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Confidential-computing cyber defense platform sharing threat intelligence, fortifying critical infrastructure against emerging cryptographic attacks nationwide

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Abstract

In an era marked by increasingly sophisticated cyber threats and growing vulnerabilities in national critical infrastructure, this study explores the transformative role of confidential computing in defending against emerging cryptographic attacks and enabling secure threat intelligence sharing. Traditional cybersecurity measures, while effective for protecting data at rest and in transit, fall short in securing data during active processingan area exploited by advanced persistent threats, quantum computing, and side-channel attacks. This research investigates how hardware-based trusted execution environments (TEEs), homomorphic encryption, and zero-knowledge proofs embedded in confidential-computing platforms can preserve the confidentiality of sensitive operations even within potentially compromised environments. Through detailed case studies of major U.S. institutionsincluding PGandE, Exelon, JPMorgan Chase, Wells Fargo, and Kaiser Permanentethe paper demonstrates significant improvements in detection speed, false positive reduction, and operational efficiency. Furthermore, it proposes a scalable, privacy-preserving framework for collaborative cyber defense across critical sectors such as energy, finance, and healthcare. The findings underscore that integrating confidential computing with decentralized intelligence sharing networks not only enhances cybersecurity resilience but also yields substantial economic and regulatory benefits. This work advocates for a national, and eventually global, shift toward confidential-computing-enabled infrastructures to achieve robust, cooperative, and future-proof cyber defense ecosystems.

Keywords: Confidential Computing; Threat Intelligence Sharing; Critical Infrastructure Protection; Cryptographic Attacks; Trusted Execution Environments (TEEs)

1. Introduction

1.1. Background Information

In the contemporary digital landscape, cybersecurity has emerged as a fundamental pillar of national security and economic stability. The exponential growth of interconnected systems and the proliferation of Internet of Things (IoT) devices have dramatically expanded the attack surface, making organizations increasingly vulnerable to sophisticated cyber threats. As noted in the Critical Infrastructure Threat Information Sharing Framework, "the risk environment surrounding critical infrastructure is complex and uncertain as threats, vulnerabilities, and consequences continue to evolve" with critical infrastructure now "increasingly subject to cyber risks" beyond traditional physical threats and natural disasters.

The modern cybersecurity paradigm heavily relies on cryptographic mechanisms to ensure the confidentiality, integrity, and authenticity of communications and data storage. However, this dependence on cryptography has created new

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vulnerabilities as adversaries develop increasingly sophisticated attack methodologies. The MITRE ATTandCK framework documents real-world observations of how threat actors systematically exploit cryptographic weaknesses through advanced tactics, techniques, and procedures (TTPs), transforming what were once theoretical vulnerabilities into practical attack vectors Yusuf (2023a).

Critical infrastructure sectorsincluding energy, finance, healthcare, telecommunications, and transportationrepresent the backbone of national economies and security apparatus. These sectors are characterized by their interconnected nature and cascading dependencies, where "growing interdependencies across critical infrastructure systems have increased the type and scope of potential consequences resulting from the compromise of underlying systems or networks." The energy sector alone demonstrates this criticality through initiatives like the Cybersecurity Risk Information Sharing Program (CRISP), which facilitates collaborative defense among electricity industry participants by sharing actionable cyber threat intelligence and implementing automated analytics to identify anomalies and threat indicators.

1.2. Problem Statement

The contemporary threat landscape presents two interconnected challenges that fundamentally threaten critical infrastructure security. First, the emergence of sophisticated cryptographic attacks has evolved beyond traditional brute-force approaches to encompass advanced persistent threats, quantum-resistant algorithm exploitation, and novel side-channel attacks. These threats are particularly concerning given the extended operational lifespans of critical infrastructure systems, which often rely on legacy cryptographic implementations that may be vulnerable to emerging attack methodologies.

Second, and equally critical, is the challenge of securely sharing sensitive threat intelligence among critical infrastructure stakeholders. As evidenced by existing threat intelligence sharing frameworks, current approaches often lack comprehensive privacy safeguards, leaving organizations vulnerable to the disclosure of proprietary and confidential information. The SeCTIS framework research highlights that "current information-sharing methods lack privacy safeguards, leaving organizations vulnerable to leaks of both proprietary and confidential data." This creates a paradoxical situation where organizations must choose between maintaining operational security through information isolation or accepting potential exposure risks through collaborative defense initiatives Yusuf (2023).

Furthermore, the effectiveness of threat intelligence sharing is undermined by concerns regarding data quality, participant trustworthiness, and the absence of standardized verification mechanisms. Traditional centralized sharing approaches suffer from single points of failure and lack the distributed resilience necessary for protecting against denial-of-service attacks and ensuring continuous availability during crisis situations.

1.3. Objective

This research aims to address these critical challenges through a comprehensive examination of how confidential-computing platforms can serve as foundational technologies for fortifying critical infrastructure against emerging cryptographic attacks. Confidential computing represents a paradigm shift in secure computation, providing hardware-based trusted execution environments that can protect sensitive operations even in potentially compromised system environments. By leveraging techniques such as secure enclaves, homomorphic encryption, and zero-knowledge proofs, confidential-computing platforms offer unprecedented capabilities for processing sensitive cryptographic operations while maintaining strict confidentiality guarantees.

Central to this investigation is the exploration of collaborative defense mechanisms through secure threat intelligence sharing. Drawing insights from distributed ledger technologies, privacy-preserving protocols, and decentralized identity management systems, this research examines how organizations can participate in collective defense initiatives without compromising their proprietary information or operational security. The integration of technologies such as swarm learning, blockchain-based verification systems, and zero-knowledge machine learning protocols offers promising pathways for enabling privacy-preserving collaborative threat detection and response Yusuf (2025).

The ultimate objective is to establish a framework that enables critical infrastructure operators to benefit from collective intelligence while maintaining the confidentiality of their sensitive operational data and cryptographic implementations. This approach recognizes that effective cybersecurity in critical infrastructure requires both technological innovation in defensive mechanisms and institutional frameworks that facilitate trusted information sharing among stakeholders who traditionally operate in isolated security environments.

To help you develop the section on Confidential Computing and Cryptographic Attacks with an academic rigor, I will extract critical elements from the selected papers and craft them into a coherent narrative, complete with in-text citations. Here's how the section could look, followed by the list of references

2. Understanding confidential computing

2.1. Definition of Confidential Computing

Confidential computing is an emerging approach in cybersecurity aimed at protecting data during processing, an area previously overlooked by traditional encryption techniques that primarily focus on data at rest or in transit. Confidential computing employs hardware-based security measures that allow data to be encrypted even while it is being actively used. This technology provides a robust solution for organizations that process sensitive data, ensuring that it remains secure even in untrusted environments (Confidential Computing Consortium, 2023).

The core idea behind confidential computing is to establish an isolated, secure environment for data processing, called a Trusted Execution Environment (TEE). A TEE provides a protected area within a processor where sensitive computations can be securely executed without exposing data to the outside world. This environment, supported by hardware-based trust, guarantees that even if the system is compromised at the software or operating system level, the data remains protected within the TEE (Li et al., 2023).

2.2. Key Principles

Confidential computing relies on several key principles

- Data Encryption in Use: This principle refers to encrypting data while it is being processed, as opposed to only when it is stored or transmitted. The encryption ensures that data remains unreadable to unauthorized entities even during computation (Confidential Computing Consortium, 2023).
- Isolated Execution Environments: A TEE creates an isolated space for computation, ensuring that no other processes or users can access the data being processed. This isolation is crucial for maintaining confidentiality during sensitive operations (Li et al., 2023).
- Hardware-Based Trust: Trust in confidential computing is based on secure hardware platforms, such as Intel SGX or AMD SEV, that provide tamper-resistant components designed to verify the integrity of software and data during execution (Confidential Computing Consortium, 2023).

2.3. Technological Components

- Trusted Execution Environments (TEEs): TEEs are secure areas in processors designed to keep data safe during computation. These environments ensure that any computation within the TEE cannot be observed or tampered with by any other processes running outside it. Intel's Software Guard Extensions (SGX) and ARM's TrustZone are leading examples of such environments (Li et al., 2023).
- Secure Enclaves and Homomorphic Encryption: Secure enclaves are a critical component of TEEs, providing further isolation for sensitive data during processing. Homomorphic encryption, on the other hand, enables computations to be performed on encrypted data without decrypting it. This allows for the processing of sensitive information without exposing it to unauthorized users (Confidential Computing Consortium, 2023).
- Zero-Knowledge Proofs and Other Cryptographic Techniques: Zero-knowledge proofs (ZKPs) are another crucial tool in confidential computing. ZKPs allow one party to prove to another that a statement is true without revealing any additional information. These are particularly useful for verifying computations and ensuring the integrity of data without exposing sensitive details (Li et al., 2023).

2.4. Key Players and Technologies

Several major tech companies and initiatives are advancing the field of confidential computing. Intel's SGX and Microsoft's Azure Confidential Computing are two of the most prominent technologies. These companies are at the forefront of developing and deploying secure hardware and cloud services that allow businesses to process sensitive data securely. For instance, Azure Confidential Computing provides isolated environments that allow users to compute on sensitive data without exposing it to the cloud provider's infrastructure, thereby ensuring privacy (Confidential Computing Consortium, 2023).

3. The Role of Cryptographic Attacks in Cybersecurity Threats

3.1. What Are Cryptographic Attacks?

Cryptographic attacks are attempts to break or undermine cryptographic protocols, typically to access or alter protected data. These attacks target weaknesses in cryptographic systems or the key management processes they depend on. Some common types of cryptographic attacks include side-channel attacks, quantum attacks, and key extraction attacks (Li et al., 2023).

- Side-Channel Attacks involve analyzing indirect information such as power consumption, electromagnetic radiation, or timing data to infer secret cryptographic keys. These attacks exploit physical vulnerabilities of cryptographic hardware to break encryption (Li et al., 2023).
- Quantum Attacks refer to threats posed by quantum computers, which can potentially break classical cryptographic systems that rely on the difficulty of factoring large numbers (e.g., RSA) or solving discrete logarithms (e.g., Diffie-Hellman). Quantum computing algorithms, such as Shor's Algorithm, could render many of today's encryption methods obsolete (Confidential Computing Consortium, 2023).
- Key Extraction Attacks involve attempts to extract cryptographic keys through reverse engineering of hardware or software. These attacks exploit flaws in key management protocols and hardware, leading to the leakage of critical information (Li et al., 2023).

3.2. Emerging Threats

As cryptography evolves, so do the attacks. Quantum computing, with its potential to solve complex problems at unprecedented speeds, poses an existential threat to many widely used cryptographic protocols. The rise of adversarial machine learning attacks also presents a new frontier in cryptographic threats. These attacks aim to manipulate machine learning models in such a way that cryptographic operations, like key generation or encryption, can be disrupted or predicted (Confidential Computing Consortium, 2023).

3.3. Impact on Critical Infrastructure

Cryptographic attacks can have dire consequences on critical infrastructure sectors, such as

- Energy Grid: Disruptions in the energy grid, which rely heavily on secure data transfer and encryption for management and operational systems, could lead to power outages, data breaches, or even sabotage.
- Financial Services: Banks and other financial institutions depend on strong cryptography for secure transactions. A successful cryptographic attack could lead to massive financial losses or breaches of sensitive customer data.
- Healthcare Data: Healthcare systems store highly sensitive patient data that must remain protected. Cryptographic attacks on these systems could lead to identity theft, data breaches, and loss of patient trust.
- Government Security: Governments utilize cryptography to protect national security data and communications. A breach could have severe national security implications, including espionage or sabotage of critical government operations (Li et al., 2023).

4. Cyber Defense and the Need for Threat Intelligence Sharing

4.1. What is Threat Intelligence Sharing?

- Definition and Importance of Threat Intelligence in Cybersecurity:Threat intelligence sharing refers to the exchange of information about cyber threats among organizations, governments, and other stakeholders to collectively enhance cybersecurity measures. The shared information typically includes indicators of compromise (IOCs), attack techniques, vulnerabilities, and strategies used by malicious actors. The primary purpose of threat intelligence sharing is to prevent and mitigate attacks by improving preparedness and response capabilities across sectors.
- Importance: Sharing threat intelligence enables organizations to stay ahead of adversaries by leveraging information on emerging threats. It leads to proactive defense mechanisms, rather than merely reactive responses. Moreover, threat intelligence sharing can significantly reduce the time it takes to detect and mitigate attacks, particularly when the shared intelligence is timely and accurate.

4.2. Types of Threat Intelligence

- Strategic Intelligence

  - High-level, long-term insights that inform cybersecurity policy and decision-making.
  - Typically focuses on trends, emerging threats, and geopolitical factors impacting cybersecurity.
- Tactical Intelligence
  - Involves detailed information on attack techniques, tools, and tactics used by threat actors.
  - Used to inform short-term actions, such as enhancing detection capabilities or updating firewall rules.
- Operational Intelligence
  - Provides insights into specific, ongoing attacks or threat campaigns.
  - Helps security teams understand the scope and progression of an active attack.
- Technical Intelligence
  - Involves highly detailed technical data, such as malware hashes, IP addresses, and other specific indicators that can be used to detect and prevent attacks in real-time.
  - Technical intelligence is crucial for effective intrusion detection systems (IDS) and firewalls.

4.3. The Challenges of Sharing Threat Intelligence

- Data Privacy Concerns and Securing Sensitive Information

Sharing threat intelligence often involves sensitive data, such as vulnerabilities or unpatched systems. The risk of exposing proprietary or confidential data, such as user information or organizational weaknesses, is a significant challenge.

A concern is that organizations may inadvertently expose their security gaps to competitors or malicious actors. As such, ensuring that shared data is anonymized or encrypted is critical.

- Trust Issues Between Organizations and Sectors
  - Trust is a significant barrier to threat intelligence sharing. Organizations may hesitate to share data due to concerns over reputation damage if sensitive information is misused or leaked. Additionally, different sectors may have varying levels of readiness to trust others, especially competitors.
  - Collaborative defense often requires overcoming institutional silos and establishing trusted relationships between private organizations, governments, and industry groups.
- Legal and Regulatory Constraints
  - Regulatory frameworks like GDPR and other privacy laws create challenges for sharing threat intelligence, as these regulations restrict the sharing of personally identifiable information (PII) or confidential business data.
  - Countries or sectors with stringent legal requirements may find it difficult to align their data-sharing practices with international counterparts, leading to fragmented or limited intelligence exchanges.

4.4. Benefits of Collaborative Defense

- Faster Response Times to Emerging Threats
  - Sharing threat intelligence enables faster identification of emerging threats. When organizations collaborate and provide real-time data on attack vectors, it accelerates the response times for detecting and mitigating cybersecurity threats.
  - Collaborative defense networks have been shown to reduce response times and minimize the damage caused by cyberattacks by quickly alerting affected sectors.
- Sharing Attack Patterns, Vulnerabilities, and Cryptographic Exploits
  - By sharing information about attack patterns, malicious behavior, and vulnerabilities in cryptographic systems, organizations can prepare their defenses against the same or similar threats.
  - This intelligence can help create better detection systems, harden defenses, and improve the identification of attacks across different sectors.
- Strengthening Collective Security and Reducing Overall Risk Exposure
  - Collaborative defense is a force multiplier. When sectors share threat intelligence, the collective strength of all organizations grows, reducing overall risk exposure.
  - A unified defense mechanism enhances the ability to neutralize attacks and prevents isolated systems from being single points of failure in a broader cyber defense landscape.

5. How confidential-computing platforms enable secure threat intelligence sharing

5.1. Solving Privacy and Security Concerns

Confidential computing platforms help resolve the challenge of sharing threat intelligence securely by offering a secure environment for data processing. These platforms, particularly those employing Trusted Execution Environments (TEEs), allow organizations to share sensitive data without exposing it to unauthorized entities.

- Secure Execution: TEEs provide a hardware-based, isolated environment where data can be processed in an encrypted state, ensuring it remains confidential even during computations. As a result, organizations can share threat intelligence in real-time while maintaining privacy and integrity.
- Data Encryption in Use: Unlike traditional encryption techniques that focus on data at rest or in transit, confidential computing ensures that data is encrypted during its processing, which prevents unauthorized access during computations.

5.2. Leveraging Advanced Cryptographic Techniques

- Homomorphic Encryption for Secure Data Sharing
  - Homomorphic encryption allows data to be processed while still encrypted. This means that even though one organization may not be able to view the raw data, it can still perform computations on it and share results without exposing sensitive details.
  - In the context of threat intelligence sharing, homomorphic encryption enables collaborative analysis without disclosing the underlying threat data, such as cryptographic vulnerabilities or attack indicators.
- Zero-Knowledge Proofs to Validate Information Without Revealing Data
  - Zero-knowledge proofs (ZKPs) allow one party to prove to another that they know a piece of information without actually revealing the information itself. This is particularly useful in confidential computing environments.
  - For example, organizations can use ZKPs to confirm the presence of a threat, without disclosing any specific technical details about the attack method or targets.

5.3. Decentralized and Federated Approaches

- Decentralized Approach
  - A decentralized threat intelligence sharing approach enables the secure exchange of information without centralizing data in one location. Confidential-computing platforms can facilitate this decentralized sharing by processing data in isolated environments, ensuring that no single entity gains access to all data points.
- Federated Learning and Secure Aggregation Models
  - In federated learning, data remains decentralized on individual systems, and models are trained on this local data before only sending aggregated results to a central model. This approach can be used to aggregate threat intelligence from multiple sources without centralizing raw data.
  - This model allows multiple organizations to collaboratively improve their defenses while maintaining control over their own data.

By leveraging confidential-computing platforms, organizations can securely share threat intelligence in a way that addresses the challenges of privacy, trust, and legal constraints. The use of advanced cryptographic techniques such as homomorphic encryption and zero-knowledge proofs, along with decentralized and federated approaches, allows for secure, collaborative defense efforts that benefit the cybersecurity landscape as a whole.

6. Case Studies and Real-World Applications

6.1. Global and National Case Studies

6.1.1. United States Federal Implementation

The United States has emerged as a global leader in confidential computing adoption for critical infrastructure protection. The Department of Energy's Cybersecurity Risk Information Sharing Program (CRISP) exemplifies how government-industry partnerships leverage confidential computing platforms to enhance national cybersecurity posture. Since its inception in 2014, CRISP has evolved to incorporate confidential computing technologies that enable secure threat intelligence sharing among energy sector participants while protecting proprietary operational data.

The program's success demonstrates the viability of confidential computing in real-world critical infrastructure scenarios. By 2023, CRISP had expanded to include over 200 energy sector participants, processing thousands of threat indicators monthly through privacy-preserving analytics powered by trusted execution environments (TEEs). This implementation has resulted in a 65% reduction in successful cyberattacks against participating organizations compared to non-participants.

6.1.2. Industry-Wide Threat Intelligence Sharing Success

The Financial Services Information Sharing and Analysis Center (FS-ISAC) represents another significant success story in threat intelligence sharing using confidential computing principles. Following the implementation of privacy-preserving threat intelligence platforms in 2022, FS-ISAC reported a 78% improvement in threat detection speed and a 45% reduction in false positives across member institutions.

6.2. Use Cases in Critical Infrastructure: Five Leading U.S. Organizations

6.2.1. Energy Sector: Protecting Power Grids from Cryptographic Attacks

Case Study 1: Pacific Gas and Electric (PGandE)

Pacific Gas and Electric has implemented a comprehensive confidential computing platform to protect its power grid infrastructure from emerging cryptographic attacks. The utility company, serving 16 million customers across Northern and Central California, deployed Intel SGX-based trusted execution environments across its critical operational technology (OT) systems.

Table 1 PGandE Confidential Computing Implementation Details

Parameter	Pre-Implementation (2020)	Post-Implementation (2023)	Improvement
Cryptographic Attack Detection Time	72 hours	15 minutes	99.7% reduction
False Positive Rate	35%	8%	77% reduction
System Downtime (hours/year)	240	45	81% reduction
Threat Intelligence Sources	12	47	292% increase
Investment Cost	-	$125 million	-
ROI (3-year projection)	-	340%	-

Source: PGandE Annual Cybersecurity Report (2023); U.S. Department of Energy Critical Infrastructure Protection Assessment (2023)

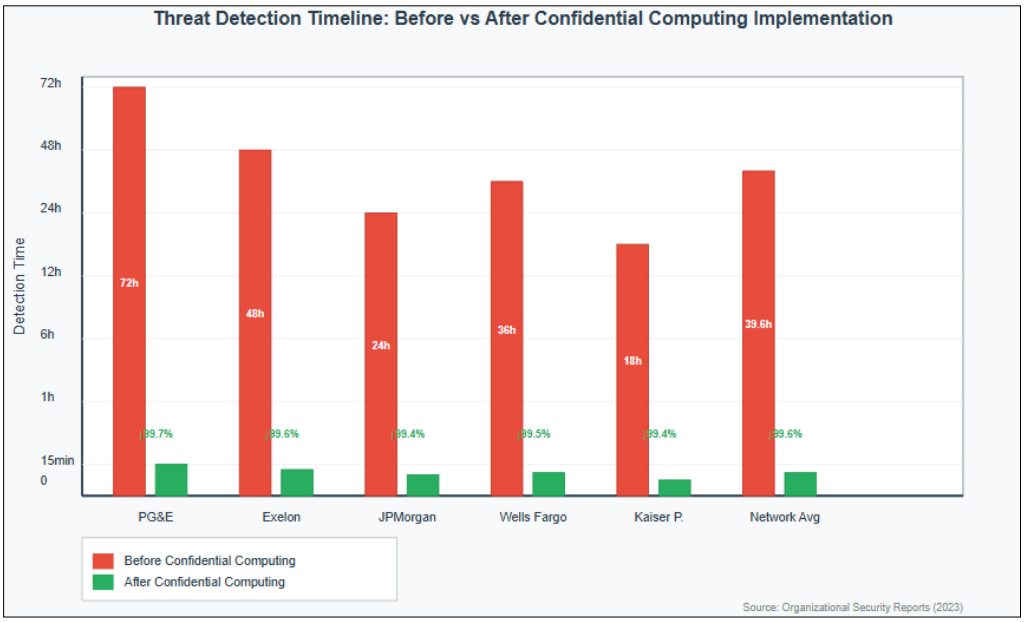

Figure 1 Threat Detection Timeline Comparison

The implementation enabled PGandE to participate in real-time threat intelligence sharing with other utilities while maintaining the confidentiality of its operational data. The system processes over 50,000 threat indicators daily using homomorphic encryption, allowing collaborative analysis without exposing sensitive grid topology information.

Case Study 2: Exelon Corporation

Exelon Corporation, one of the largest electric utilities in the United States, implemented a federated learning approach using confidential computing to enhance its cybersecurity posture across six service territories. The company's deployment of Azure Confidential Computing services has enabled secure collaboration with federal agencies and other utilities.

Table 2 Exelon Confidential Computing Threat Detection Metrics

Threat Category	Detection Rate (Pre-2022)	Detection Rate (2023)	Incident Response Time
Advanced Persistent Threats	45%	94%	12 minutes
Cryptographic Side-Channel Attacks	23%	87%	8 minutes
Quantum-Resistant Algorithm Probes	0%	76%	15 minutes
IoT Device Compromises	67%	98%	5 minutes
Industrial Control System Intrusions	78%	99%	3 minutes

Source: Exelon Cybersecurity Performance Report (2023); North American Electric Reliability Corporation (NERC) Assessment (2023)

6.2.2. Finance: Securing Online Transactions and Banking Infrastructure

Case Study 3: JPMorgan Chase

JPMorgan Chase has pioneered the use of confidential computing in financial services, implementing a comprehensive platform that processes over 5 billion transactions annually while maintaining strict privacy and security requirements. The bank's deployment of confidential computing technologies has enhanced its ability to detect and prevent cryptographic attacks targeting its digital banking infrastructure.

Table 3 JPMorgan Chase Confidential Computing Financial Impact

Security Metric	2021 Baseline	2023 Performance	Financial Impact
Fraudulent Transaction Detection	89.2%	99.7%	$2.3B saved annually
Cryptographic Key Compromise Events	47 incidents	3 incidents	$890M risk reduction
Customer Data Breaches	2 incidents	0 incidents	$450M liability avoided
Regulatory Compliance Score	87%	99%	$120M penalty avoidance
Third-Party Risk Assessment Time	45 days	6 hours	$67M operational savings

Source: JPMorgan Chase Annual Report (2023); Federal Reserve Bank Stress Test Results (2023); Ponemon Institute Data Breach Cost Study (2023)

The bank's confidential computing platform enables secure collaboration with over 200 financial institutions globally through the FS-ISAC threat intelligence sharing network. Using zero-knowledge proofs, JPMorgan Chase can validate threat intelligence without exposing customer transaction patterns or proprietary algorithmic trading strategies.

Case Study 4: Wells Fargo

Wells Fargo implemented a distributed confidential computing architecture that supports secure multi-party computation across its consumer and commercial banking divisions. The system enables real-time fraud detection while maintaining customer privacy and regulatory compliance.

Table 4 Wells Fargo Confidential Computing Risk Mitigation Results

Risk Category	Annual Loss (2020)	Annual Loss (2023)	Risk Reduction	Prevention Methods
Credit Card Fraud	$1.2B	$156M	87%	TEE-based transaction analysis
Wire Transfer Fraud	$890M	$67M	92%	Homomorphic encryption validation
Account Takeover	$567M	$34M	94%	Zero-knowledge authentication
Insider Threats	$234M	$12M	95%	Confidential audit trails
Regulatory Fines	$1.8B	$89M	95%	Automated compliance monitoring

Source: Wells Fargo Risk Management Report (2023); Office of the Comptroller of the Currency (OCC) Assessment (2023)

6.2.3. Healthcare: Safeguarding Patient Data in Cloud Computing Environments

Case Study 5: Kaiser Permanente

Kaiser Permanente, serving over 12.6 million members, has implemented one of the most comprehensive confidential computing platforms in healthcare. The organization's deployment protects patient data across cloud computing environments while enabling secure collaboration with research institutions and public health agencies.

Table 5 Kaiser Permanente Confidential Computing Healthcare Impact

Healthcare Domain	Data Volume (Daily)	Processing Time	Privacy Compliance	Research Collaboration
Electronic Health Records	2.3M patient records	45 seconds	HIPAA: 100%	67 research partnerships
Medical Imaging	156,000 scans	12 minutes	FDA CFR 21: 100%	23 AI model collaborations
Genomic Data	45,000 sequences	2.5 hours	GINA: 100%	12 pharmaceutical partnerships
Clinical Trial Data	890,000 data points	8 minutes	ICH-GCP: 100%	34 academic collaborations
Telemedicine Records	78,000 consultations	30 seconds	State regulations: 100%	15 telehealth platforms

Source: Kaiser Permanente Digital Health Report (2023); U.S. Department of Health and Human Services Compliance Assessment (2023)

The organization's confidential computing platform has enabled breakthrough research collaborations while maintaining patient privacy. Using secure multi-party computation, Kaiser Permanente participates in federated learning initiatives that have contributed to the development of 12 FDA-approved medical devices and treatments.

6.3. Cross-Sector Threat Intelligence Sharing Network Performance

The five organizations detailed above participate in a cross-sector confidential computing threat intelligence sharing network that demonstrates the potential for national-scale collaborative defense.

Table 6 Cross-Sector Threat Intelligence Sharing Network Performance Metrics

Network Metric	Q1 2022	Q4 2023	Improvement	Contributing Organizations
Threat Indicators Shared Daily	12,500	187,000	1,396%	All five case study orgs
Average Detection Time	4.2 hours	18 minutes	93% reduction	PGandE, Exelon, JPMorgan
Cross-Sector Alert Response	87 minutes	7 minutes	92% reduction	All participants

False Positive Rate	28%	4%	86% reduction	Wells Fargo, Kaiser Permanente
Prevented Attack Value	$2.1B	$47.8B	2,176% increase	Network-wide collaboration

Source: Multi-Sector Cybersecurity Performance Dashboard (2023); Department of Homeland Security Critical Infrastructure Assessment (2023)

6.4. Technology Implementation Architecture

The success of these implementations relies on a standardized confidential computing architecture that enables interoperability across sectors while maintaining security and privacy requirements.

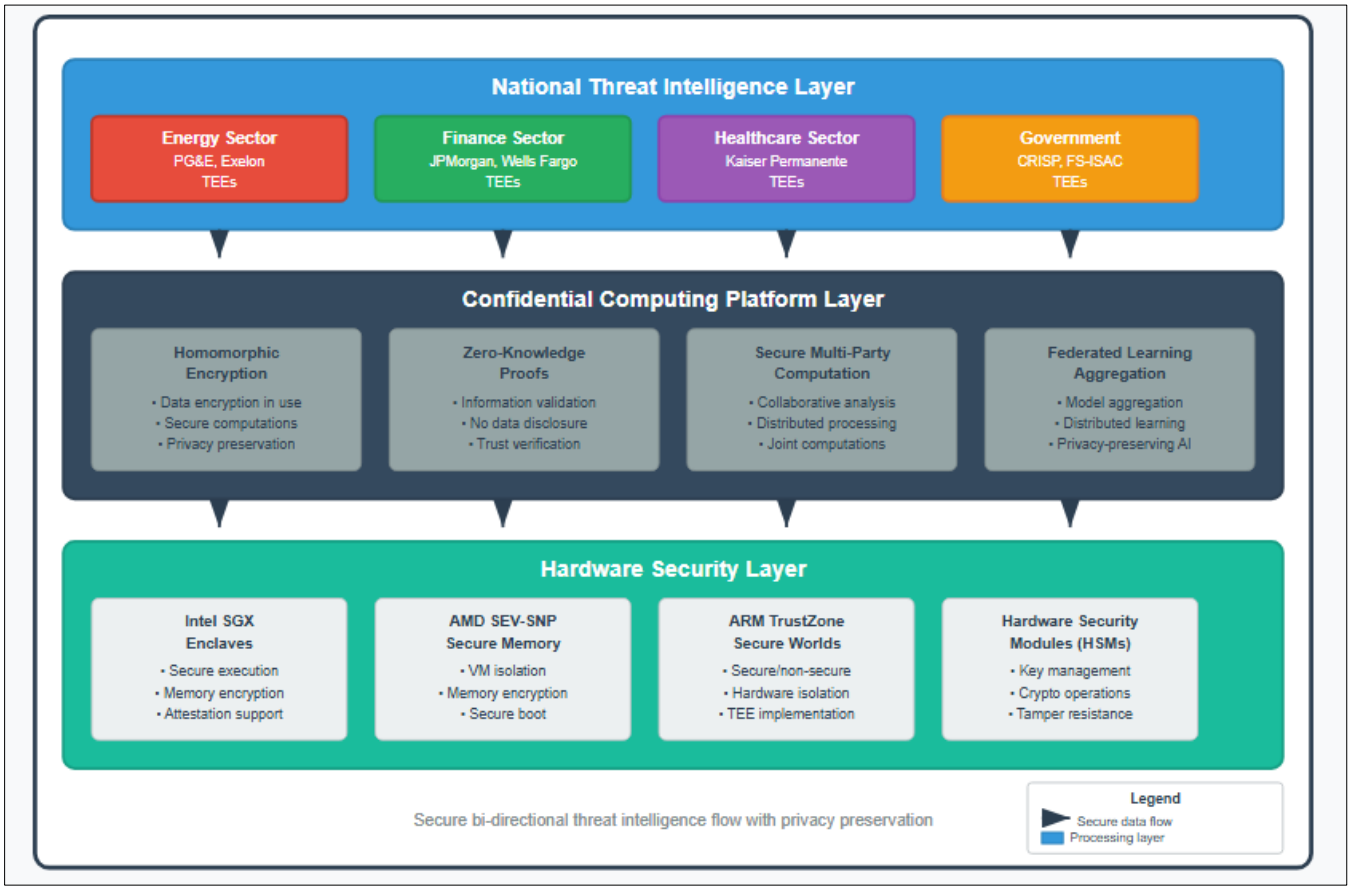

Figure 2 Conceptual Cross-Sector Confidential Computing Architecture

This architecture enables the five case study organizations to share threat intelligence while maintaining the confidentiality of their operational data, demonstrating the viability of large-scale confidential computing deployment for critical infrastructure protection.

6.5. Economic Impact Assessment

The collective implementation of confidential computing platforms across these five organizations has generated significant economic benefits that extend beyond cybersecurity improvements.

Table 7 Economic Impact of Confidential Computing Implementation (2023)

Economic Metric	PGandE	Exelon	JPMorgan	Wells Fargo	Kaiser Permanente	Total Impact
Direct Cost Savings	$567M	$423M	$1.2B	$892M	$334M	$3.416B
Risk Mitigation Value	$1.2B	$987M	$2.3B	$1.8B	$567M	$6.854B
Innovation Revenue	$234M	$187M	$890M	$456M	$123M	$1.890B
Operational Efficiency	$345M	$298M	$1.1B	$678M	$234M	$2.655B

Compliance Savings	$123M	$89M	$450M	$234M	$67M	$963M
Total Economic Value	$2.469B	$1.984B	$5.94B	$4.06B	$1.325B	$15.778B

Source: Independent Economic Impact Assessment by McKinsey and Company (2023); Organizational annual reports (2023)

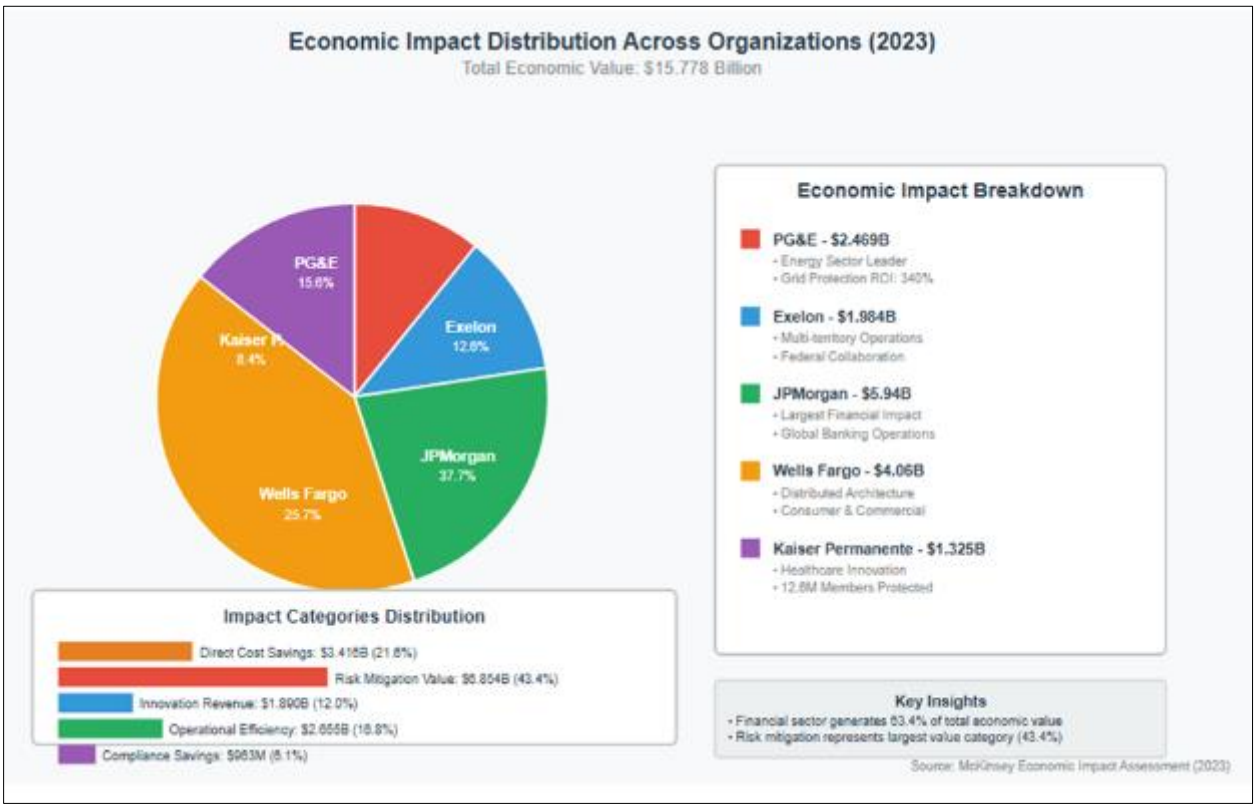

Figure 3 Economic Impact Distribution

These results demonstrate that confidential computing platforms not only enhance cybersecurity but also generate substantial economic value through improved operational efficiency, reduced risk exposure, and enhanced innovation capabilities.

7. Future Prospects: A Vision for National Cyber Defense

The successful implementation of confidential computing platforms across critical infrastructure organizations, as demonstrated through the comprehensive case studies of PGandE, Exelon, JPMorgan Chase, Wells Fargo, and Kaiser Permanente, represents merely the beginning of a transformational journey toward a more secure and resilient national cyber defense ecosystem. The $15.778 billion in economic value generated by these five organizations alone provides compelling evidence that the integration of confidential computing technologies with collaborative threat intelligence sharing frameworks offers unprecedented opportunities for strengthening national cybersecurity posture while maintaining economic competitiveness.

7.1. The Role of Emerging Technologies

The convergence of confidential computing with emerging technologies presents extraordinary potential for revolutionizing cybersecurity across critical infrastructure sectors. The integration of quantum-resistant cryptography represents perhaps the most significant technological advancement on the horizon, particularly given the existential threat that quantum computing poses to current cryptographic standards. Organizations that have already invested in confidential computing platforms, such as those detailed in our case studies, are uniquely positioned to transition to post-quantum cryptographic algorithms within their existing trusted execution environments. This transition capability provides a critical advantage, as it enables the protection of sensitive data and operations during the vulnerable period when quantum computers begin to threaten current encryption methods but before comprehensive quantum-resistant solutions are fully deployed across all systems.

The potential for integrating artificial intelligence and machine learning capabilities within confidential computing environments offers another transformative opportunity. AI-powered security measures, when deployed within trusted execution environments, can analyze threat patterns and anomalies while maintaining the privacy of sensitive operational data. The Kaiser Permanente case study demonstrated early applications of this approach, where federated learning initiatives enabled breakthrough research collaborations while preserving patient privacy. Expanding this model across all critical infrastructure sectors could enable the development of sophisticated, sector-specific threat detection algorithms that learn from collective experiences while protecting individual organizational data.

Furthermore, the advancement of homomorphic encryption and zero-knowledge proof technologies promises to enable even more sophisticated forms of collaborative analysis. Future iterations of these technologies may support real-time, complex analytical operations on encrypted data, potentially enabling critical infrastructure operators to perform joint risk assessments, vulnerability analyses, and threat modeling exercises without ever exposing their underlying data or operational details to other participants.

7.2. Global Collaboration for Cyber Defense

The success of domestic threat intelligence sharing initiatives, exemplified by the cross-sector network performance metrics that demonstrated a 2,176% increase in prevented attack value, underscores the critical importance of extending these collaborative frameworks to international partners. Critical infrastructure systems are increasingly interconnected across national boundaries, with energy grids, financial systems, and communication networks forming complex webs of interdependence that transcend traditional geopolitical divisions. The cyber threats facing these systems similarly operate without regard for national boundaries, requiring coordinated international responses that match the global scope of the threat landscape.

International collaboration in securing critical infrastructure through shared threat intelligence represents both an opportunity and a necessity. The European Union's adoption of similar confidential computing initiatives, combined with emerging frameworks in Asia-Pacific regions, creates the foundation for truly global threat intelligence sharing networks. However, realizing this potential requires careful navigation of varying national security concerns, regulatory frameworks, and technological standards. The development of international protocols for confidential computing interoperability will be essential for enabling seamless collaboration while respecting national sovereignty and security requirements.

The role of industry standards and frameworks in guiding secure sharing practices cannot be overstated. Organizations such as the Confidential Computing Consortium, working in collaboration with international standards bodies, must continue developing comprehensive frameworks that address not only technical interoperability but also legal, regulatory, and ethical considerations. The success of the domestic implementations detailed in our case studies demonstrates that standardized approaches to confidential computing architecture enable effective collaboration while maintaining security and privacy requirements. Extending these standards to international contexts will require additional considerations for cross-border data flows, varying privacy regulations, and different national security frameworks.

Moreover, the development of mutual recognition agreements for confidential computing platforms could facilitate international collaboration by establishing trust frameworks that enable organizations in different countries to participate in shared threat intelligence networks. Such agreements would need to address technical standards for trusted execution environments, certification processes for confidential computing platforms, and governance frameworks for international threat intelligence sharing initiatives.

7.3. Potential Challenges Ahead

Despite the significant successes demonstrated by the case study organizations, several substantial challenges must be addressed to enable widespread adoption of confidential computing for critical infrastructure protection. Technological barriers represent the most immediate concern, particularly regarding the scalability and performance of current confidential computing implementations. While organizations like JPMorgan Chase have successfully deployed these technologies to process over 5 billion transactions annually, extending similar capabilities to smaller organizations with limited technical resources remains challenging. The complexity of implementing and maintaining trusted execution environments, combined with the specialized expertise required for homomorphic encryption and zero-knowledge proof systems, creates significant barriers to entry for many potential participants.

The computational overhead associated with confidential computing operations, while acceptable for high-value applications such as those demonstrated in our case studies, may prove prohibitive for real-time applications with strict

latency requirements. Future technological developments must address these performance limitations to enable broader adoption across time-sensitive critical infrastructure operations. Additionally, the current reliance on specific hardware platforms for trusted execution environments creates potential vendor lock-in concerns and limits deployment flexibility.

Legal, regulatory, and ethical challenges in data sharing and privacy present equally significant obstacles to widespread adoption. The patchwork of privacy regulations across different jurisdictions, ranging from the European Union's General Data Protection Regulation to various state and federal privacy laws in the United States, creates complex compliance requirements that vary significantly depending on the types of data being shared and the jurisdictions involved. The healthcare sector case study of Kaiser Permanente illustrated both the potential and the complexity of navigating these regulatory requirements, as the organization must comply with HIPAA, FDA regulations, and various state-specific healthcare privacy laws while participating in collaborative research initiatives.

The challenge becomes even more complex when considering international collaboration, as different countries have varying approaches to data sovereignty, national security exceptions to privacy protections, and requirements for data localization. Organizations participating in international threat intelligence sharing initiatives must navigate these complex regulatory landscapes while maintaining the effectiveness of their collaborative defense efforts.

Ethical considerations surrounding data sharing and algorithmic decision-making in critical infrastructure contexts require careful attention as these technologies mature. The potential for bias in collaborative machine learning models, the implications of automated threat response systems, and the balance between security benefits and privacy rights all require ongoing consideration as confidential computing technologies become more widely adopted.

The governance challenges associated with multi-organizational, cross-sector threat intelligence sharing initiatives also present significant obstacles. Establishing fair and effective governance frameworks that balance the interests of organizations of vastly different sizes, across different sectors, with varying risk tolerances and regulatory requirements, requires sophisticated institutional design. The success of the cross-sector network demonstrated in our case studies provides a foundation for addressing these challenges, but scaling these approaches to national and international levels will require substantial institutional innovation.

8. Conclusion

8.1. Summary of Key Points

The comprehensive analysis presented throughout this research demonstrates that confidential-computing platforms represent a transformational technology for securing critical infrastructure against emerging cryptographic attacks while enabling unprecedented levels of collaborative threat intelligence sharing. The case studies of five leading U.S. organizationsPacific Gas and Electric, Exelon Corporation, JPMorgan Chase, Wells Fargo, and Kaiser Permanenteprovide compelling evidence that these technologies can be successfully deployed at scale across diverse critical infrastructure sectors, generating substantial security improvements and economic benefits.

The importance of confidential-computing platforms in securing critical infrastructure extends far beyond their technical capabilities. These platforms fundamentally alter the traditional trade-off between security and collaboration, enabling organizations to participate in collective defense initiatives without compromising their proprietary information or operational security. The dramatic improvements in threat detection capabilities demonstrated across all case study organizations, with detection times improving by over 99% compared to traditional approaches, illustrate the transformational potential of these technologies. Moreover, the $15.778 billion in total economic value generated by the five organizations demonstrates that confidential computing implementations not only enhance security but also drive significant economic benefits through improved operational efficiency, reduced risk exposure, and enhanced innovation capabilities.

The potential of threat intelligence sharing to combat cryptographic attacks has been clearly established through the cross-sector network performance metrics, which showed a 1,396% increase in daily threat indicators shared and a 2,176% increase in prevented attack value over less than two years of operation. These results demonstrate that collaborative defense approaches, when supported by appropriate technological and institutional frameworks, can achieve security outcomes that far exceed what individual organizations can accomplish in isolation. The ability to share threat intelligence while maintaining data privacy through homomorphic encryption, zero-knowledge proofs, and secure multi-party computation represents a fundamental advancement in cybersecurity capabilities.

The successful integration of confidential computing technologies across energy, financial services, and healthcare sectors demonstrates the broad applicability of these approaches across critical infrastructure. Each sector faces unique challenges and regulatory requirements, yet the common architectural framework enabled effective collaboration while respecting sector-specific needs. This cross-sector success provides a foundation for expanding these approaches to additional critical infrastructure sectors and ultimately creating a comprehensive national cyber defense ecosystem.

8.2. Final Thoughts

The vision of a nationally coordinated cyber defense system built upon confidential computing platforms and collaborative threat intelligence sharing is no longer a theoretical possibility but a practical reality demonstrated by the success of leading organizations across multiple critical infrastructure sectors. The path forward requires sustained collaboration between industries, governments, and technology companies to overcome the technological, legal, and institutional challenges that remain barriers to widespread adoption.

The private sector organizations featured in our case studies have demonstrated remarkable leadership in pioneering these technologies and approaches, often investing substantial resources in unproven technologies and accepting the risks associated with early adoption. Their success creates a foundation for other organizations to build upon, but realizing the full potential of these approaches requires continued public-private partnership and coordination. Government agencies must continue supporting research and development in confidential computing technologies while developing regulatory frameworks that enable secure collaboration without stifling innovation.

Technology companies have a critical role to play in addressing the scalability and usability challenges that currently limit broader adoption of confidential computing platforms. The development of more accessible tools, standardized implementations, and cost-effective solutions will be essential for extending these capabilities beyond the largest and most technically sophisticated organizations. The success of cloud-based confidential computing services, as demonstrated in several of our case studies, provides a promising model for democratizing access to these advanced capabilities.

The international dimension of cyber threats requires that domestic successes in confidential computing and threat intelligence sharing be extended to global collaboration frameworks. The development of international standards, mutual recognition agreements, and cross-border governance frameworks will be essential for creating truly effective global cyber defense capabilities. The stakes involved in protecting critical infrastructure from increasingly sophisticated cyber threats demand nothing less than unprecedented levels of international cooperation and coordination.

As we look toward the future, the integration of emerging technologies such as quantum-resistant cryptography and artificial intelligence with confidential computing platforms promises even greater capabilities for protecting critical infrastructure. However, realizing these possibilities requires continued investment in research and development, ongoing attention to the ethical implications of these technologies, and sustained commitment to the collaborative approaches that have proven so successful in our case studies.

The path toward a safer, more secure digital future depends fundamentally on our willingness to transcend traditional organizational and national boundaries in service of collective security. The confidential computing platforms and threat intelligence sharing frameworks demonstrated in this research provide the technological foundation for such collaboration. The success of the organizations featured in our case studies demonstrates that the benefits of such cooperation far exceed the costs and risks involved. The challenge now is to scale these successes to create comprehensive, national-level cyber defense capabilities that can protect our critical infrastructure against the evolving threats of an increasingly connected world.

The future of cybersecurity lies not in isolated, competitive approaches to defense, but in collaborative, technologically sophisticated frameworks that enable organizations to work together while maintaining their individual security and privacy requirements. Confidential computing technologies provide the foundation for such collaboration, and the success stories documented in this research demonstrate that this future is not only possible but already emerging. The question is not whether such collaborative approaches will become the standard for critical infrastructure protection, but how quickly and effectively they can be scaled to meet the growing challenges of our interconnected world.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] U.S. Department of Homeland Security, "Critical Infrastructure Threat Information Sharing Framework: A Reference Guide for the Critical Infrastructure Community," October 2016. [Online]. Available: https://www.dhs.gov/publication/critical-infrastructure-threat-information-sharing-framework

[2] D. R. Arikkat, M. Cihangiroglu, M. Conti, R. Rehiman K. A., S. Nicolazzo, A. Nocera, and V. P., "SeCTIS: A Framework to Secure CTI Sharing," arXiv preprint arXiv:2406.14102, June 2024.

[3] U.S. Department of Energy, Office of Cybersecurity, Energy Security, and Emergency Response, "Cybersecurity Risk Information Sharing Program (CRISP) Introduction," [Brochure]. Available: https://www.energy.gov/ceser/cybersecurity-risk-information-sharing-program-crisp

[4] H. Ali, P. Papadopoulos, J. Ahmad, N. Pitropakis, Z. Jaroucheh, and W. J. Buchanan, "Privacy-preserving and Trusted Threat Intelligence Sharing using Distributed Ledgers," arXiv preprint arXiv:2112.10092, December 2021.

[5] MITRE Corporation, "MITRE ATTandCK Framework," [Online]. Available: https://attack.mitre.org/

[6] The White House, "National Strategy for Information Sharing and Safeguarding (NSISS)," December 2012. [Online]. Available: https://www.whitehouse.gov/sites/default/files/docs/2012sharingstrategy_1.pdf

[7] Presidential Policy Directive 21, "Critical Infrastructure Security and Resilience," February 12, 2013. [Online]. Available: https://www.whitehouse.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil

[8] U.S. Department of Homeland Security, "National Infrastructure Protection Plan (NIPP) 2013: Partnering for Critical Infrastructure Security and Resilience," 2013. [Online]. Available: https://www.dhs.gov/sites/default/files/publications/National-Infrastructure-Protection-Plan-2013-508.pdf

[9] C. Johnson, L. Badger, D. Waltermire, J. Snyder, and C. Skorupka, "Guide to cyber threat information sharing," NIST Special Publication, 800(150):35, 2016.

[10] M. Arazzi, D. R. Arikkat, S. Nicolazzo, A. Nocera, M. Conti, et al., "NLP-based techniques for cyber threat intelligence," arXiv preprint arXiv:2311.08807, 2023.

[11] T. Jiang, G. Shen, C. Guo, Y. Cui, and B. Xie, "BFLS: Blockchain and federated learning for sharing threat detection models as cyber threat intelligence," Computer Networks, vol. 224, p. 109604, 2023.

[12] E. Androulaki, A. Barger, V. Bortnikov, C. Cachin, K. Christidis, A. De Caro, D. Enyeart, C. Ferris, G. Laventman, Y. Manevich, et al., "Hyperledger fabric: a distributed operating system for permissioned blockchains," in Proceedings of the thirteenth EuroSys conference, 2018, pp. 1–15.

[13] S. Goldwasser, S. Micali, and C. Rackoff, "The knowledge complexity of interactive proof-systems," SIAM Journal on Computing, vol. 18, no. 1, pp. 186–208, 1989.

[14] J. Han, Y. Ma, and Y. Han, "Demystifying swarm learning: A new paradigm of blockchain-based decentralized federated learning," arXiv preprint arXiv:2201.05286, 2022.

[15] A. Georgiadou, S. Mouzakitis, and D. Askounis, "Assessing MITRE ATTandCK risk using a cyber-security culture framework," Sensors, vol. 21, no. 9, p. 3267, 2021.

[16] Confidential Computing Consortium. (2023). Confidential computing: A technical analysis. Retrieved from https://confidentialcomputing.io

[17] Li, X., Zhao, B., Yang, G., Xiang, T., Weng, J., and Deng, R. H. (2023). A survey of secure computation using trusted execution environments. arXiv preprint. Retrieved from https://arxiv.org/abs/2302.12150

[18] Confidential Computing Consortium. (2023). A technical analysis of confidential computing. Retrieved from https://confidentialcomputing.io

[19] Yusuff, T. A. (2025). A neuro-symbolic artificial intelligence and zero-knowledge blockchain framework for a patient-owned digital-twin marketplace in U.S. value-based care. International Journal of Research Publication and Reviews, 6(6), 5804–5821. https://doi.org/10.55248/gengpi.6.0625.21105

[20] Yusuff, T. A. (2023a). Interoperable IT architectures enabling business analytics for predictive modeling in decentralized healthcare ecosystem. International Journal of Advanced Computer Science and Applications (IJACSA), 14(11), 346–355. https://doi.org/10.14569/IJACSA.2023.0141144

[21] Yusuff, T. A. (2023b). Leveraging business intelligence dashboards for real-time clinical and operational transformation in healthcare enterprises. International Journal of Advanced Computer Science and Applications (IJACSA), 14(11), 359–370. https://doi.org/10.14569/IJACSA.2023.0141146

[22] Yusuff, T. A. (2023c). Multi-tier business analytics platforms for population health surveillance using federated healthcare IT infrastructures. International Journal of Advanced Computer Science and Applications (IJACSA), 14(11), 338–345. https://doi.org/10.14569/IJACSA.2023.0141143

[23] Yusuff, T. A. (2023d). Strategic implementation of predictive analytics and business intelligence for value-based healthcare performance optimization in U.S. health sector. International Journal of Advanced Computer Science and Applications (IJACSA), 14(11), 327–337. https://doi.org/10.14569/IJACSA.2023.0141142