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— Global 2021 — July 13-14

Computational Storage Security Challenges and Solutions for the Hybrid Cloud

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Current Threat Landscape

- Social Engineering
- Advanced Persistent Threat (APT)
- Ransomware/Malware
- Unpatched/Updated Systems
- Security Misconfiguration
- Denial of Service
- Sensitive Data Exposure
- Injection Flaws
- Cryptojacking
- Cyber Physical Attacks
- Broken Authentication
- Broken Access Control
- Third Party (Supplier)
- Insider Theft
- Mobile Malware
- Physical Loss of Devices
- Cross-site Scripting (XSS)
- Man-in-the-Middle Attacks
- IoT Weaponization

Common Threat Actors

- Cyber Terrorists
- Government-sponsored/State-sponsored Actors
- Organized Crime/Cybercriminals
- Hacktivists
- Insiders
- Script Kiddies
- Internal User Errors

Common Motivations

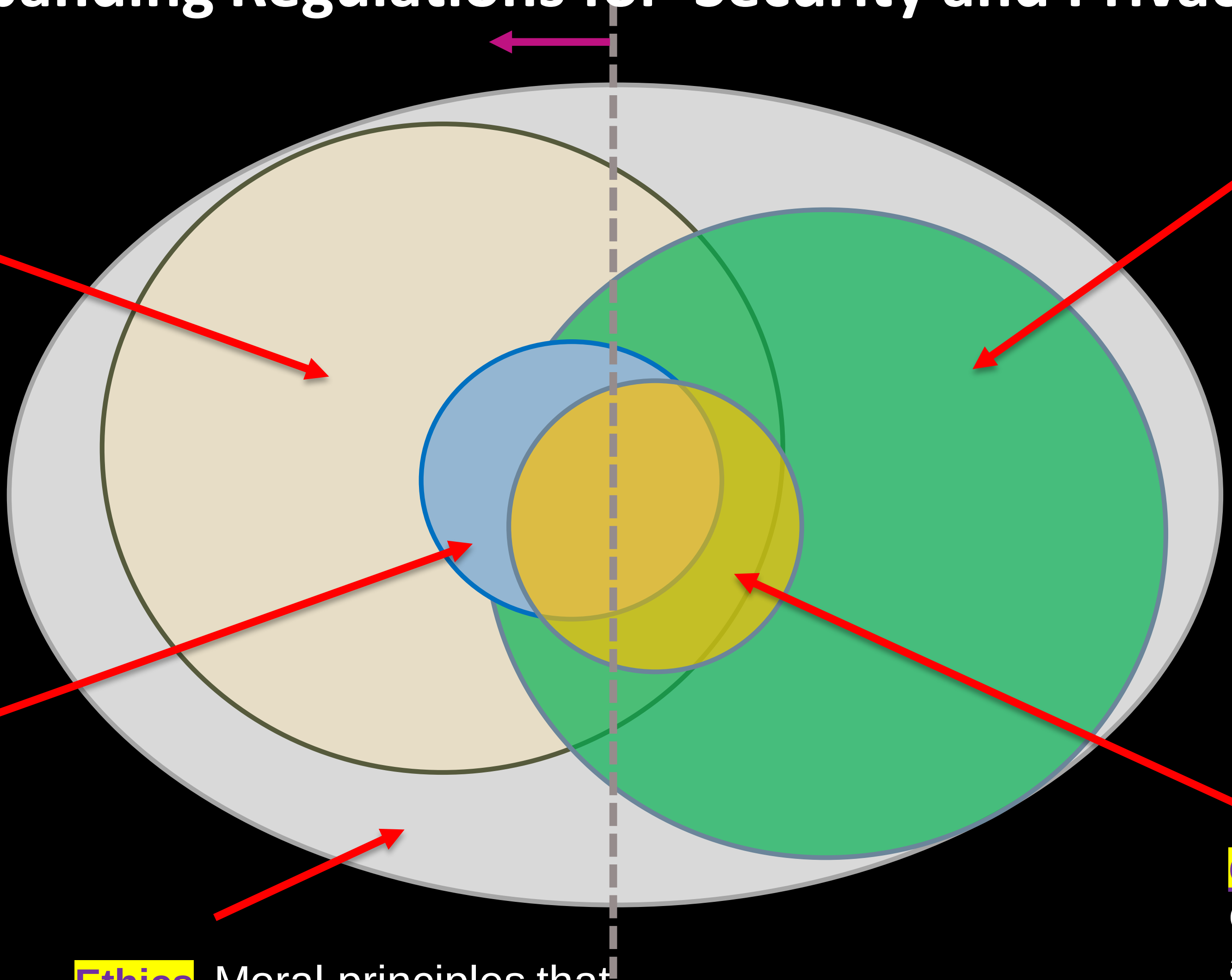
- Political, Economic, Technical, and Military Agendas
- Profit/Financial Gain
- Notoriety
- Revenge
- Multiple/Ov

Security is a People Problem!

Expanding Regulations for Security and Privacy

Privacy:
Collection Limitations, Data Quality, Purpose Specification, Use Limitation, Security Safeguards, Openness, Individual Participation Accountability

Information Security
Ensures Confidentiality Integrity, and Availability (CIA) of information



Personal Data Protection
Safeguards applying under various laws and regulations to personal data (PII, PHI, etc.) about individuals that organizations collect, store, use and disclose

Ethics Moral principles that govern Person's behavior or the conducting of an activity

Cybersecurity
Confidentiality, Integrity, and Availability of data; Identify, Protect, Detect, Respond, Recover

Security and Data Resiliency at Par

Data Security

Data Protection

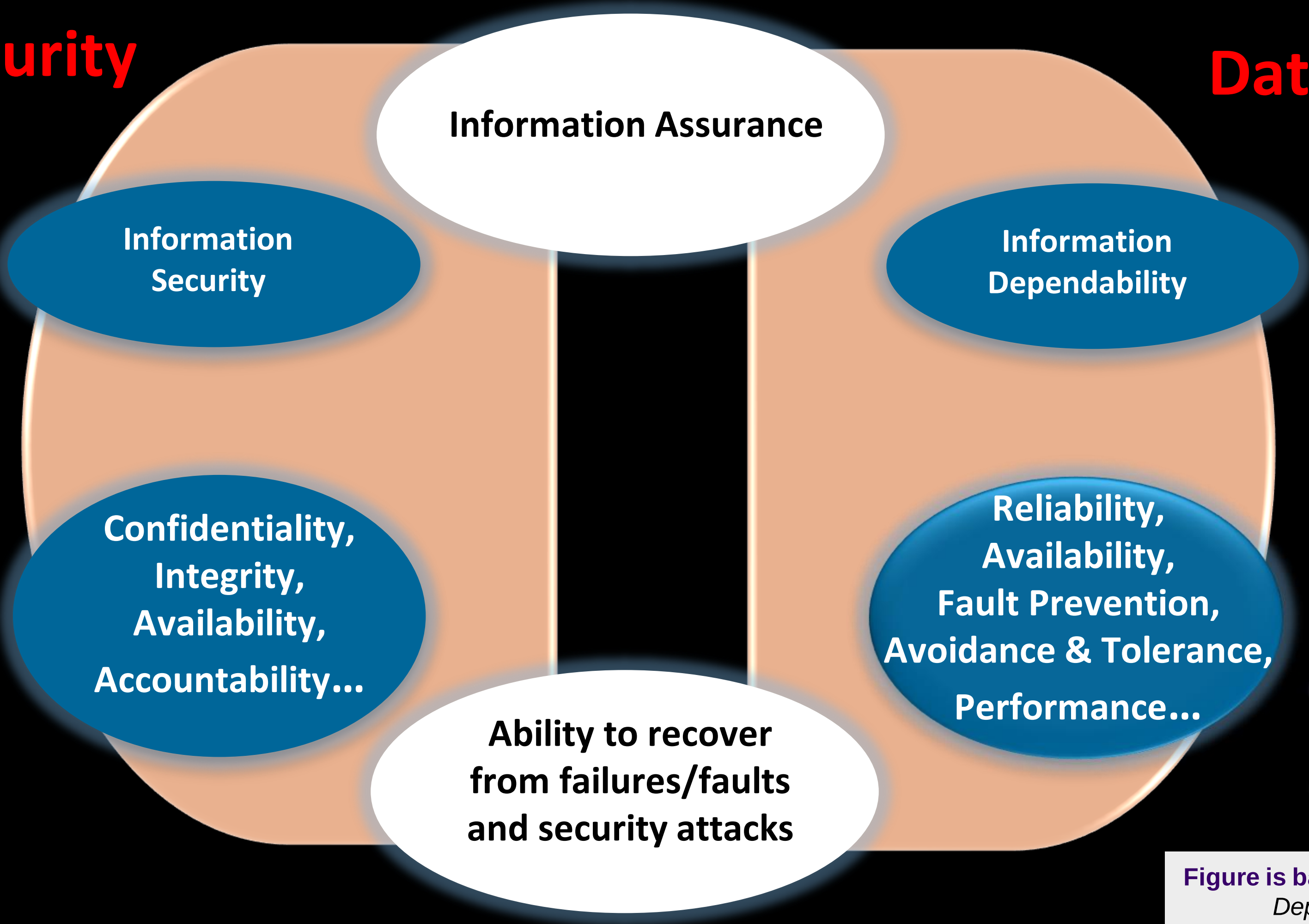
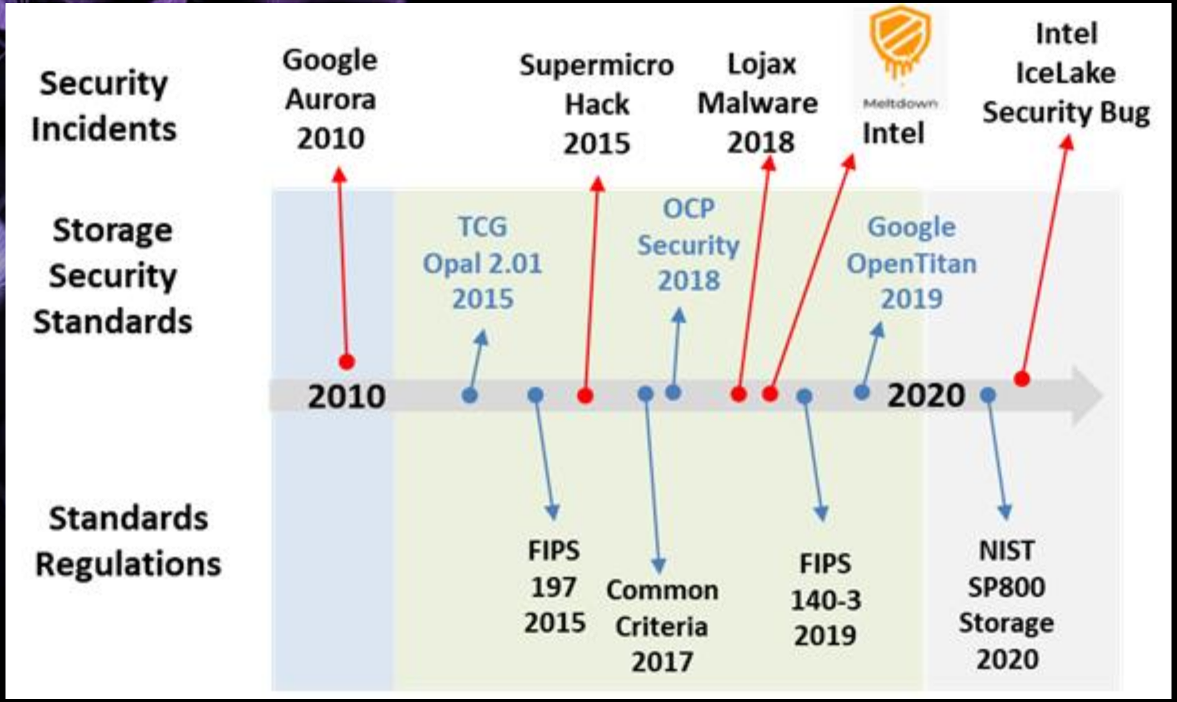


Figure is based on the: *Information Assurance – Dependability and Security in Networked Systems*, Qian, Joshi, Tipper, Krishnamurthy, 2008, New York, ISBN: 978-0-12-373566-9.

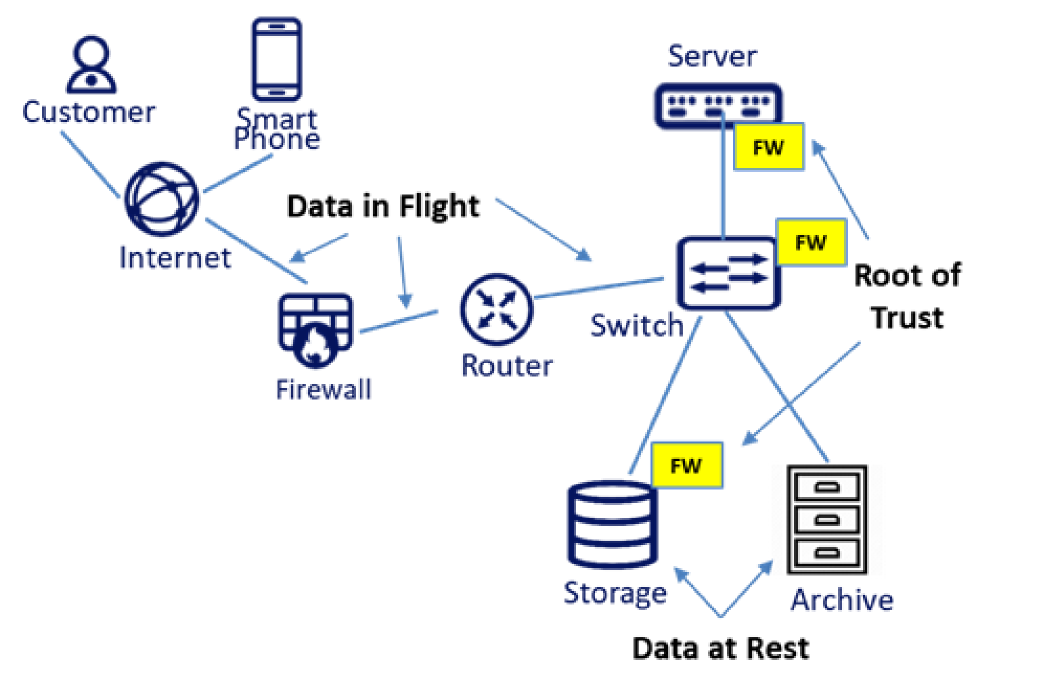
Data Center Security and Standards

Rapid Changing Security Standards



Standards, Security threats growing in past 10 yrs.
New Security Standards organizations emerged
- Open Compute Security Initiative
- TCG Opal SSC (Enterprise, Device)
- DMTF SPDM* (Enterprise, Manageability)

Data Center Security Considerations



Data in Flight: Network security
Data at Rest: Against theft of data or keys, and ransomware (esp. SSD media and key encryption with SSDs
HW Root of Trust : Dedicated security engine to ensure Secure Boot, Secure FW, and Key Management across all peripherals

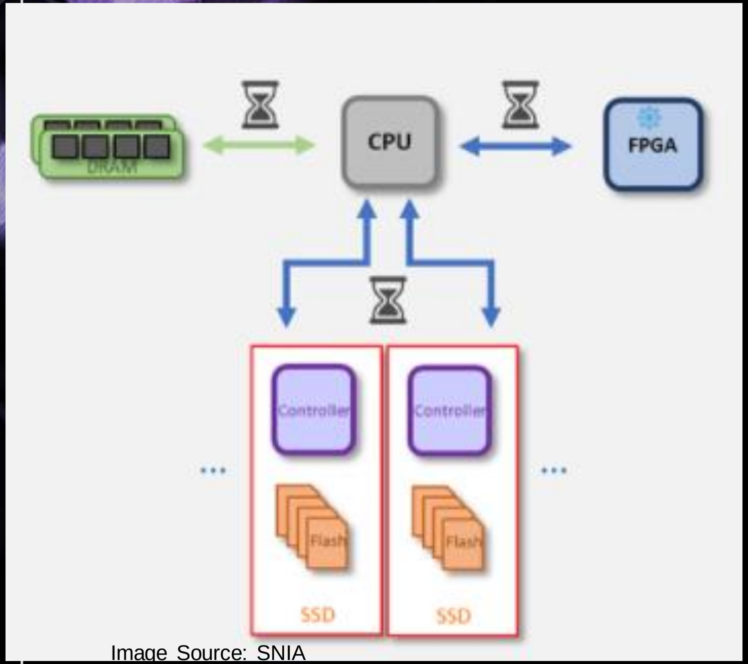
Computational Storage Security Risks

- **Introduction to Computational Storage Drives (CSDs)**
- **New security risks exposed by CSDs**
- **Security standards for Computational Storage**
- **Addressing risks**
  - **CSD security features**
  - **Other features: SW, HW, system-level**
- **Call to Action**

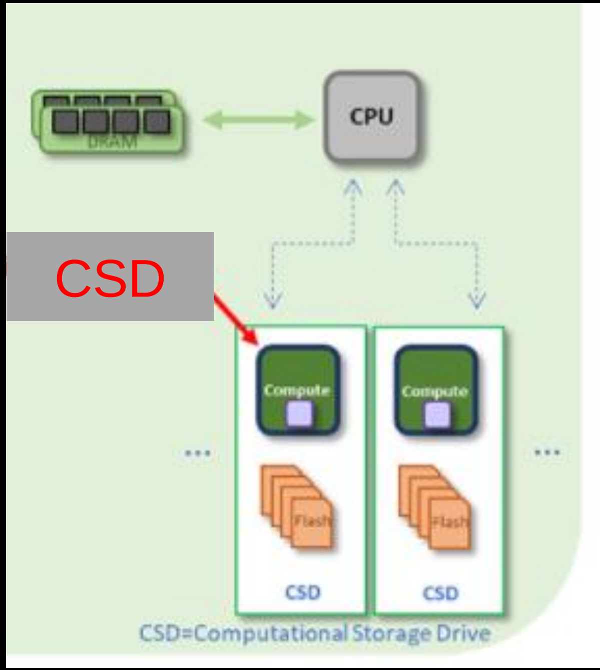
Computational Storage Drives (CSD) Overview

Move Compute Closer to Storage

Current Compute/Storage Architecture



Computational Storage Architecture

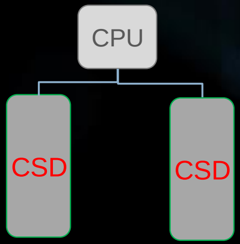


Moving data between storage and host CPU creates performance bottlenecks for data-intensive applications

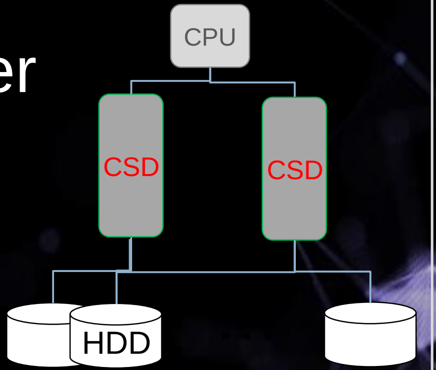
Data processed directly on the CSD => no large data transfers, Adding CSDs adds processing power and internal bandwidth => scalable acceleration

Deployment Examples

Compute/Storage Server

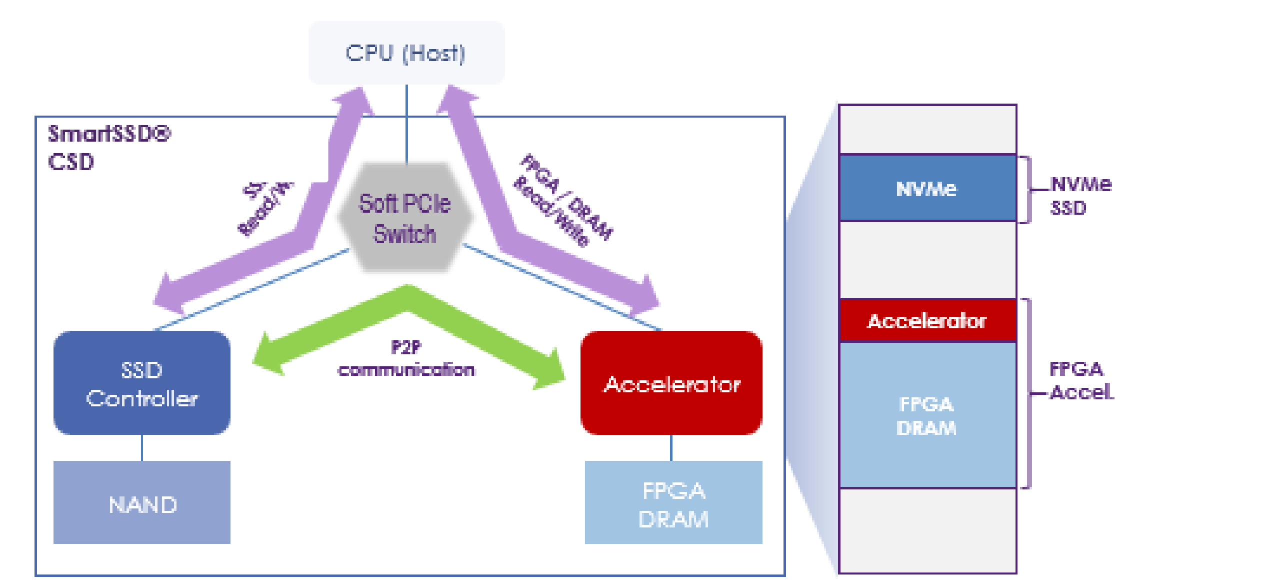


Smart Cache Layer



Cloud to Edge Compute

Potential Computational Storage Drive Implementation and Exposure



CSD Potential Implementation

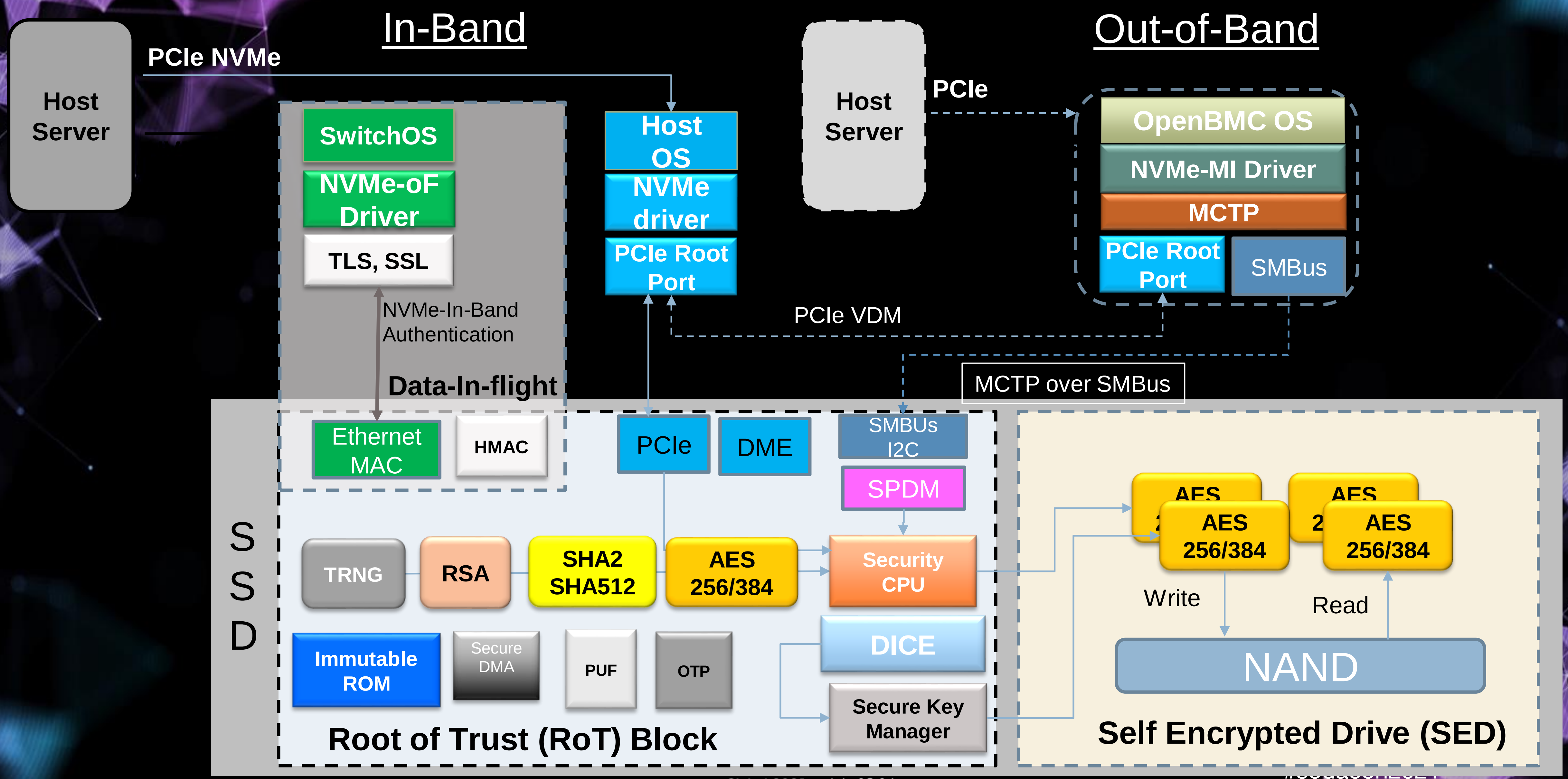
FPGA Accelerator, Flash Controller, DRAM, NAND

- Peer-to-peer (P2P) communication enables unlimited concurrency

SSD-to-Accelerator data transfers use internal data path

- Save precious L2:DRAM Bandwidth (Compute Nodes) / Scale without costly x86 front-end (Storage Nodes)
- Avoid the unnecessary funneling and data movement of standalone accelerators
- FPGA DRAM is exposed to Host PCIe address space
- NVMe commands can securely stream data from SSD to FPGA peer-to-peer

One View of Host-CSD Framework



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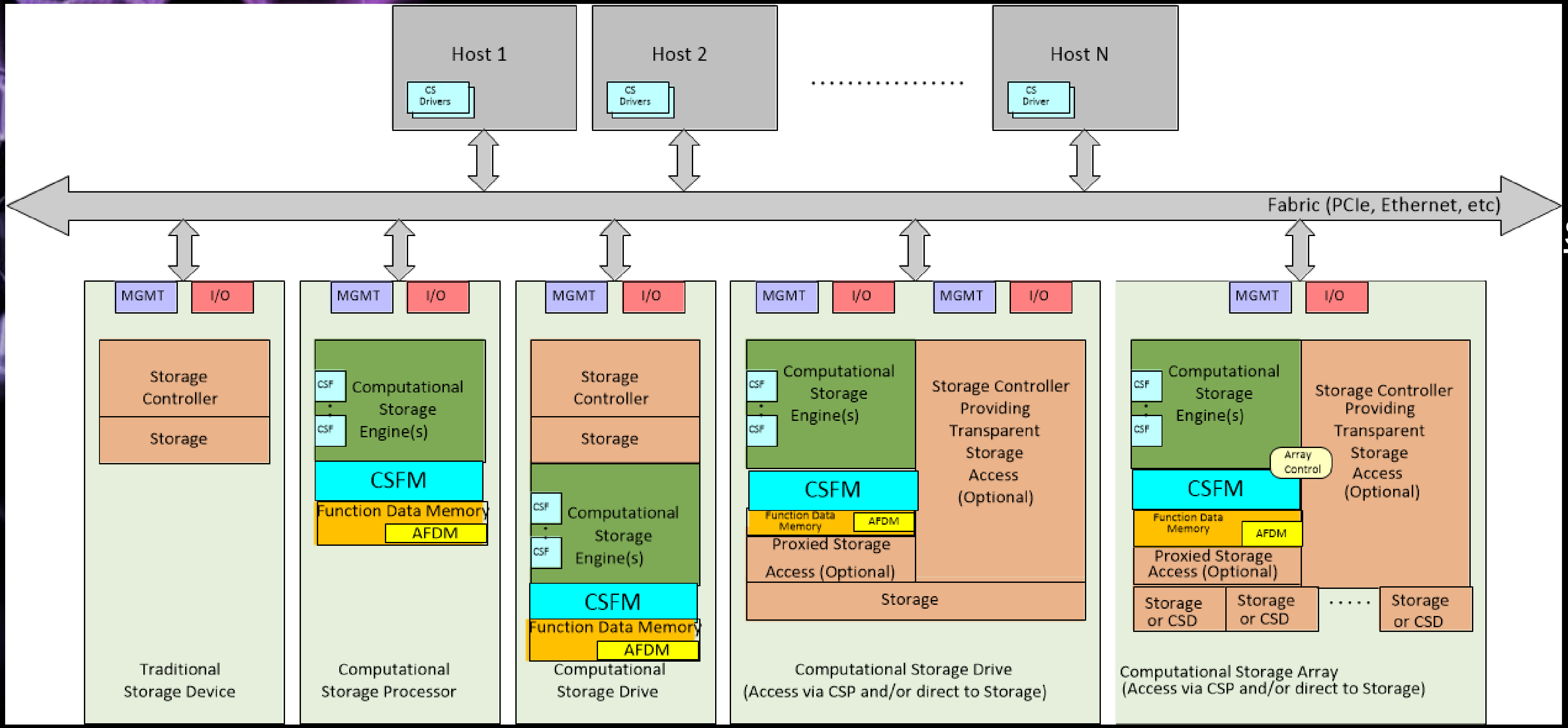
New Risks Exposed by Computational Storage Drives



Security Functions:

Authentication.
Host agent to CSD
Authorization.
Secure data access & permissions
Encryption.
Encrypted data mechanisms
Auditing.
Generating/ retrieving secure logs

Risks vs standard storage:

- **The CSD may delete/add/modify data on the drive**
- **The CSD functionality may be programmed**
- **Virtualization**

Risks vs external accelerator:

Direct access to storage
FPGA programming
Access to network infrastructure (NVMe-oF)
Decryption of data prior to processing

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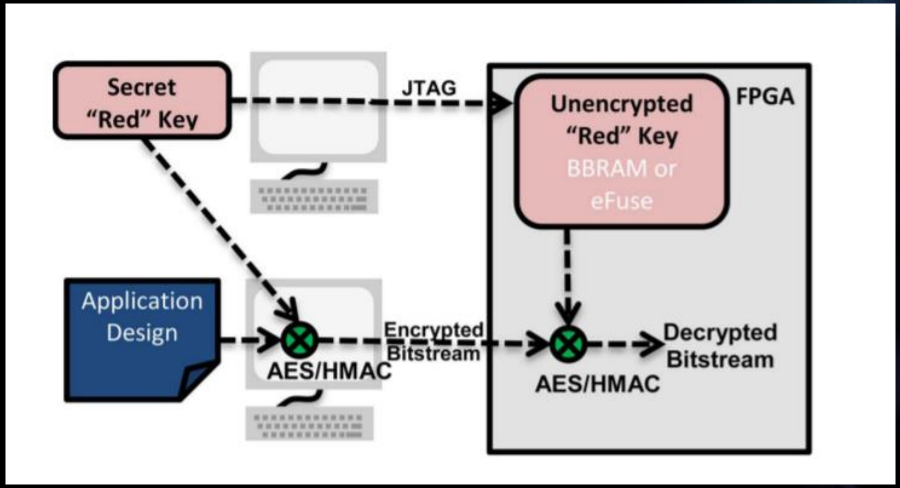
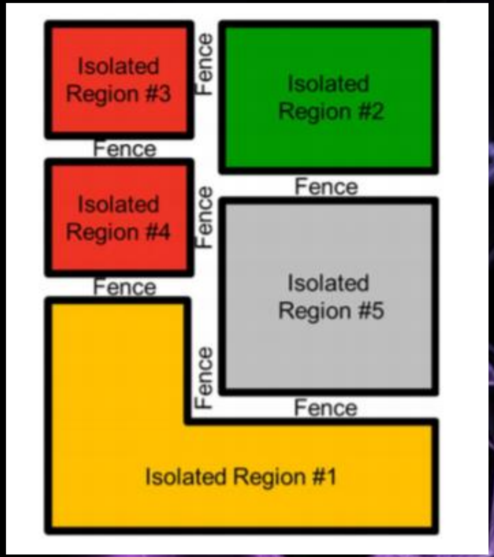
Component level considerations e.g. FPGA

- **FPGAs are SRAM based devices which are programmed by secure bit streams**
  - Key is programmed via JTAG port
  - Bitstream is encrypted with design tools
  - FPGA identifies encrypt/no encrypt for field testing
- **AES 256 secures bitstream programs**
- **Additional Security Measures**
  - Design Region Isolation
  - JIT Partial Reconfiguration
  - SOC and Bus Isolation
  - PUF files for device dependency
  - E-fusing





https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6849432

Developments in Standards Orgs for Computational Storage Security

- **SNIA – Computational Storage TWG**
  - Host access and interfaces
  - API standardization in progress
  - *Q4'2021 – standard (expected)*
- **NVMe – Computational Storage Task Group**
  - Device access, interfaces and implementation
  - *Q1'2022 – standard (expected)*

Security Considerations by Cloud Service Providers

- Notable Cloud Service Provider Security Policy Categories
  - Data-in-flight
  - Processing requirements in data handling
  - Buffering, caching
  - Data-at-rest policies
  - Containers
  - Virtualization
  - Multi-tenant
  - Edge deployments for in-situ storage processing

Computational Storage Potential Security Considerations

1. Root of Trust — Microsoft Cerberus; Google OpenTitan; Intel TXT/TPM
2. Crypto — FIPS-140-2
3. Secure Enclaves — NIST *CSRC; OCP; Microsoft
4. Self-Encrypting Drive — TCG Opal; NIST SP 800
5. Key Management — *TCG DICE; NIST SP 800-57; *DMTF
6. Security Lifecycle — Manufacturing/ Vendor Specific; *NIST SP 800

[illegible] of Standards and Technology
[illegible]g Group
[illegible]ation [illegible] Standards
[illegible]a Protection [illegible]
[illegible] Computer Security Resource Center
[illegible]d Management Task Force

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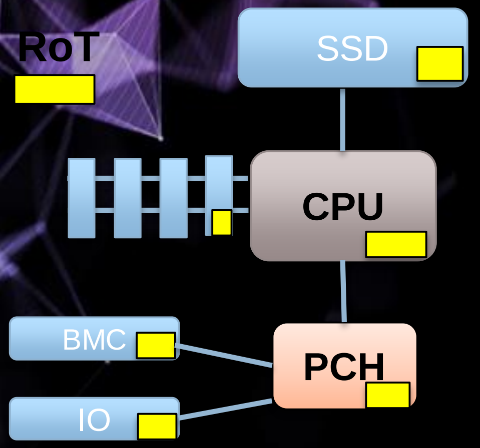
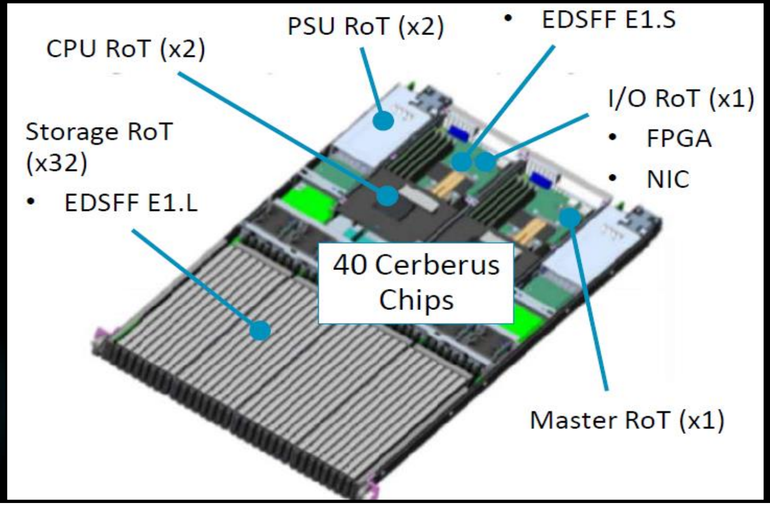
1. Roots of Trust

allow a system to trust its peripheral components

OCP Cerberus RoT

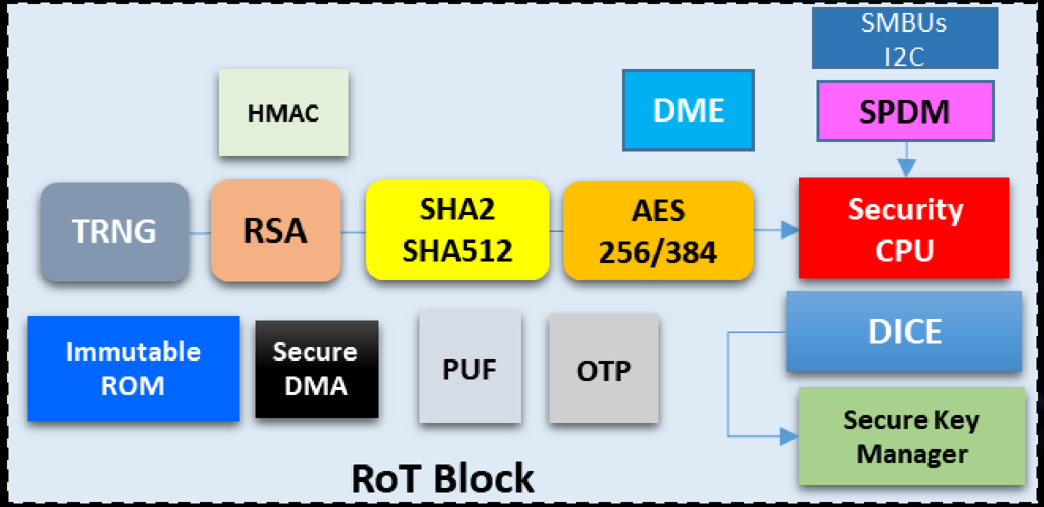


Enables standard secure boot across all devices on the platform
Prevents physical and side-channel attacks
Automated and Secure Key Management



Microsoft Storage Server with 40 Cerberus chips

MSFT Cerberus Components



Secure Boot
Secure key storage and protocol for key management
Advanced security strength with AES 256, ECDSA 384
Host/Client secure communication via I2C/SMBus
Security through-out the Lifecycle of SSD Data and Keys

2. Crypto / 3. Secure Enclaves

allow a system to securely handle drive boot firmware and unencrypted keys

2. Crypto

Cryptography standards are recommended by NIST and FIPS-140 for use in data processing
FIPS-140 sets the standards for Security Strength Requirements for **CRYPTOGRAPHIC** Modules.

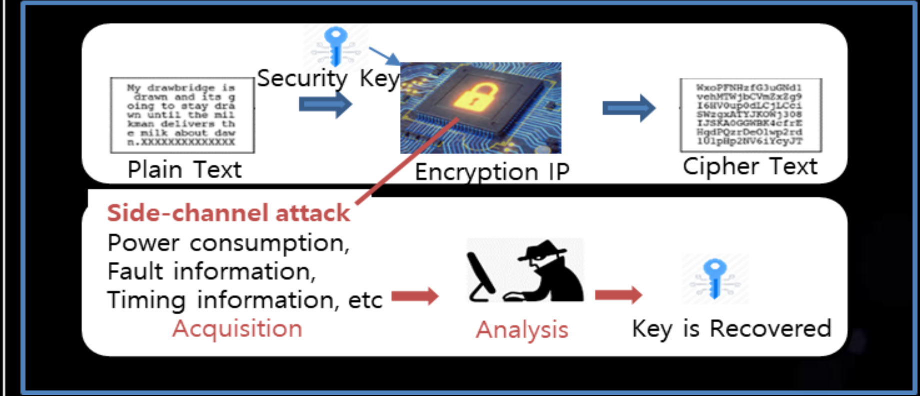
SSD Cryptographic Modules

- RSA
- AES
- ECDSA
- HMAC
- Security CPU

Security Strength	2030	2030+
AES	AES 128 →	AES 256
ECDSA	ECDSA 256 →	ECDSA 384
RSA	3072 →	4096

3. Secure Enclaves

Protection against Physical & Side-Channel attacks are generated with Power monitoring, EMT, and Timing.
Secure Enclaves are recommended for NIST and Common Criteria (EU) compliance and required by Cloud companies



Hardware Tampering
Side-Channel Attack
with Differential
Power Consumption

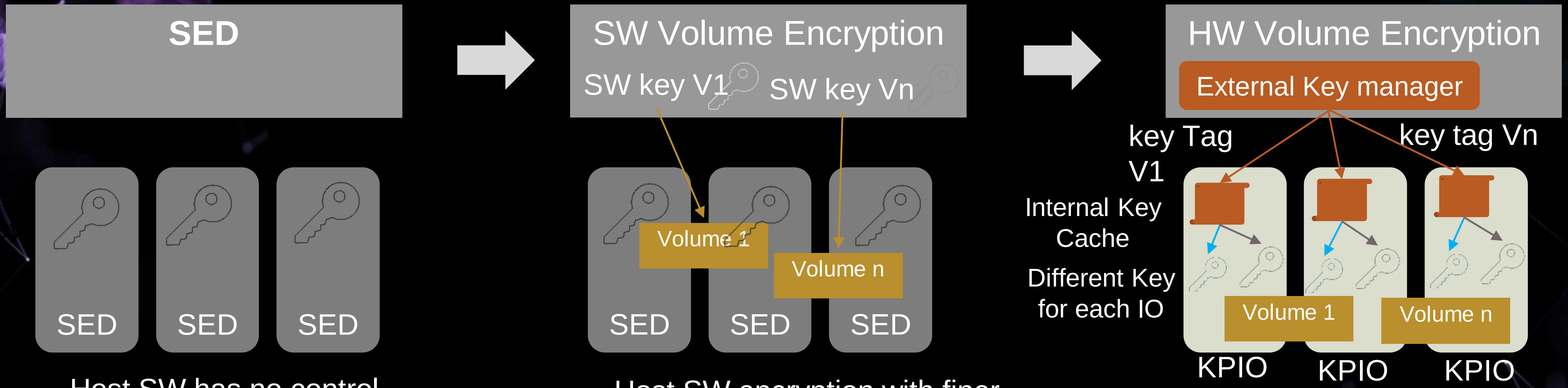
Security Subsystem	
SSD Cont CPU	NAND

→

Security Subsystem	
SSD Cont CPU	NAND

SSD with Enclaves

4. From SED today to Key per IO in the Future

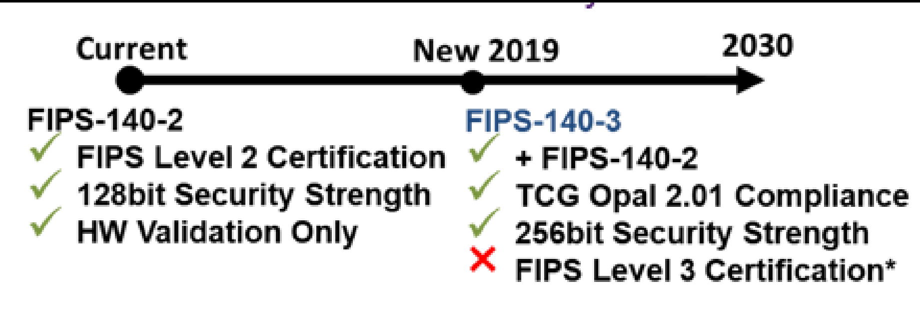


Host SW has no control
SED drive encryption all IO blocks with same key.

Host SW encryption with finer granularity for volume
SED drive encryption all IO blocks for volumes with same key
FIPS-140-2

Fine-grain HW encryption (new key per volume, per VM, or per IO)
Offloads the CPU
FIPS-140-3

<u>**New SSD controller required**</u>



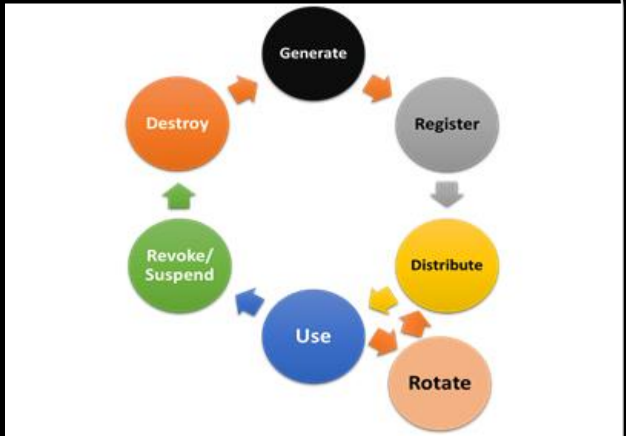
- Level 3 requires physical tamper circuitry inside SSD enclosure
- FIPS-140: US Government Security Requirements for Cryptographic Modules

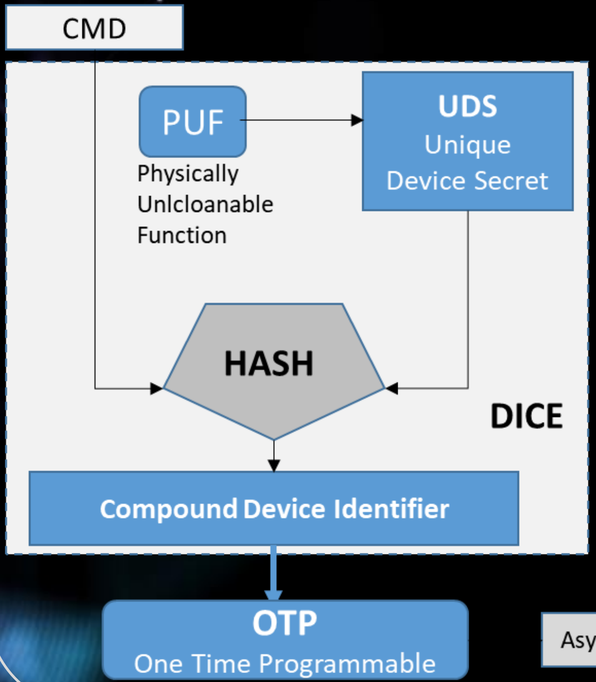
5. Key Management / 6. Security Lifecycle

allow peripherals to implement and interoperate with security best practices

5. Key Management

Key management focuses on **protecting keys from threats**, and **ensuring** security of keys thru lifecycle of SSD.





Asymmetric Key Table

TCG DICE is a requirement for Cerberus RoT and enables:

- **Attestation protocol**
- **Secure boot**
- **Key management**

6. Security Lifecycle

Security Lifecycle: Customers have requirements covering every stage from Manufacturing to Cloud Deployment to Infrastructure Decommissioning.

NIST 800-88 and ISO recommends how Keys generated, Crypto Erase and Media Sanitization. TCG Opal Spec recommends standards for Crypto Erase.

Manufacturing

- PUF
- UDS
- TRNG
- OTP

Vendor ID Inject

- DME
- Cerberus
- OTP

Decommission/Retire

- Crypto Erase
- Crypto Sanitize
- OTP

Microsoft Cerberus and Google OpenTitan

Cerberus spec is complex & several specifications including custom Azure lifecycle requirements

Security Pillars	Microsoft / facebook	Google
Root of Trust	Project Cerberus, arm	opentitan, RISC-V
Crypto Modules	✓ AES-256, ECDSA 384 ✓ SHA-512, RSA-4096,	✓ AES-128, ECDSA 256 ✓ RSA 3076, HMAC-SHA2
Secure Enclaves	✓ Isolated Power Domain ✓ Tamper shield, Temp	✓ Alert Responder
SED	✓ TCG Opal 2.01 ✓ PSID	✓ TCG Opal 2.01
Key Management	✓ TCG DICE ✓ 768-bits of OTP	✓ OTP
Security Lifecycle	✓ DME, PUF, UDS ✓ Crypto-Erase	✓ OTP fuses
Schedule	Microsoft Gen8 1H'21	2022+

Meets highest requirements

Meets minimum requirements

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Summary and Actions

- ➢ Computational Storage provides better application performance with new security challenges to solve.
  - Data at rest
  - Processed data
  - CSD to host data
- ➢ Cloud Service Provider data security policies need to be supported
- ➢ Hybrid cloud deployments need to address security concerns
  - On-premise or colocated
  - Cloud
- ➢ Industry Standards working groups are defining computational storage architectures with security in mind.
- ➢ Participate in standards committees and contribute to a secure computational storage ecosystem!

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