

This white paper introduces the foundational concepts of ISAC, explores the technical implementation of passive radar sensing through commercial wireless signals, including 4G, 5G, and Non-Terrestrial Networks (NTN) supported by Low Earth Orbit (LEO) satellites, and compares cooperative and non-cooperative ISAC configurations. It also examines how passive radar technologies offer resilient, infrastructure-friendly alternatives to traditional sensing modalities. Finally, it showcases Tiami Networks' PolyEdge solution, a field-tested, software-defined ISAC platform designed for flexibility and real-world defense applications.

Introduction to Integrated Sensing and Communications (ISAC)

Integrated Sensing and Communications (ISAC) represents a significant evolution in wireless system design, unifying what have historically been two distinct functions: wireless communications and radar-based environmental sensing. At its core, ISAC seeks to utilize the same radio-frequency (RF) hardware and spectrum resources to simultaneously support both data transmission and sensing operations. This results in a more streamlined, spectrum-efficient, and multifunctional infrastructure.

Traditionally, defense and commercial wireless systems have required separate spectrum allocations and specialized equipment for sensing (e.g., radar) and communication (e.g., cellular, satellite). The ISAC framework consolidates these functionalities, enabling RF systems, such as 5G base stations, LEO satellite constellations, or tactical radios, to serve as both communication nodes and environmental sensors.

This integration is not merely theoretical. In defense settings, ISAC introduces the potential to significantly reduce hardware footprints, enhance spectrum agility, and provide persistent situational awareness without deployment of additional dedicated sensing platforms. ISAC also aligns closely with the Department of Defense's FutureG strategic objectives, which prioritize dual-use, software-defined systems capable of operating effectively across contested and congested spectral environments.

Passive Radar Sensing Using Commercial Cellular Signals

A foundational aspect of many ISAC implementations, particularly non-cooperative variants, involves passive radar sensing. This approach leverages "signals of opportunity," meaning that rather than emitting a signal of its own, the sensing node listens to and analyzes reflections of ambient transmissions from existing commercial or government infrastructure.

Examples of such ambient transmissions include cellular signals from 4G LTE and 5G base stations, or downlinks from LEO satellite networks that form part of modern Non-Terrestrial Networks (NTN). These signals are abundant, high power, and structured in a predictable way, making them ideal for opportunistic sensing applications.

Passive radar systems use a combination of signal processing techniques, including Doppler shift analysis, time difference of arrival (TDOA), and waveform correlation, to detect, localize, and track objects within the environment. Because these systems do not emit any signal, they offer significant stealth advantages, making them difficult to detect or jam. This quality, known as low probability of intercept (LPI), is particularly valuable in contested electromagnetic environments.

The characteristics of commercial cellular and NTN signals make them especially suitable for this form of sensing:

- Abundant: Existing infrastructure provides dense and widespread coverage in both urban and rural areas.
- Persistent: Continuous transmission patterns enable real-time, around-the-clock sensing.
- Multi-band: Cellular networks operate across multiple frequency bands, enhancing resolution and detection range.

- Structured: Known modulation formats and transmission schedules simplify signal correlation and interpretation.

By using these signals as a passive illuminator, ISAC-capable systems can achieve meaningful situational awareness without requiring dedicated radar installations.

Passive Radar Benefits in Defense Applications

The utility of passive radar in defense operations stems from its unique combination of stealth, scalability, and adaptability. Key benefits include:

- Infrastructure Compatibility: Passive radar systems can be rapidly integrated with existing telecommunications or satellite infrastructure, reducing time-to-deploy and capital expenditure.
- Low Probability of Intercept (LPI): Since the sensor does not emit any signal, it is inherently difficult for adversaries to detect or jam, enhancing survivability.
- Detection of RF-Silent Targets: This is particularly advantageous for identifying small, low-RCS (Radar Cross Section) drones or UAS that do not emit RF signatures, such as those operating autonomously.
- All-Weather and Day/Night Performance: Unlike optical or infrared systems, passive radar is not impeded by environmental conditions like fog, rain, or darkness.
- SWaP-C Optimization: Compact, power-efficient hardware enables deployment on tactical platforms, border posts, and other constrained environments without excessive logistical burdens.

These characteristics make passive radar, especially when powered by ISAC principles, a uniquely resilient and future-proof sensing modality.

Cooperative vs Non-Cooperative ISAC Approaches

ISAC systems can be divided into two broad categories based on the degree of coordination between the sensing and communication functions: cooperative and non-cooperative.

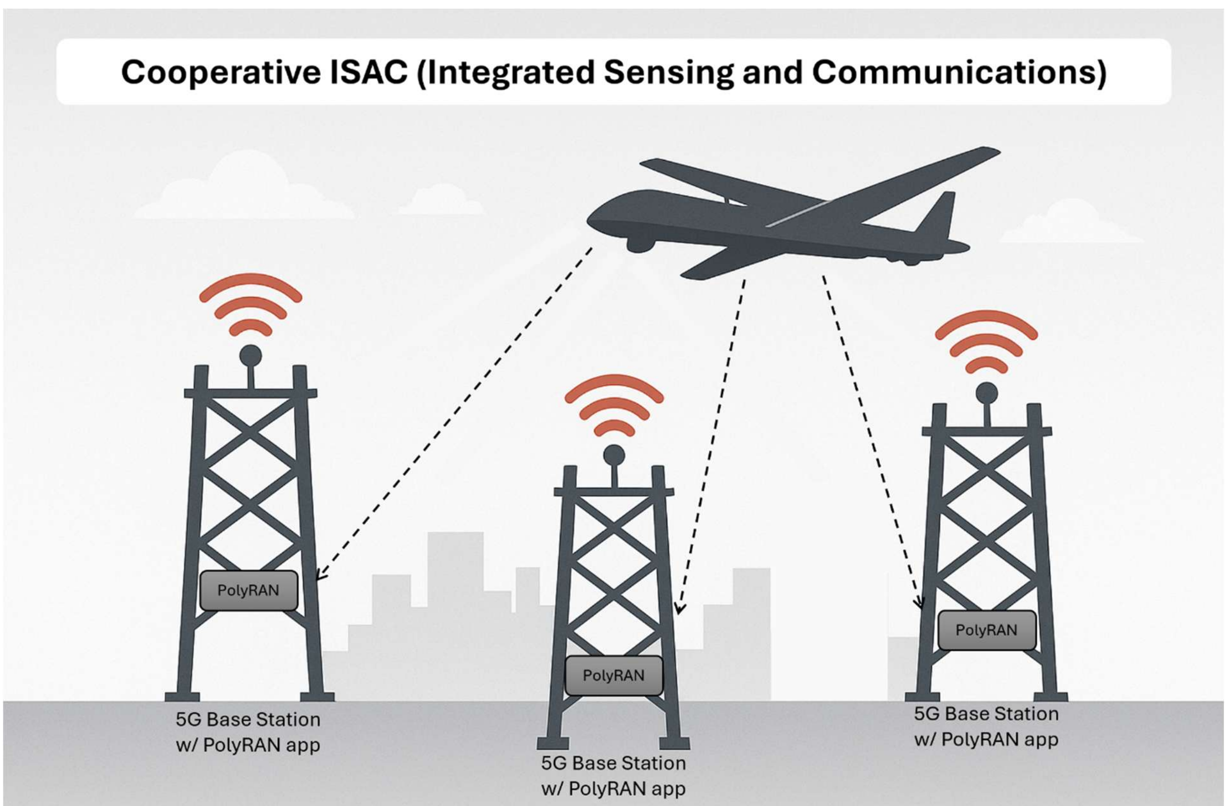
Cooperative ISAC systems involve deliberate co-design of sensing and communication functions. The transmitters, receivers, and waveforms are all developed with joint optimization in mind.

Advantages:

- Superior sensing performance due to waveform optimization.
- Coordinated multi-device and multi-frequency support enhances spatial and spectral diversity.
- Simplifies integration with higher-level sensor fusion and command-and-control (C2) systems.

Challenges:

- Increased deployment complexity, particularly in decentralized or forward-operating environments.
- Higher initial costs due to customized hardware and software stack.
- Regular updates and standardization requirements may slow fielding across joint forces.



Non-Cooperative ISAC systems leverage existing transmission sources, such as commercial 5G base stations or LEO satellites, without any modifications to the transmit infrastructure.

Advantages:

- Extremely rapid and cost-effective to deploy.
- Stealthy operation with minimal electromagnetic footprint.
- Broad applicability, including in urban, rural, or denied environments.

Challenges:

- Limited control over waveform characteristics and transmission timing.
- Potential vulnerabilities if adversaries attempt to spoof or interfere with signals of opportunity.

The latter challenge is an area where additional research and development are urgently needed. While non-cooperative ISAC offers a near-term tactical advantage, continued DoD investment is essential to develop robust counter-spoofing techniques, adversarial signal modeling, and adaptive sensing algorithms that can mitigate these risks.

Applications of ISAC in Defense & Security

The versatility of ISAC, particularly in its non-cooperative form, supports a wide range of defense, intelligence, and homeland security applications:

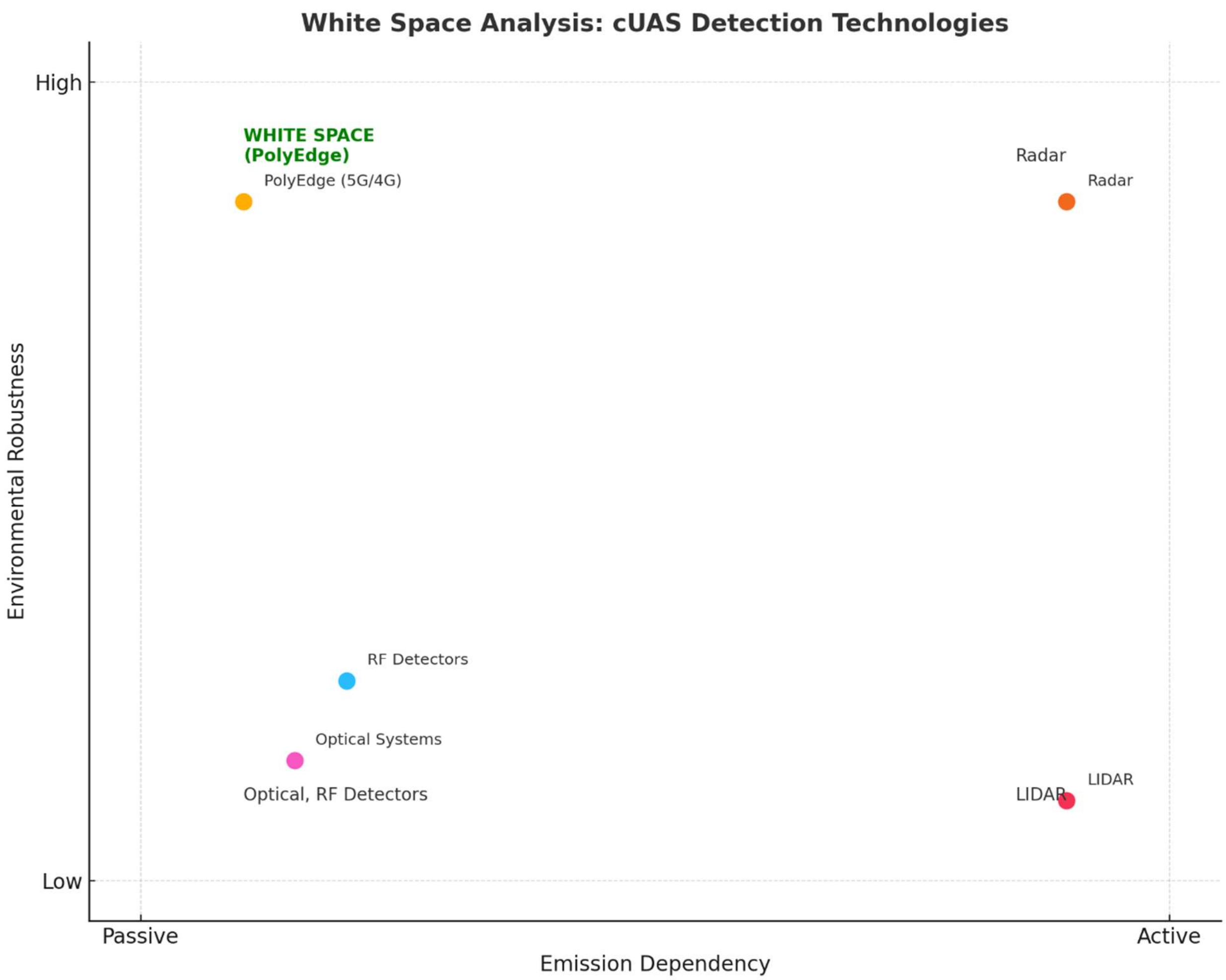
- Drone and UAS Detection: Detect and track small, low-flying, and RF-silent drones in sensitive airspace without relying on optical or RF emissions.
- Occupancy and Human Presence Monitoring: Monitor foot traffic or unauthorized personnel in facilities, remote outposts, or tactical perimeters - without relying on privacy-sensitive camera systems.
- Ground Vehicle Tracking: Provide persistent monitoring of vehicle movements, especially in areas with poor visibility or limited sensor coverage.
- Wildlife and Runway Intrusion Alerts: Detect large mammals or birds near airfields to support wildlife hazard management.

Each of these applications can be supported by passive sensing systems that require minimal infrastructure and are easy to deploy, reconfigure, and maintain throughout the operational lifecycle.

Comparison to Traditional Sensing Modalities

Passive ISAC systems stand apart from traditional modalities by offering an optimal balance of low-cost, low-maintenance, and all-weather performance. They also avoid many of the privacy and regulatory concerns associated with camera-based systems, particularly in civilian or dual-use settings.

Feature	Passive ISAC	Cameras	LIDAR	Active Radar
Cost	Low	Medium	High	High
Stealth	High	Low	Medium	Low
All-weather	Yes	No	No	Yes
Power Consumption	Low	Medium	High	High
Maintenance	Low	High	Medium	High
Privacy Concerns	None	High	None	None



Tiami Networks' PolyEdge: Real-World ISAC in Action

Tiami Networks has developed PolyEdge, a multifunction sensor platform that operationalizes the ISAC concept using a software-defined, edge-deployed architecture. PolyEdge harnesses ambient 4G, 5G, Wi-Fi, and NTN signals to passively sense the environment while leveraging onboard AI/ML accelerators (via Altera FPGAs) to perform real-time inference at the edge.

The PolyEdge platform has been successfully validated in a series of defense-relevant use cases:

- Drone detection in airport no-fly zones and sensitive airspace.
- Occupancy sensing in transportation hubs, military facilities, and smart buildings.

- People and vehicle tracking for perimeter security, smart city analytics, and forward operating base awareness.

PolyEdge is designed for rapid deployment, requires no new transmission infrastructure, and supports dynamic software updates for mission-specific configurations. Its small form factor, low power requirements, and modular interface make it suitable for integration with larger C5ISR systems or for standalone deployments.

As a proven and field-tested ISAC solution, PolyEdge aligns closely with the DoD's FutureG priorities. It provides a pathway to deploy advanced sensing capabilities today, while retaining the flexibility to evolve alongside mission needs and emerging spectrum environments.

Conclusion & Strategic Call to Action

Integrated Sensing and Communications marks a critical step forward in aligning U.S. defense infrastructure with 21st-century operational realities. As near-peer adversaries invest in counter-surveillance, jamming, and spectrum denial capabilities, the United States must maintain a technological edge through the deployment of adaptive, dual-use, and spectrum-efficient systems.

Passive radar sensing - particularly through non-cooperative ISAC configurations - offers a pragmatic and scalable solution. Tiami Networks' PolyEdge demonstrates that ISAC is not a distant future concept, but a viable tool for real-world situational awareness today. However, to fully exploit this potential, targeted DoD investment is needed in areas such as adversarial signal modeling, real-time AI/ML inference, and counter-exploitation tactics.

The FutureG community, in collaboration with agile innovators like Tiami Networks, is uniquely positioned to lead this charge. Together, we can redefine the role of wireless infrastructure - not just as a conduit for information, but as a foundational asset for national defense, situational awareness, and strategic deterrence.

Sources and Citations

The concepts, definitions, and technologies discussed in this white paper are informed by and aligned with recent research and publications from leading institutions and government programs.

Key references include:

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- The descriptions of Tiami Networks' PolyEdge platform are derived from proprietary field results and demonstrations, including joint evaluations with public sector and industry partners.