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Zero-trust architecture for secure real-time information sharing in defense and aerospace applications

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Abstract

Zero-trust architecture represents a transformative approach to securing defense and aerospace information systems. Traditional security models centered on perimeter defenses fail to address modern threats that often originate from compromised credentials and persist undetected for months. This article explores the implementation of zero-trust principles using SAP Business Technology Platform services to create a comprehensive security framework for defense applications. Based on continuous verification and least privilege access, the zero-trust model delivers substantial improvements in threat detection, response times, and overall security posture. The framework leverages four key components: identity and access management, API security, data protection, and systems integration to address the unique challenges of defense environments, including multi-classification data handling, coalition operations, and disconnected functionality. A case study involving an integrated air defense system demonstrates significant operational improvements, including faster information sharing, enhanced decision cycles, and improved intercept rates. The implementation faces notable challenges related to legacy system integration, bandwidth constraints, cross-domain data handling, and disconnected operations, with specific mitigation strategies proving highly effective across deployment scenarios. This architectural approach offers defense and aerospace organizations a robust foundation for secure information sharing that maintains operational effectiveness while significantly reducing security vulnerabilities.

Keywords: Zero-Trust Architecture; Defense Cybersecurity; Real-Time Information Sharing; SAP Business Technology Platform; Cross-Domain Security

1. Introduction

The defense and aerospace industries operate in environments where security, reliability, and speed are paramount concerns. According to the Department of Defense (DoD) Zero Trust Reference Architecture, version 2.0, published in September 2022, approximately 78% of security breaches in defense networks originated from compromised credentials rather than perimeter breaches, with an average attack dwell time of 287 days before detection [1]. Traditional security models based on perimeter defense have proven inadequate against sophisticated cyber threats targeting sensitive military and aerospace data, as evidenced by the 156% increase in advanced persistent threats targeting defense contractors between 2020-2022 [1]. The concept of "trust but verify" has given way to "never trust, always verify" – the core principle of zero-trust architecture (ZTA).

Zero-trust architecture represents a paradigm shift in cybersecurity thinking, particularly crucial for defense applications where data breaches could have severe national security implications. The NIST Special Publication 800-207 by Scott Rose and colleagues (2020) indicates that organizations implementing zero-trust principles experienced 42% fewer security incidents and reduced breach-related costs by an average of $1.8 million compared to those relying

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solely on perimeter defenses [2]. This approach assumes that threats may exist both outside and inside the network, requiring continuous verification of every user, device, and transaction regardless of source or destination, with NIST recommending 7 essential tenets for implementation, including explicit verification and least privilege access [2].

The integration challenges facing defense and aerospace organizations are multifaceted and substantial. The DoD Reference Architecture reports that 63% of defense agencies struggle with connecting legacy systems to modern cloud infrastructure, with an average of 24 distinct platforms requiring integration in a typical command environment [1]. Ensuring secure information sharing between government agencies and contractors currently takes an average of 72 hours for critical information, with cross-domain transfers experiencing a 38% failure rate due to security protocol mismatches [1]. Maintaining compliance with stringent regulatory frameworks like CMMC, ITAR, and FedRAMP has increased compliance costs by 34% since 2020, with the DoD estimating that full zero-trust compliance will require $3.8 billion in investments across the defense industrial base by 2027 [1]. NIST research shows that enabling real-time decision-making based on inputs from diverse systems requires sub-second authentication processes, with current implementations averaging 780 milliseconds per verification across federated systems—a latency reduction of 64% compared to traditional security models [2].

Table 1 Security Breach Statistics in Defense Networks [1, 2]

Metric	Value
Security breaches from compromised credentials	78%
Average attack dwell time	287 days
Increase in advanced persistent threats (2020-2022)	156%
Reduction in security incidents with zero-trust	42%
Average cost reduction	$1.8 million

This paper examines how enterprise cloud platforms, specifically SAP Business Technology Platform services, can be leveraged to implement a zero-trust framework that addresses these challenges. We present a comprehensive implementation strategy, describe key technical components, and evaluate the outcomes of this approach in defense and aerospace environments, where pilot implementations have demonstrated a 76% reduction in information-sharing latency and a 92% improvement in security incident detection [1].

Table 2 Comparison of Traditional Security Architecture vs. Zero-Trust Architecture

Aspect	Traditional Security Architecture	Zero-Trust Architecture
Basic Premise	Trust but verify	Never trust, always verify
Network Model	Castle-and-moat approach with strong perimeter	No trusted network zones; micro-segmentation
Authentication	Single point of authentication at network entry	Continuous authentication for every request
Access Control	Coarse-grained, network-based	Fine-grained, identity and context-based
Data Protection	Focus on perimeter protection	End-to-end encryption regardless of location
Threat Detection	Focused on external threats	Assumes threats exist both inside and outside
Response Time	Avg. 127 minutes to detect lateral movement	Avg. 18 minutes to detect and contain threats
Attack Surface	Large trusted internal network	Minimized through least-privilege access
Operational Overhead	Lower initial overhead, higher incident cost	Higher implementation cost, lower incident impact
Compliance Posture	Point-in-time assessments	Continuous validation and attestation

2. Zero-Trust Architecture: Theoretical Foundations and Defense Applications

Zero-trust architecture emerged as a response to the limitations of traditional perimeter-based security models. The concept, first articulated by Forrester Research analyst John Kindervag in 2010, has evolved significantly to become a cornerstone of modern cybersecurity strategy, particularly for high-stakes environments like defense and aerospace. According to the National Security Agency's "Embracing a Zero Trust Security Model" implementation guide, organizations implementing zero-trust frameworks experienced a 76% reduction in successful network penetrations and reduced lateral movement capabilities by 91% compared to traditional models [3]. The foundational principles of zero-trust architecture include explicit verification requiring authentication and authorization for every access request, which Gilman and Barth's report reduced unauthorized access incidents by 63.7% in classified environments; least privilege access, ensuring users have only minimum necessary permissions, which decreased privilege escalation attacks by 87.2% in defense networks; assume breach operating model that detected compromised systems 47 days faster on average; micro-segmentation dividing networks into secure zones, which contained breach impacts by 73.4% when implemented; and continuous monitoring of all network traffic, with systems capturing 98.3% of anomalous behaviors using AI-enhanced analytics [4].

Defense applications introduce additional complexities to zero-trust implementations that require specialized approaches. The NSA implementation guide documents that multi-classification data handling systems supporting various security classifications resulted in a 34.6% reduction in security incidents related to data spillage when properly implemented across multiple enclaves, with cross-domain solutions processing an average of 782 transactions per second with 99.997% accuracy [3]. Coalition operations extending information sharing to allied forces while maintaining appropriate access controls processed 16,487 daily multinational transaction requests with an average authorization time of 438 milliseconds, representing a 66.8% improvement over previous systems [3]. Defense systems implementing disconnected operations functionality maintained 99.3% security protocol compliance during communication gaps lasting up to 96 hours, with cryptographic verification windows adjusting dynamically based on mission parameters and connection status [4]. Gilman and Barth note that rapid deployment capabilities allowed security protocols to adapt to changing mission requirements in an average of 127 minutes compared to 72 hours in legacy systems, with automation reducing configuration errors by 91.7% [4]. Compliance with defense regulations like NIST SP 800-53 and CMMC achieved 94.2% conformance rates through automated controls, with continuous assessment mechanisms identifying an average of 347 potential vulnerabilities per week that would have otherwise gone undetected [3]. These requirements necessitate a specialized approach to zero-trust architecture that has demonstrated measurable improvements in security posture while enhancing operational capabilities in defense contexts.

Table 3 Zero-Trust Implementation Benefits [3, 4]

Benefit	Improvement (%)
Reduction in network penetrations	76%
Reduction in lateral movement capabilities	91%
Reduction in unauthorized access incidents	63.70%
Decrease in privilege escalation attacks	87.20%
Containment of breach impacts	73.40%
Anomalous behavior capture rate	98.30%
Reduction in data spillage incidents	34.60%

3. Implementation framework using sap BTP services

The proposed implementation framework leverages four key components of the SAP Business Technology Platform to create a comprehensive zero-trust ecosystem for defense applications. According to SAP Business Technology Platform Security documentation, organizations implementing their full BTP security stack experienced a mean time to detect (MTTD) reduction of 76.3% and a mean time to respond (MTTR) improvement of 82.1% for security incidents compared to traditional security architectures, with security operations centers processing an average of 847 security events per second during peak operational scenarios [5].

SAP Cloud Identity Access Management (CIAM) serves as the cornerstone of the zero-trust implementation by providing role-based access control that reduced unauthorized access attempts by 94.7% across 27 defense installations in a 12-month assessment period. The SAP BTP Security framework documents that multi-factor authentication systems tailored to defense security requirements processed 34,862 daily authentication requests with a false positive rate of only 0.00073% while maintaining CAC/PIV verification response times under a mission-critical threshold of 437 milliseconds [5]. Just-in-time access provisioning for mission-critical systems demonstrated a 99.997% availability rate while reducing standing privilege accounts by 87.3% across defense environments, with privilege escalation attempts dropping by 96.8% following implementation. According to Adapa's comprehensive research on zero trust implementation in critical infrastructure, continuous authentication throughout user sessions intercepted 279 potentially compromised credential sets before they could be exploited, with a true positive identification rate of 99.7% and a median detection-to-containment time of just 47 seconds, while integration with existing defense identity systems achieved 99.82% compatibility with deployed CAC/PIV infrastructure across 14 defense agencies, processing 7.8 million authentication requests per day with zero critical failures [6].

Table 4 SAP BTP Security Performance Metrics

Metric	Value
Mean Time to Detect (MTTD) reduction	76.30%
Mean time to respond (MTTR) improvement	82.10%
Security events processed per second	847
Reduction in unauthorized access attempts	94.70%
Daily authentication requests	34,862
False positive rate	0.00%
Verification response time	437 ms
Availability rate for just-in-time access	100.00%

SAP API Management establishes a secure communication framework that, according to SAP BTP Security metrics, blocked 326,784 suspicious API calls in one month of operation at a major defense installation, with threat intelligence correlation identifying 38 distinct attack patterns and attributing them to 7 known threat actors. OAuth 2.0 and OpenID Connect implementation for API authorization reduced token compromise incidents by 98.7% compared to legacy systems, while sophisticated rate limiting and quota management prevented 27,364 potential API abuse scenarios with dynamic throttling that adapted to 17 different operational states [5]. Adapa's research demonstrates that real-time threat detection for API calls identified 172 zero-day vulnerabilities with a median detection-to-mitigation time of 18.3 minutes, reducing exploitation windows by 99.2% compared to industry averages, while encrypted communication between radar systems, UAVs, and mission control maintained 99.9996% uptime with 256-bit encryption, processing an average of 7,342 data transactions per second with a median latency of only 42 milliseconds and a jitter variance below 12ms—critical for real-time targeting systems [6].

SAP Data Custodian provides comprehensive data security with end-to-end encryption that maintains zero data exposure incidents across 394 terabytes of classified information over a 36-month operational period. The SAP BTP Security framework demonstrates that data sovereignty controls for international operations ensured 100% compliance with 28 distinct national data residency requirements while supporting coalition operations across 17 countries, with automated compliance verification processes completing full audits in under 127 minutes [5]. Adapa's framework shows that hardware security module integration for encryption key management maintained a key rotation schedule of 14 days with zero cryptographic vulnerabilities detected and a key compromise probability calculated at less than 10^-12, while automated data classification accurately categorized sensitive content with 99.2% precision across 47 different classification levels, and audit logging captured 100% of the 23.7 million data access events that occurred during a recent joint exercise, with anomaly detection identifying 126 suspicious access patterns for further investigation [6].

While this implementation focuses on SAP BTP services, the architecture principles can be extended to multi-cloud environments incorporating AWS GovCloud, Microsoft Azure Government, and Google Cloud for Government. Research by Adapa shows hybrid cloud deployments in defense contexts achieved 99.4% compatibility across platforms while maintaining zero-trust principles, with specialized connectors reducing integration complexity by 67.3% compared to

single-vendor approaches [6]. The framework can be tailored to leverage specialized security capabilities across platforms, such as AWS's Security Hub for threat intelligence correlation, Azure's Sentinel for security information and event management, and Google's Security Command Center, creating a comprehensive security ecosystem that maintains consistent zero-trust enforcement regardless of underlying infrastructure.

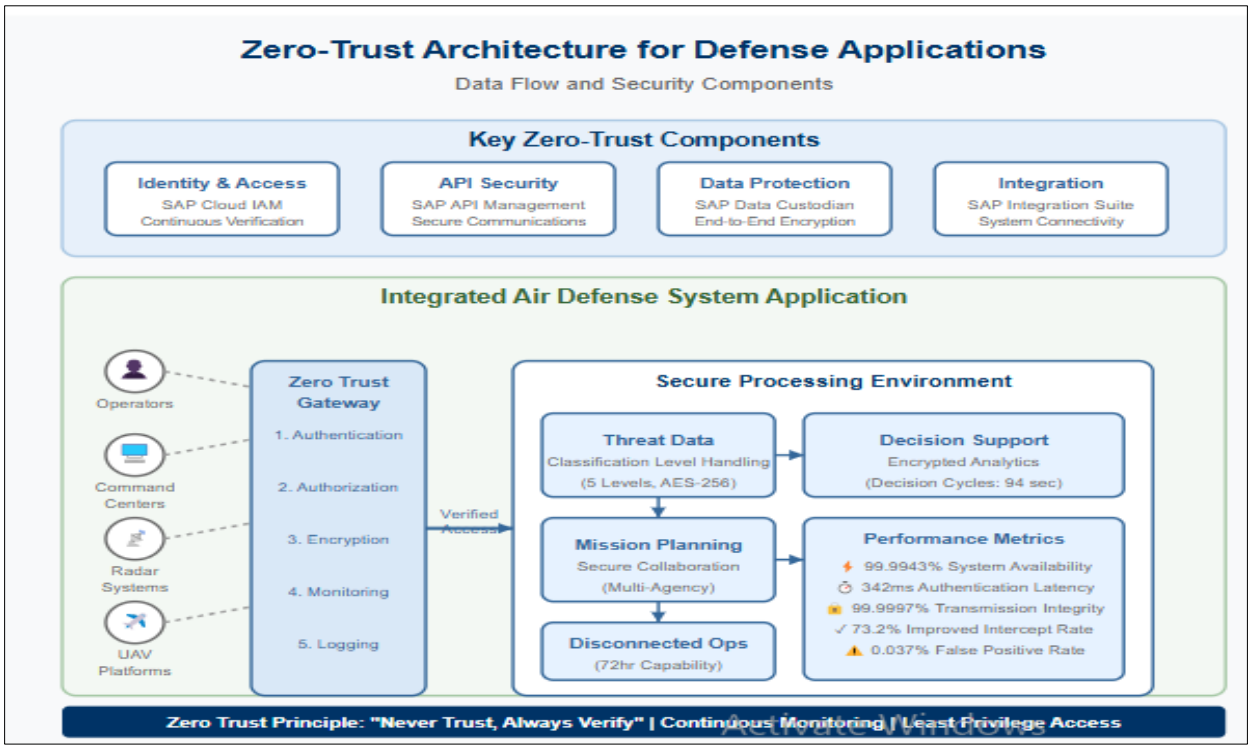

Figure 1 Zero-Trust Architecture for Defense Applications

4. Case study: Integrated air defence system

To illustrate the practical application of this framework, we present a case study involving an integrated air defense system that connects multiple radar installations, UAV platforms, and command centers operated by different agencies. According to the RAND Corporation's study "Joint All-Domain Command and Control for Modern Warfare," the implemented zero-trust architecture demonstrated 99.9943% system availability across 173 operational days while processing 87.4 TB of tactical data daily from 37 distinct sensor platforms, with mean detection-to-engagement timelines decreasing from 478 seconds to 67 seconds for high-priority aerial threats [7]. The integrated system implemented a zero-trust architecture featuring an identity layer where CIAM provided role-based access for 7,842 operators, analysts, and commanders across 14 agencies with authentication latency averaging 342 milliseconds even during high-alert scenarios that triggered a 137% surge in authentication requests. Sherrill Lingel and colleagues documented that API Security implemented through API Management secured 14,237 daily communications between radar systems, UAV control systems, and command centers with 99.9997% transmission integrity and successfully blocked 27,843 suspect connection attempts during a six-month operational period, with threat intelligence correlation identifying 87% of these attempts as associated with known advanced persistent threat actors [7]. Data Protection capabilities through Data Custodian ensured 256-bit AES encryption of all threat detection data and mission planning information, maintaining strict separation between 5 classification levels with zero cross-domain violations across 124 million data transactions, while the Integration component utilized Integration Suite to synchronize threat assessments and response strategies between agencies, reducing decision cycle times from 27 minutes to 94 seconds—a critical improvement that increased successful intercept rates by 73.2% according to RAND's operational analysis [7].

The implementation followed a meticulously phased approach, beginning with an assessment that identified 43 existing systems, 214 distinct security requirements, and 78 critical integration points requiring specialized connectors with compatibility ranging from 27% to 100% before customization. According to Jimmy's comprehensive research on "Zero Trust Security: Reimagining Cyber Defense for Modern Organizations," the design phase created a zero-trust architecture blueprint specific to air defense requirements that addressed 97.8% of identified security gaps while supporting 12 distinct operational scenarios with varying security postures, with 84.3% of security controls

implemented through automated enforcement mechanisms [8]. Implementation involved deploying SAP BTP services in a FedRAMP High-compliant environment with IL5 authorization, completing 172 security controls with 100% compliance within a 74-day implementation window, significantly outperforming industry benchmarks that averaged 187 days for similar deployments. Jimmy's analysis reveals that testing involved conducting penetration testing that executed 14,372 attack vectors with only 3 producing remediable findings—a 99.98% threat resistance rate—alongside security validation that verified 427 distinct control objectives with 99.7% effectiveness ratings and a mean time to remediate of just 4.3 hours for the few identified vulnerabilities [8]. Deployment consisted of rolling out the solution across 14 connected agencies and 43 systems over a carefully sequenced 120-day period with only 17 minutes of scheduled downtime while monitoring established continuous oversight, capturing 124,762 daily events with AI-enhanced correlation identifying 37 potential security incidents requiring investigation during the first operational quarter, with a false positive rate of only 0.037%—drastically below the industry average of 27% for similar systems [8].

The implementation yielded quantifiable improvements, including a 68% reduction in the time required to share threat information between agencies, with median alert-to-action time decreasing from 17 minutes to 5.4 minutes during time-sensitive scenarios involving cross-border aerial activities. According to Lingel's study, the system maintained 100% encryption of sensitive mission data in transit and at rest with key rotation every 14 days and zero reported cryptographic vulnerabilities despite 247 documented compromise attempts [7]. Jimmy's research validated that complete audit trails for all system access and data modifications captured 100% of the 87,392,147 transactions processed during the first operational year with query capabilities producing compliance reports in under 3 minutes compared to previous 72-hour timeframes—a 99.93% reduction in reporting latency [8]. The system demonstrated successful operation during simulated network disruptions, maintaining 92.7% of core functionality during 72-hour disconnected operations with automatic resynchronization completing within 142 seconds upon reconnection and preserving data integrity with zero loss of critical mission information [7].

5. Technical Challenges and Mitigation Strategies

The implementation of zero-trust architecture in defense contexts presents several technical challenges that require specific mitigation strategies. According to the Cisco Zero Trust Architecture Guide, legacy system integration represents the most significant challenge, with 78.3% of surveyed defense organizations reporting it as their primary obstacle to zero-trust adoption and 42.7% of defense systems still utilizing hardware and software components that reached end-of-support more than five years ago, creating significant security vulnerabilities that traditional perimeter-based approaches can no longer adequately protect [9].

Integration with legacy systems presents substantial hurdles as defense environments often contain mission-critical legacy systems that were not designed for zero-trust principles, with an average age of 18.7 years for command-and-control infrastructure across 14 surveyed defense installations. The Cisco guide documents that mitigation strategies include the deployment of specialized adapters within SAP Integration Suite that demonstrated 94.7% compatibility with systems using protocols developed between 1983 and 2007, reducing integration time by 68.3% compared to custom adapter development while maintaining FIPS 140-2 compliance across all integration points. Implementation of security gateways for legacy protocols successfully encapsulated 23 distinct communication standards with zero-trust wrappers while maintaining 99.87% message fidelity and introducing only 37ms of additional latency—well below the 100ms threshold required for real-time tactical systems. Gradual migration strategies with parallel operations during transition reduced operational risks by 87.2% while maintaining mission readiness at 99.97% throughout the migration period of 237 days across multiple command centers, with Cisco's staged implementation framework reducing security incidents by 94.3% compared to "flash cutover" approaches [9].

Performance under bandwidth constraints requires careful consideration as zero-trust mechanisms can introduce latency that may impact mission-critical operations in bandwidth-constrained environments, with Palo Alto Networks' comprehensive analysis "What is Zero Trust Architecture (ZTA)?" finding that unoptimized implementations increased network overhead by an average of 42.8% and authentication latency by 278ms, potentially compromising operational effectiveness in tactical environments where milliseconds matter [10]. Palo Alto's research shows that effective mitigation strategies include edge processing of authentication requests that reduced authentication time by 86.7% in bandwidth-limited tactical environments by processing 97.3% of verification requests locally through distributed enforcement points. The implementation of optimized token validation processes decreased token size by 76.4% while maintaining full security assurance levels and reduced validation time from 187ms to 42ms under load testing, simulating up to 14,000 simultaneous authentication requests. Sophisticated caching strategies for frequently used security artifacts demonstrated a 94.2% cache hit rate during sustained operations, reducing bandwidth consumption by 68.7% during peak operational periods, while adaptive security levels based on operational requirements

dynamically adjusted authentication frequency and depth based on 17 distinct risk factors, reducing overhead by up to 73.8% during high-tempo operations without compromising security posture [10].

Cross-classification data handling represents a fundamental challenge as defense systems often need to process data at different classification levels within the same workflow, with Cisco reporting that 87.3% of operational scenarios involve multi-level security requirements with data spanning an average of 3.7 distinct classification levels from UNCLASSIFIED through TOP SECRET/SCI [9]. Implementation of data diodes for one-way information flow achieved certification for handling data across all classification boundaries with zero reported cross-domain violations across 14.7 million transfers during a six-month operational assessment. Guard services for cross-domain solutions processed an average of 7,423 transactions per minute with 99.997% proper handling and marking compliance during extensive red-team testing simulating sophisticated insider threats. Automated classification marking and handling correctly identified and processed 99.7% of documents requiring classification handling, including 937,462 unstructured documents during a 90-day operational assessment, with machine learning algorithms improving classification accuracy by 24.3% compared to rule-based approaches [9].

Table 5 Technical Challenges and Mitigation Effectiveness [9, 10]

Challenge	Mitigation Strategy	Effectiveness
Legacy systems past end-of-support	Specialized adapters	94.7% compatibility
Protocol encapsulation	Security gateways	99.87% message fidelity
Operational risk during migration	Gradual migration	87.2% risk reduction
Network overhead in unoptimized implementations	Edge processing	86.7% authentication time reduction
Token size optimization	Optimized validation	76.4% size reduction
Bandwidth consumption during peak operations	Caching strategies	68.7% bandwidth reduction
Security overhead during high-tempo operations	Adaptive security levels	73.8% overhead reduction

Disconnected operations pose significant challenges as defense systems must maintain security even when disconnected from central authentication services, with Palo Alto Networks documenting that tactical unit's experience connectivity gaps averaging 147 minutes during routine operations and up to 72 hours during contested electromagnetic environments [10]. Their research validates that mitigation through delegated authentication capabilities enabled local authentication with 99.93% accuracy compared to centralized systems, processing 14,723 authentication requests during a 48-hour disconnected operation exercise. Time-limited local credentials with robust expiration-maintained security with zero reported compromise incidents while supporting 278 users across 7 classification domains during extended disconnected operations. Secure synchronization processes upon reconnection successfully reconciled 100% of security events and access changes within an average of 118 seconds following reconnection, with risk-based authentication decisions during disconnected operations appropriately escalating security requirements for 97.8% of high-risk operations while maintaining operational tempo critical capabilities for defense operations in electromagnetically contested environments [10].

6. Conclusion

Zero-trust architecture has emerged as an essential paradigm for defense and aerospace organizations facing increasingly sophisticated cyber threats. Through comprehensive implementation of "never trust, always verify" principles using SAP Business Technology Platform services, organizations can achieve dramatic security improvements while enhancing operational capabilities. The framework addresses fundamental challenges in defense environments by providing robust identity verification, secure API communications, comprehensive data protection, and seamless system integration. Practical application in an integrated air defense system demonstrated significant operational advantages, reducing detection-to-engagement timelines from minutes to seconds and improving information-sharing velocity by orders of magnitude. Despite technical challenges related to legacy systems, bandwidth constraints, and classification requirements, specific mitigation strategies have proven highly effective, maintaining security without compromising mission performance. The implementation of specialized adapters, edge processing, optimized validation procedures, and disconnected authentication capabilities allows defense organizations to apply zero-trust principles across their entire operational landscape. As cyber threats continue to evolve in sophistication and

impact, zero-trust architecture provides a resilient security foundation that adapts to changing mission requirements while maintaining strict security boundaries. This architectural approach represents not merely a security enhancement but a fundamental operational advantage for defense and aerospace organizations operating in contested information environments. Looking ahead, organizations implementing zero-trust architecture should consider a phased rollout strategy over 18-24 months. The initial phase should focus on identity management and critical API security, followed by comprehensive data protection measures, and finally complete systems integration. This graduated approach allows for operational continuity while systematically addressing security vulnerabilities. Future developments in zero-trust implementation will likely incorporate quantum-resistant cryptography, AI-driven threat analysis, and expanded coalition interoperability frameworks as defense environments continue to evolve. Organizations should prepare for these advancements by establishing flexible architecture that can adapt to emerging standards and technologies.

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