Radar Types & Applications for WOLF Products

INTRODUCTION

Radar technology plays a crucial role in a variety of industries, including defense, aerospace, automotive, and industrial monitoring.
While traditional radar processing has long relied on FPGA-based architectures due to their real-time determinism and low latency, modern radar workloads increasingly demand advanced AI, flexible signal interpretation, and rapid algorithm evolution—areas where GPUs excel.

WOLF Advanced Technology delivers high-performance radar processing solutions that harness the power of NVIDIA GPUs, either as standalone accelerators or in tightly integrated FPGA + GPU hybrid systems. These solutions enable developers to leverage the real-time signal control of FPGAs alongside the parallel processing and AI capabilities of GPUs—unlocking new levels of radar performance, adaptability, and mission readiness.

GPUs can act as a more flexible and user-friendly processing platform that complements or even replaces certain FPGA workloads, particularly in applications involving signal classification, image formation, AI inference, or post-processing. As radar systems evolve beyond basic signal detection toward more sophisticated signal processing and interpretation, GPUs enable faster development cycles and easier experimentation with new algorithms and processing types, using familiar high-level programming environments like CUDA, OpenCL, and TensorRT.

This information paper explores the advantages of WOLF's GPU and FPGA+GPU radar solutions, highlights specific use cases across military and aerospace domains, and details how leveraging NVIDIA GPUs in VPX and XMC form factors supports both traditional radar pipelines and next-gen AI-enhanced radar systems.

Radar platforms have advanced significantly by incorporating AI-driven processing, adaptive threat detection, and real-time data fusion. While FPGA-only systems remain indispensable for certain low-latency and RF front-end control tasks, they often involve longer development timelines and specialized engineering expertise.

WOLF's high performance solutions address this by providing greater development flexibility, AI-optimized performance, and scalable compute capabilities for both non-FPGA-centric and hybrid architectures, empowering teams to stay agile and future-ready in demanding radar environments.

ADVANTAGES OF GPU-BASED RADAR PROCESSING:

High-Performance Parallel Processing. GPUs excel in handling vast amounts of radar data in parallel, allowing real-time processing and analytics. NVIDIA GPUs integrated with WOLF VPX and XMC solutions optimize radar imaging and Doppler signal processing.

AI AND MACHINE LEARNING INTEGRATION: Deep learning models can be deployed on GPUs to enhance target classification, anomaly detection, and clutter removal. NVIDIA Tensor Cores accelerate AI workloads for adaptive radar processing.

REDUCED DEVELOPMENT COMPLEXITY: Unlike FPGA implementations, GPUs enable radar engineers to develop applications using common AI and signal processing frameworks such as CUDA, TensorFlow, and PyTorch. WOLF's solutions allow for faster prototyping and deployment, reducing time-to-market.

SCALABILITY & UPGRADABILITY: GPU-based solutions are more adaptable to evolving AI and radar processing needs, allowing users to upgrade software and hardware without complete system redesigns. VPX and XMC modules support modular expansion, ensuring future-proof investment.

AEROSPACE, DEFENSE AND SURVEILLANCE APPLICATIONS:
Real-time target detection and tracking using Synthetic Aperture Radar (SAR) and Moving Target Indication (MTI) techniques. Enhanced electronic warfare capabilities by leveraging AI-driven signal processing for threat classification. Integration with unmanned systems for autonomous radar-based situational awareness. Spaceborne radar systems benefit from high-speed imaging and AI-driven anomaly detection.

RADAR APPLICATIONS AND USE CASES

Military Radar Design Recommendations by Mission Profile

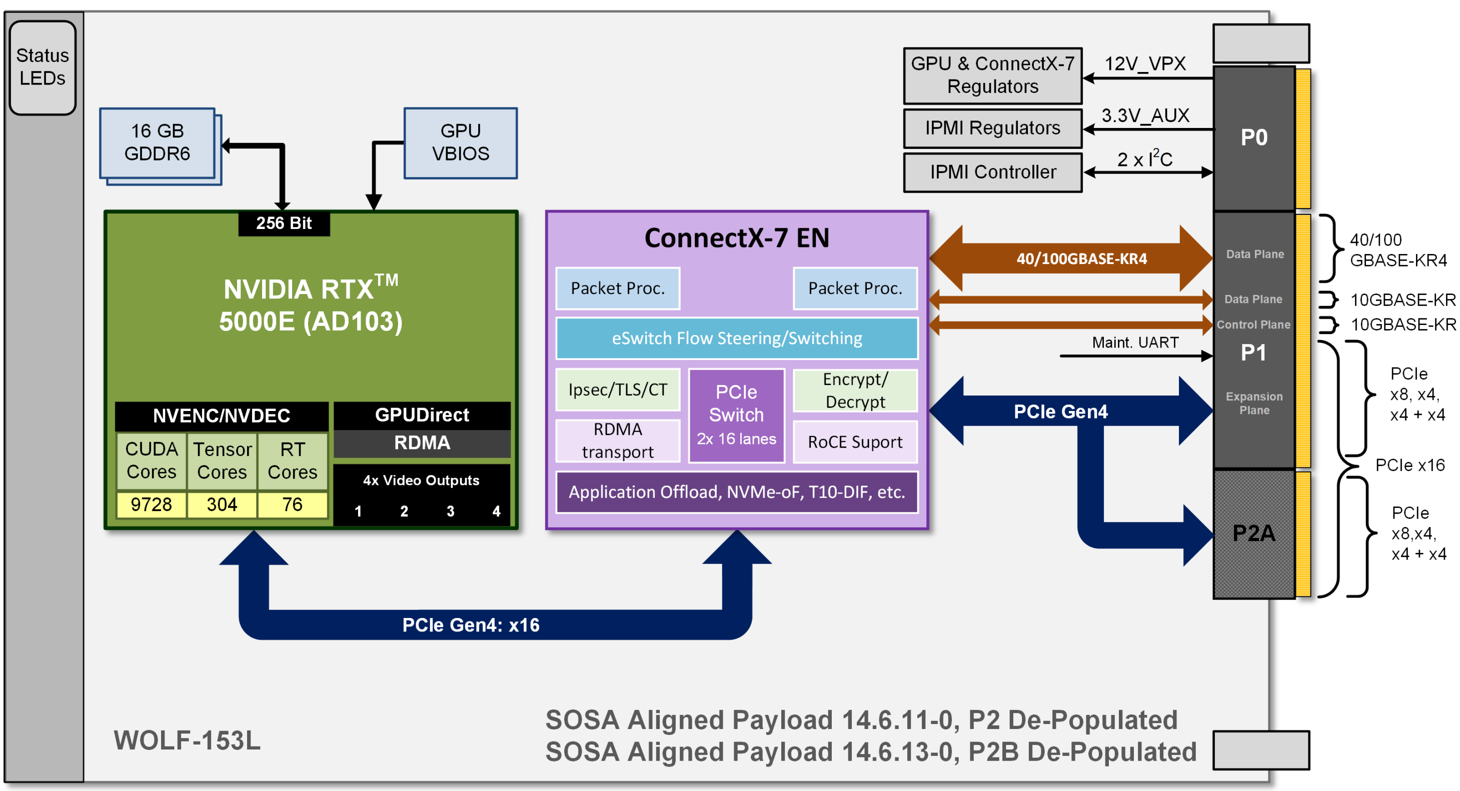
MISSION	RADAR TYPE	COMPUTE
Airborne ISR	AESA + SAR	FPGA + GPU
Missile Defense	AESA Pulse-Doppler	FPGA
Space Recon	SAR	FPGA (onboard) + GPU (ground)
Border Surveillance	MTI + SAR	FPGA + GPU
Electronic Warfare	Passive/Multistatic	GPU
Naval Operations	3D AESA	FPGA (real-time) + optional GPU (backend)

AIRBORNE SURVEILLANCE (e.g., AWACS, UAV-based ISR)

- Recommended Radar: AESA + SAR hybrid
- Key Features: Wide-area scan, target tracking, high-res imaging
- Platform: FPGA + GPU hybrid
- FPGA for real-time AESA beam steering & tracking
- GPU for SAR image formation & object classification
- Example: E-8 JSTARS or Global Hawk UAV

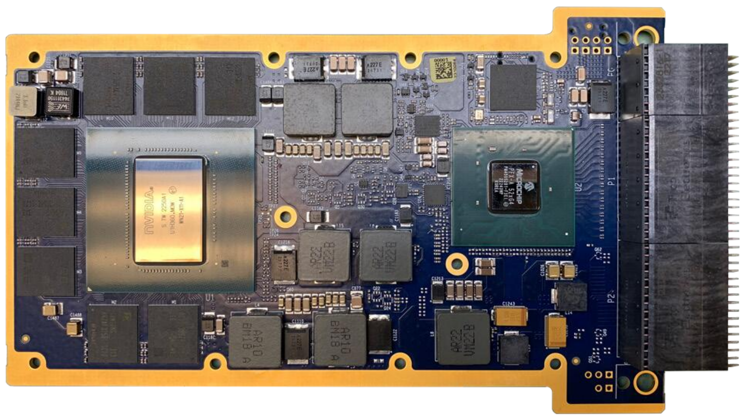
The **WOLF-153L** is a great solution with the Ada RTX5000 GPU and powerful networking ConnectX-7 smartNIC. It features 2× 10GBase-KR ports & 1x 40/100GBase-KR4 port through the CX-7. It can also support Multi-Host & act as the Ethernet switch in larger system networks. It is available in both 14.6.11 & 14.6.13 slot profiles.

The Blackwell **WOLF-163L** will be ICD compatible & available by the end of 2025.



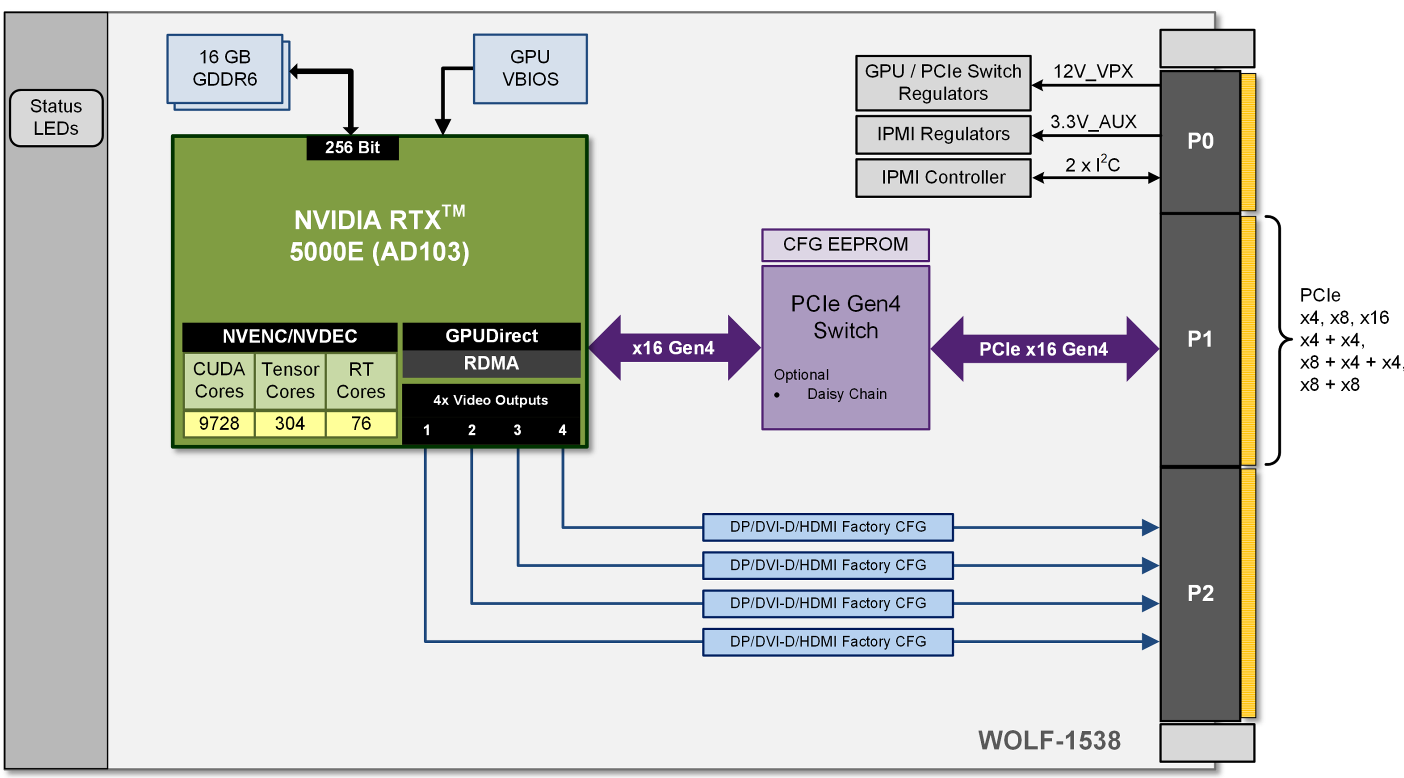
MISSILE DEFENSE / FIRE-CONTROL RADAR

- Recommended Radar: Pulse-Doppler AESA
- Key Features: Fast target acquisition, velocity detection, low-latency tracking
- Platform: FPGA-based
- Needs deterministic, low-latency signal chain
- GPU may be used offline for threat pattern analysis
- Example: Aegis SPY-1 or Patriot Radar



The **WOLF-1538** is an ideal solution for offline GPU processing utilizing the Ada RTX5000 GPU & Gen 4 PCIE switch. It is available in both SOSA 14.6.11-0 & OPENVPX slot profiles. Up to 4x Outputs on P2.

The 1538 is ICD compatible with Ampere WOLF-1448 & with the new Blackwell 1638 coming soon.

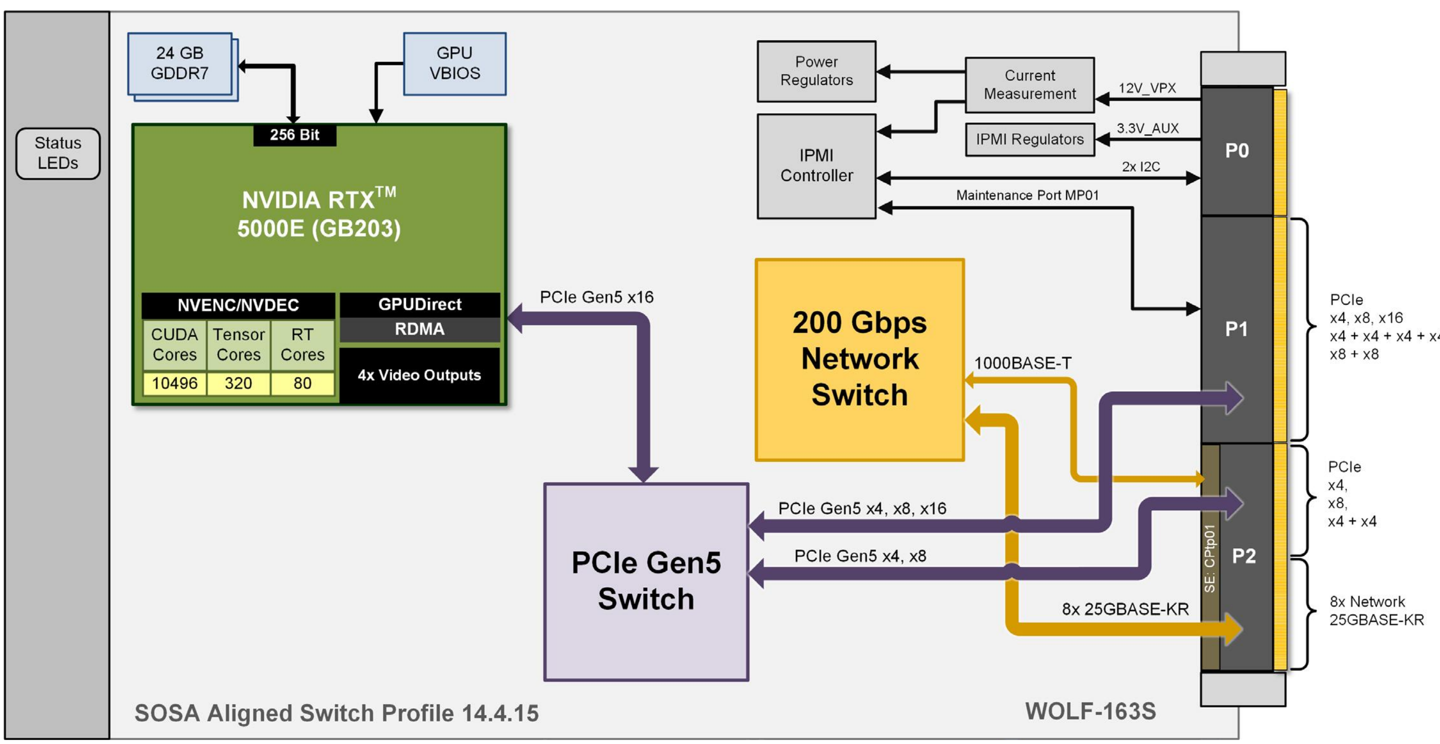


SATELLITE-BASED RECONNAISSANCE (Spaceborne ISR)

- Recommended Radar: Synthetic Aperture Radar (SAR)
- Key Features: High-resolution earth imaging through clouds/night Platform: GPU-based (ground processing) + FPGA (onboard preprocessing)
- Onboard FPGA for raw data compression & preprocessing (due to space constraints)
- Ground-based GPU clusters for image processing and AI-enhanced analytics
- Example: Sentinel-1, military grade SAR satellites

The VPX 3U **WOLF-163S** is a high performance, high port networking board with a Blackwell RTX5000 GPU & 200 Gpbs Ethernet switch supporting 8× 25GBase-KR ports. There is also a 1000BASE-T port. It is available with (163S) & without the GPU (160S).

The **WOLF-163S** is the first TSN product released and will be ICD compatible with the now EOL 134S.

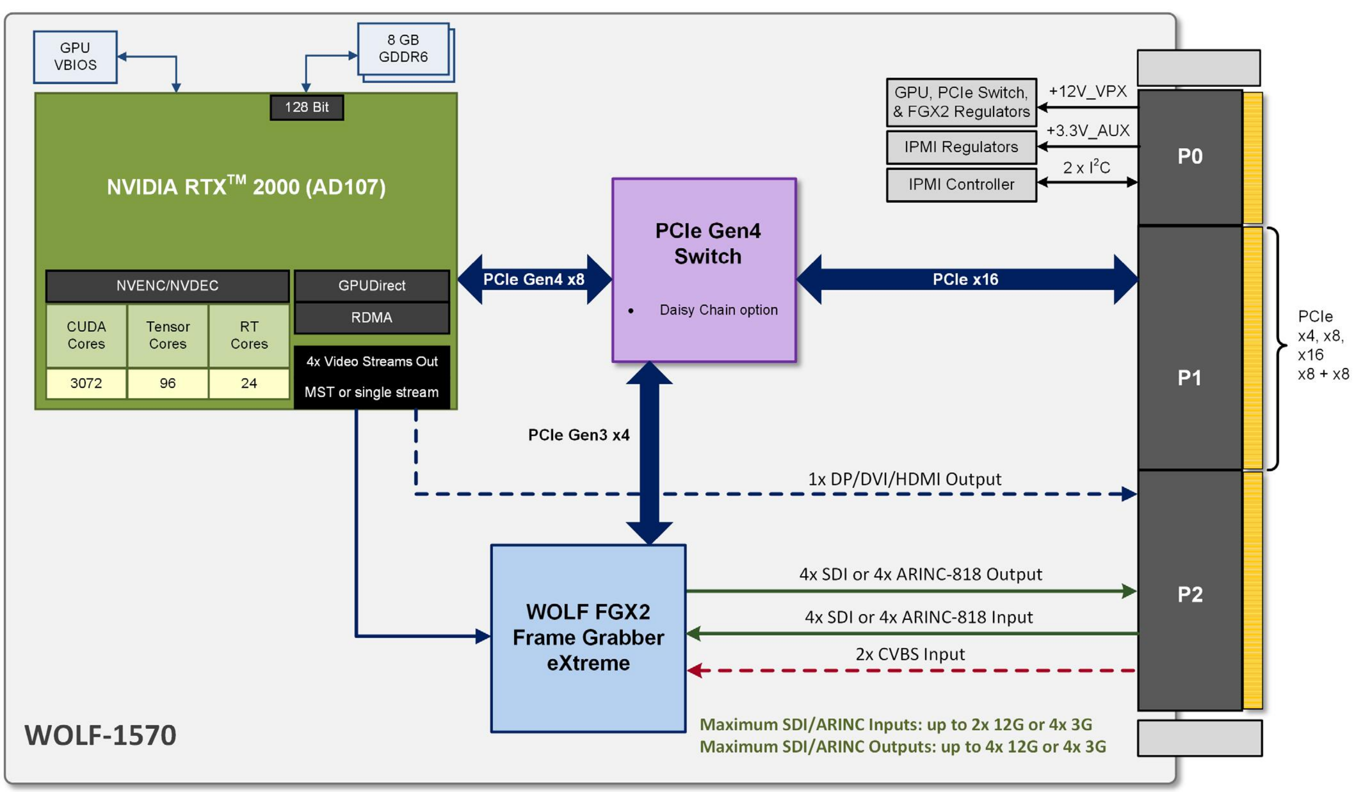


BORDER MONITORING / GROUND SURVEILLANCE

- Recommended Radar: MTI + SAR
- Key Features: Track personnel, vehicles, and detect movement in cluttered terrain
- Platform: Hybrid (FPGA + GPU)
- FPGA for real-time MTI processing
- GPU for terrain imaging and AI-based classification
- Example: G-BOSS or similar ground radar stations

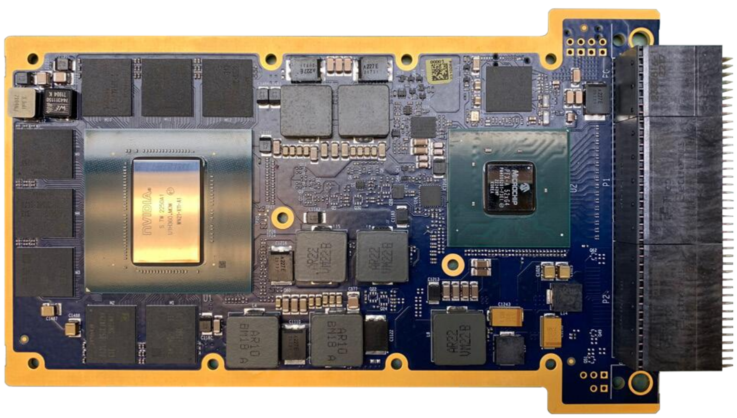
The VPX 3U **WOLF-1570** is a high performance, flexible design with an Ada RTX2000 GPU, Xilinx FGX2 FPGA & PCIe Gen 4 switch. It has up to 4x 12G-SDI Inputs plus 4× 12G-SDI Outputs.

The SDI can be converted to ARINC 818 channels. There is also an option for legacy 2x CVBS Inputs.



ELECTRONIC WARFARE / RADAR JAMMING DETECTION

- Recommended Radar: Passive or Multistatic Radar
- Key Features: Stealth target detection, low probability of intercept (LPI)
- Platform: GPU-based
- High throughput, correlation-heavy signal processing
- GPU excels at time-frequency analysis & ML-based threat detection
- Example: ELINT/ESM systems



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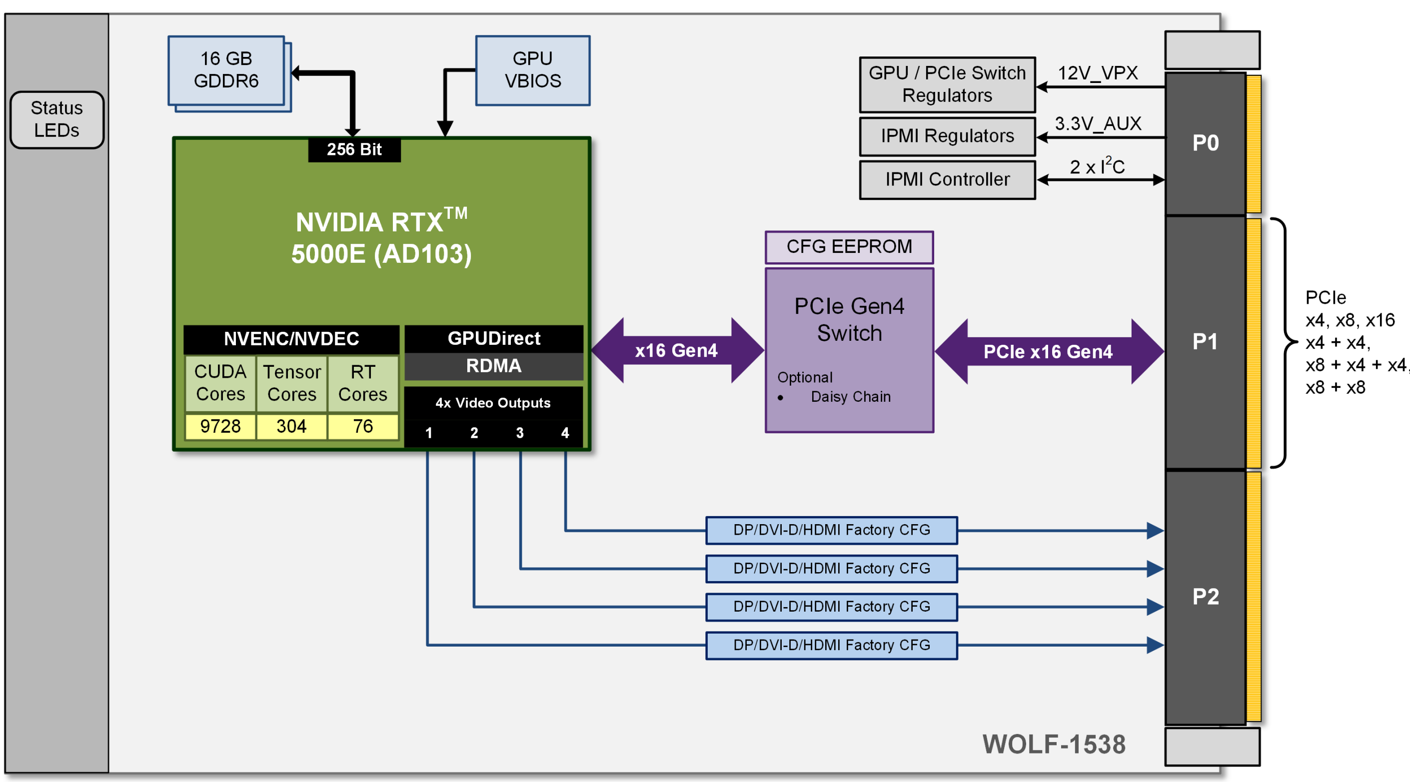
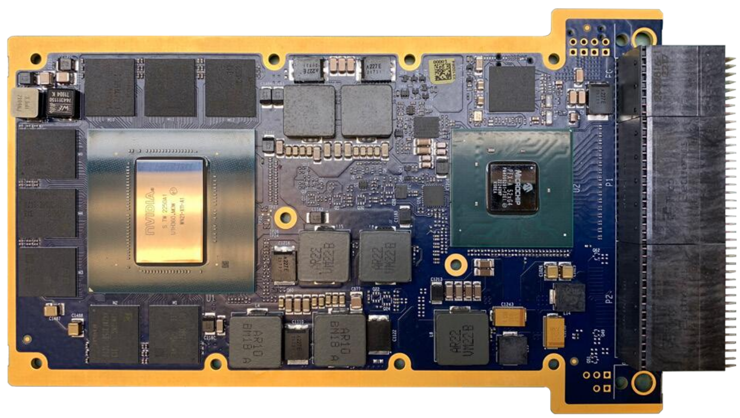


NAVAL SURVEILLANCE & TARGETING

- Recommended Radar: 3D AESA Pulse-Doppler
- Key Features: Maritime target tracking, anti-air/anti-missile capabilities
- Platform: FPGA-based, possibly with GPU for backend processing
- Real-time response to fast threats requires FPGA
- GPU may assist in data fusion and threat prediction
- Example: SPY-6 or Sea Fire radars



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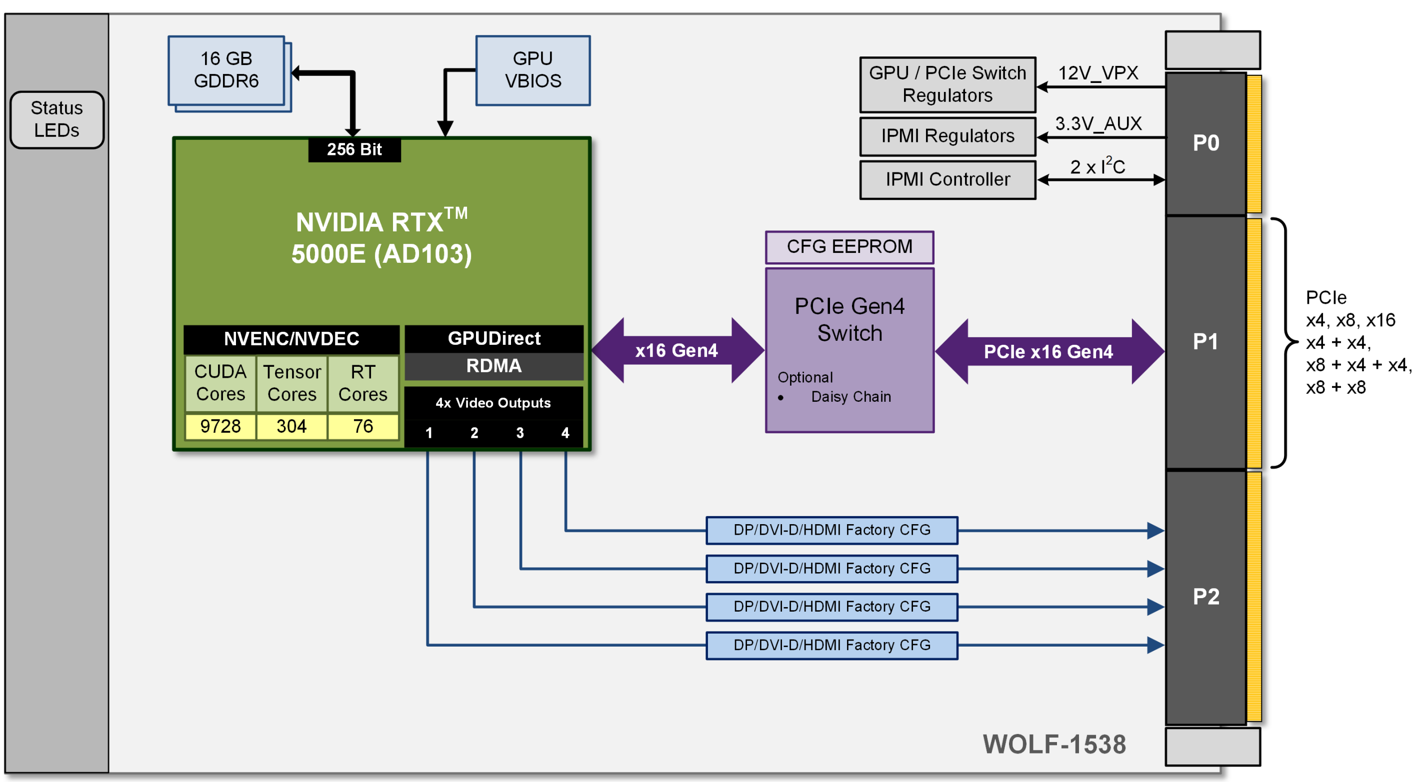


MILITARY RADAR TYPES & PROCESSING SUITABILITY

LEGEND
- **FPGA Required for RF Front-End:** Indicates if precise, real-time hardware control of analog signals is required (e.g., beamforming, ADC interfacing).
- **FPGA (SoC) + GPU Suitability:** Reflects systems that benefit from hybrid architecture (e.g., NVIDIA Jetson AGX Xavier + Xilinx Zynq SoC).
- **GPU-Only Suitability:** Systems where the radar data can be post-processed or processed with less strict real-time constraints.

KEY TAKEAWAYS
- **Use GPU-only when:** latency is not critical (e.g., SAR, GPR, post-processing).
- **Use FPGA + GPU hybrid when:** real-time signal chain is essential, but enhanced AI/image analysis is desired (e.g., AESA, Pulse-Doppler, Passive Radar).
- **Always use FPGA for RF front-end when:** working with real-time beamforming, modulation/demodulation, or phase-coherent pulse generation.

RADAR TYPE	PRIMARY USE CASE	REQUIRES FPGA FOR RF FRONT-END?	FPGA (SOC) + GPU SUITABILITY?	GPU-ONLY SUITABILITY	NOTES ON GPU USE
AESA (Active Electronically Scanned Array)	Beam Steering, Target Tracking, Fire Control	YES	VERY HIGH	LOW	FPGA handles beamforming & timing; GPU can assist in backend data fusion or tracking AI
SAR (Synthetic Aperature Radar)	High-res imaging from Aircraft / Satellites	NO	HIGH	VERY HIGH	GPU excels at SAR image formation (backprojection, FFT's, etc)
Spaceborne SAR ex) Satellites	Imaging for ISR or mapping	OFTEN	VERY HIGH	HIGH (ground station)	Onboard FPGA's preprocess; GPU on ground does SAR image reconstruction & AI
GPR (Ground Penetrating Radar)	Subsurface detection (IED's, mines, tunnels)	NO	HIGH	HIGH	GPU good for 3D imaging & pattern detection; no high-speed RF processing needed
MTI (Moving Target Indicator)	Differentiating moving from stationary targets	YES	HIGH	LOW	FPGA handles Doppler filtering & real-time movement detection
Pulse-Doppler Radar	Range & Velocity detection in cluttered environments	YES	HIGH	LOW	Real-time pulse processing on FPGA; GPU helps with post-analysis & AI
Passive Radar	Uses third-party signals (TV, radio, comms) to detect targets	OFTEN	HIGH	MODERATE	GPU handles correlation-heavy processing; FPGA needed for front-end tuning
Multistatic Radar	Multiple spatially separated receivers	YES	HIGH	LOW	GPU useful for real-time signal correlation & threat detection
Weather / Meteorological Radar	Atmospheric scanning for weather tracking	USUALLY NOT	MODERATE	HIGH	GPU helps with large data volume analysis, storm prediction & visualization
OTH (Over The Horizon) Radar	Long-range radar using ionospheric bounce	YES	HIGH	HIGH	GPU good for signal modeling & noise reduction
Height-Finder Radar	Precise elevation of Air Targets	YES	MODERATE	LOW	FPGA handles real-time trigonometry & beam steering
3D AESA (Naval Radar)	Elevation, azimuth & range targeting	YES	VERY HIGH	LOW	FPGA is crucial for fast threat tracking; GPU may assist in backend threat prediction
Airborne Tactical Radar ex) UAV	Lightweight radar for recon/strike support	OFTER	HIGH	MODERATE	GPU helps with image processing & AI-based target detection post-capture

NVIDIA-BASED GPU SOLUTIONS IN VPX & XMC FORM FACTORS:

Combining Digital Signal Processing (DSP), AI inference, and RF signal applications (like RF10, a common military tactical radio system) is right at the cutting edge of modern military radar and EW systems.

Here's a detailed breakdown of military and aerospace radar use cases involving DSP, with analysis of where GPU-based AI inference is viable, especially in RF signal environments like RF10:

USE CASES FOR DSP IN MILITARY & AEROSPACE RADAR:

USE CASE	DESCRIPTION	DSP ROLE	AI INFERENCE VIA GPU	RF10 SUITABILITY
1. Signal Classification / Emitter ID (ELINT)	Identifies enermy radar or communication signals	FFT's, filtering, matched filtering	AI models classify modulation, protocol, threat type	RF10 RF analysis/ monitoring possible
2. Electronic Countermeasure (ECM)	Detects jamming & triggers counter-jamming strategies	Direction finding, pulse analysis, phase correlation	Real-time inference to identify jamming patterns	RF10 used for jamming/ anti-jamming tests
3. Synthetic Aperature Radar (SAR)	High-res imagin from UAV's, satellites	Backprojection, range-Doppler processing, FFT's	AI-based image segmentation & object detection	Not typically RF10 related
4. Radar-Based Target Recognition (ATR)	Classifies targets (ex; tanks, drones) based on radar returns	Feature extraction from Doppler/return signatures	AI models detect/classify target shapes/speeds	If RF10 is used to transmit return data
5. Beamforming in AESA Radars	Electronically steers radar beams without mechanical movement	Phase shifting delay alignment, adaptive filtering	Usually FPGA-based; GPU too slow for hard real-time	Not related to RF10
6. Passive Radar (using RF10 as illuminator)	Uses existing RF (ex; from RF10 radios) to track movement or stealth targets	Cross-correlation. Doppler shift analysis	GPU can help track & infer movement across channels	RF10 signal is the illuminator
7. Spectrum Monitoring & Anomaly Detection	Monitors RF spectrum for anomalies, interference or enemy comms	STFT, wavelet transforms	Deep learning can detect unknown signals/ patterns	Common with RF10 field deployments
8. Adaptive Filtering / Noise Cancellation	Filters out interference, clutter or multi-path echoes	LMS/RLS filters, adaptive notch filtering	ML models can learn noise profiles dynamically	In radio-restricted zones using RF10

- **GPUs are viable** for AI inference in **RF signal environments** like RF10, but usually in a **backend or tactical compute platform**, not in the field device itself.
- AI models running on GPUs can:
- Classify RF waveforms
- Detect spoofing/jamming
- Recognize modulation types (e.g., QPSK, OFDM)
- Flag anomalies in received radar returns
- GPUs can accelerate **inference from spectrograms, I/Q data,** or **compressed signal snapshots.**

RF10 + GPU-BASED AI USE CASE EXAMPLE:

Use Case: In a tactical ground unit, RF10 radios are used for comms and ambient RF monitoring. Data is:

- **Pre-processed** on embedded DSP/FPGAs in the radio node (FFT, filtering).
- **Forwarded** to a mobile compute unit with GPU (e.g., NVIDIA Jetson, RTX-based laptop).
- **AI Inference** (deep learning model) determines:
- Enemy comms present?
- Known radar or jamming signal detected?
- RF anomaly flagged?

TECHNOLOGY	USED FOR	GPU INFERENCE VIABLE?
DSP (FFT, filters)	Baseband signal processing	No, done before GPU inference
AI Inference (GPU)	Signal classification, anomaly detection	Very effective
RF10 Signals	Tactical RF environment for comms/monitoring	Can be input for AI/DSP

CONCEPTUAL ARCHITECTURE THAT COMBINES:

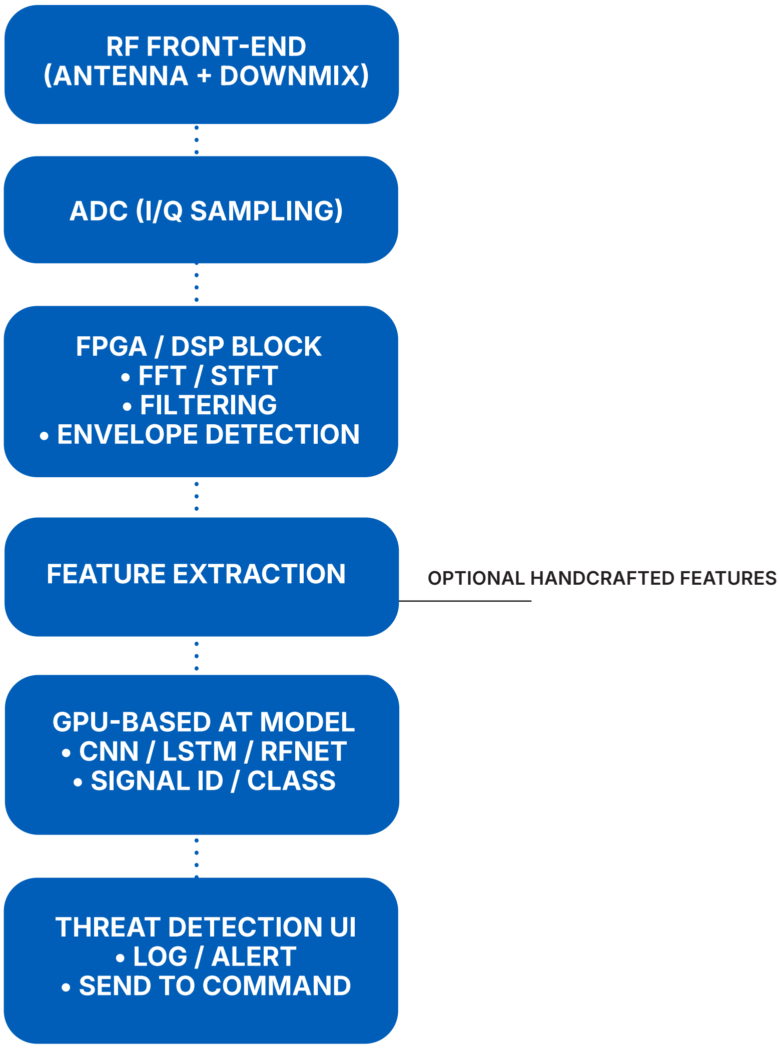
- RF front-end
- DSP preprocessing
- GPU-based AI inference
- RF10 as a signal source or target

Mission: A mobile military unit uses RF10 radios for tactical communication. A surveillance system monitors the RF spectrum for:

- Hostile jammers
- Unknown transmitters
- Specific modulation patterns (e.g., enemy drones or EW threats)

The system uses AI to classify incoming RF signals in real-time.

CONCEPTUAL BLOCK DIAGRAM:



STAGE	FUNCTION
RF Front-End	Captures wideband signals from environment (can include RF10 bands)
ADC	Digitizes signal into I/Q samples
DSP (FPGA)	Filters signal, performs FFT or spectrogram transform
Feature Extraction	Extracts key signal traits; bandwidth, modulation shape, burst pattern
AI Inference (GPU)	Classifies signal ex) friendly comms, jammer, radar pulse, unknow
Alert System	Sends results to operator or command system in real-time

MODEL IDEAS FOR AI INFERENCE

- 1D CNN: For raw I/Q waveform classification
- 2D CNN: For spectrogram-based classification (like image recognition)
- LSTM/RNN: For temporal pattern analysis (e.g., jammers with burst behavior)
- Autoencoders: For anomaly detection in RF traffic

GPU (e.g., NVIDIA Jetson or RTX) handles this efficiently, especially in tactical edge deployments.

NVIDIA-BASED GPU SOLUTIONS IN VPX & XMC FORM FACTORS

RUGGED AND SWAP-OPTIMIZED DESIGNS: WOLF's conduction-cooled and liquid-cooled solutions ensure high reliability in harsh environments. Designed to meet military and aerospace standards for durability and performance. Specifically, **WOLF-1538, WOLF-163L** & **WOLF-163S**. All WOLF products are ICD compatible so upgrades can be made without changing hardware as new generation GPU's become available.

SOFTWARE AND DEVELOPMENT SUPPORT: Compatibility with AI frameworks, CUDA, and OpenCL for streamlined radar software development. Pre-validated AI models and signal processing libraries accelerate deployment.

CHALLENGES AND CONSIDERATIONS

Power Consumption: GPU-based solutions require efficient power management, and WOLF products incorporate optimized power regulation to maximize processing efficiency.

Thermal Management: High-performance GPUs generate significant heat, and WOLF's advanced cooling methods (air, conduction, and liquid-cooled solutions) ensure reliable operation in rugged environments.

Real-Time Processing Constraints: While GPUs provide excellent parallel processing, applications requiring ultra-low-latency may require a hybrid CPU-GPU approach for optimized performance.

FUTURE TRENDS IN RADAR TECHNOLOGY WITH GPUS

Edge AI Integration: More radar systems will shift towards GPU-based edge computing for real-time data processing and reduced latency.

Quantum Computing Influence: GPUs in Quantum Radar & Sensing: As quantum radar and sensing technologies emerge, GPUs will be key for handling the complex data processing required—such as quantum state estimation and real-time signal interpretation—enabling breakthroughs in stealth detection and ultra-sensitive sensing.

5G and IoT Connectivity: Radar systems will increasingly integrate with 5G networks and IoT sensors for improved situational awareness and data fusion.

CONCLUSIONS

For customers who require high-performance radar processing without the complexity of FPGA-based solutions, WOLF's GPU-powered VPX and XMC solutions offer a compelling alternative. These solutions provide the necessary computational power for AI-enhanced radar applications while reducing development time and increasing scalability.

By leveraging WOLF's rugged, high-efficiency cooling designs and NVIDIA's cutting-edge GPU technology, non-FPGA-centric customers can achieve superior radar performance across defense, aerospace, automotive, and environmental monitoring industries.