Guide to the CSA IoT Controls Matrix v3

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The permanent and official location for Cloud Security Alliance Internet of Things research is https://cloudsecurityalliance.org/working-groups/internet-of-things/

Acknowledgments

The CSA IoT Controls Matrix is updated and released at least annually. The following volunteers have generously contributed to the matrix over its lifetime.

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Introduction

The Internet of Things (IoT) market continues to expand with newly introduced advances in connectivity and autonomy across industry sectors. A reliance on IoT-generated data and features requires organizations that adopt these new technologies to plan for accessible, secure, and resilient deployments. Given the rapid evolution of connected technologies and the constant flow of new threats, these aspirations are challenging. Creating a safe IoT environment requires security engineering that addresses unique risks and employs appropriate mitigation measures. The *Cloud Security Alliance (CSA) IoT Security Controls Framework* provides a starting point for organizations that wish to better understand and implement security controls within their IoT architecture. This accompanying guide explains how enterprise organizations can use the Framework to securely evaluate and implement IoT systems.

Tailoring the Matrix

The *IoT Security Controls Framework* is relevant for enterprise IoT systems that deploy a diverse set of connected devices and associated cloud services, networking technologies, and application software. The Framework has utility across many IoT domains, ranging from systems processing only "low-value" data with limited impact potential, to sensitive systems that support critical services. System owners classify components based on the value of stored and processed data and the potential impact of various physical security threats.

The Framework helps users identify appropriate security controls and allocates them to specific architectural components, including:

- Devices
- Networks
- Gateways
- Cloud Services

Controls allocated to each layer in the architecture represent best-case security postures. In some cases, architectural components cannot implement specifically recommended controls in this Framework. In these cases, the system security architect should identify those shortcomings and develop plans to mitigate residual risk using alternative measures.

The framework can be tailored to specific cybersecurity architecture goals. For example, although no specific controls are included for zero trust, a security engineer can use the Framework to identify controls that would enable a zero-trust architecture (ZTA). Framework controls that call for microsegmentation (SNT-04), limiting privileged service operations (IAM-04), bootstrapping devices onto the network (IAM-07), and authenticating devices through a software-defined perimeter (SNT-02) can be used as a starting point for building a device-based ZTA.

Industry Profiles

Version 3 of this guide now includes industry profiles. These profiles represent starting points for securing industry-specific IoT devices such as medical devices, vehicles, and generic autonomous systems. Version 4 will see the addition of vehicle and generic autonomous systems controls, and ICS/IIoT controls.

Goal

The *IoT Security Controls Framework* is a tool to guide and evaluate security implementations as they progress through the development lifecycle to ensure they meet industry-specified best practices.

Audience

The *IoT Security Controls Framework* is a resource for system architects, developers, and security engineers to design secure IoT ecosystems. IoT system evaluators such as auditors and penetration testers may leverage the Framework to validate controls and implementations.

Versioning

Version 1 of the *IoT Security Controls Framework* introduces 160 base-level security controls required to mitigate many risks IoT systems face operating in various threat environments.

Version 2 of the *IoT Security Controls Framework* evolves the Version 1 Framework to categorize controls into a new set of domains, minimize control allocation to components within an IoT architecture, and reduce security controls to 155.

Version 3 of the *IoT Security Controls Framework* evolves the Version 2 Framework increasing the number of controls to 199 while adding a new incident management domain and improving technical clarity and referencing.

Future Changes - Version 4 may include one or more of the following improvements:

- Supply Chain Domain
- Vehicle and generic autonomous systems controls, and ICS/IIoT controls
- IoT Framework Shared Responsibility Matrix
- Safety specific controls
- Indicators of compromise
- IoT Framework mapping to the European Union Agency for Network and Information Security (ENISA)
- Guidelines for Securing the Internet of Things
- IoT Framework mapping to the National Institute of Standards and Technology (NIST)
- Cyber Security Framework (CSF) and 800-53 Mappings
- NIST Informative Reference Classification Application

Using the IoT Security Controls Framework

Figure 1 below details the flow that users of the CSA *IoT Security Controls Framework* should follow as they assess and then implement security controls for a unique environment. The letters in this illustration correspond to columns in the Framework (spreadsheet).

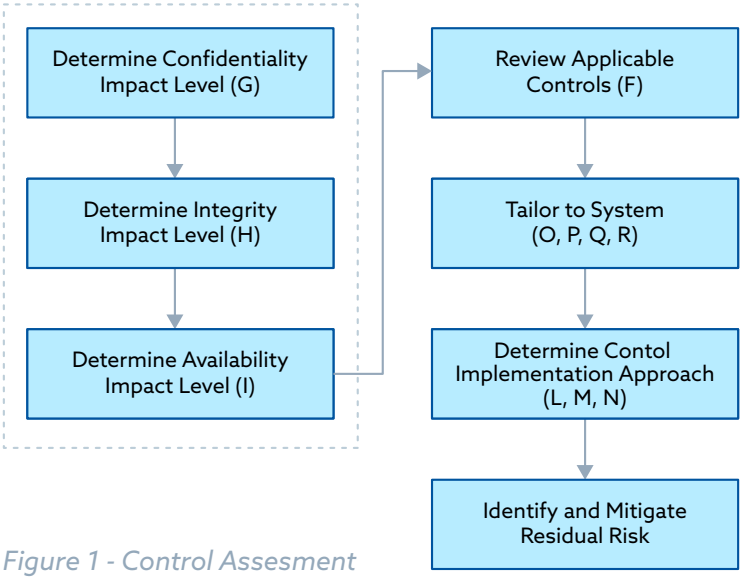


Figure 1 - Control Assesment

Evaluation begins by understanding the system architectures' security and data impact levels. These are characterized based on standard processes, such as Federal Information Processing Standard (FIPS) 199 "Standards for Security Categorization of Federal Information and Information Systems" Once impact-level determinations are made for system confidentiality, integrity, and availability, the Framework can be filtered to show only the controls applicable to those impact levels.

Review each of the resulting controls in Column F and review any additional guidance in Column J. Columns O, P, Q, and R include a tool for allocating controls to different architectural components. These columns allow users to filter controls based on whether they apply to the device, the network that hosts the device, a gateway, or cloud services.

Users can also understand how to implement each control using columns L, M, and N. These columns offer control-type recommendations, whether controls should be manual, automated, or a combination of both, and how often controls should be exercised.

The Framework provides insight into an idealized version of a secure baseline tailored to an IoT system architecture following this initial process. Some components within an IoT architecture may not meet a subset of the controls. In these cases, the security architect must understand the residual risk and identify compensating controls to mitigate that risk.

Security Control Objectives (Columns A, B, C, D, E, F)

A	B	C	D	E	F
			For more details about the framework, download the "Guide to the CSA IoT Controls Matrix" at: <link>		
Control Domain	**Control Domain**	**Control Sub-Domain**	**Control ID**	**CCM v4 Domain**	**Control**

Control Domain (Column A): Organized by logical groupings of the individual security control measures (see table below) and detailed in column F (Control), the name of each corresponding control specification is italicized below the category of "Control Domain."

Control Domain (Column B): Domains are categorized for filtering purposes.

Control Sub-Domain (Column C): Sub-domains provide granularity for filtering purposes.

#	Control Domain	Abbr.	Control Sub-Domain
1	Asset Management	ASM	Naming Convention, Inventory Assets, Monitor Assets
2	Configuration Management	CON	Configuration Files, Firmware Updates, Configuration Control, End-of-Life Planning
3	Cloud Services	CLS	Cloud IAM, Cloud Data Security, Cloud Infrastructure Security, Cloud Monitoring, Cloud API Security
4	Secure Data	DAT	Data Classification and Taxonomy, Data Cleansing, Encrypted Data at Rest
5	Governance	GVN	Governance Framework, Regulatory and Legal Requirements, Compliance Management, Privacy, Business Continuity, Safety
6	Identity and Access Management	IAM	Password Management, Authentication, Authorization, Access Control, Certificate Management, Key Management, Trust Anchor Management, Bootstrap, Account Audit
7	Incident Managemnt	IMT	Incident Planning, Incident Response, Collaboration, Remediation, Forensics, Automation
8	IoT Device Security	IOT	Certified Devices, Secure Platform, Secure Configuration
9	Legal	LGL	Legal Assessment, Legal Implementation Plan, Document Measures for Legal Purposes, Terms & Conditions & Privacy Policy, Contracts, Disclaimers, Disclosures, Notifications, Waivers, Liability, Data Transfer

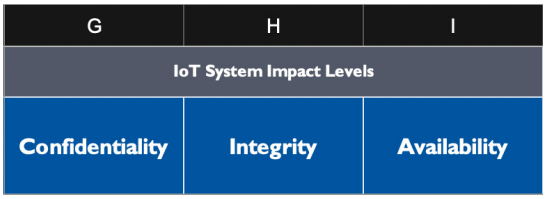
10	Monitoring and Logging	MON	Threat Intelligence, Threat Hunting, Automated Malware, Log Management, Analytics, Attack Sensing, RF Monitoring, Network Visualization
11	Operational Availability	OPA	Maintenance, Fail-over, DDoS Protection, Service Level Agreements
12	Physical Security	PHY	Physical Access Controls
13	Policy	POL	Policy Definition, Acquisition Security Policy, Secure Disposition
14	Risk Management	RSM	Risk Management Strategy, Risk Management Execution, Limit Liability
15	Secure Applications	SAP	Mobile Applications, ICS/IIoT, Autonomous Systems, Vehicles, Medical Devices
16	Secure System Development Lifecycle	SDV	Process Security, Supply Chain/ Acquisition, Secure Development Practices
17	Secure Networks	SNT	Secure Messaging, Secure Discovery, Automation, Encryption, Segmentation/VLANs, Network Access Control, Software-Defined Networking (SDP), Hardening, Single Packet Authentication, Secure Messaging, Whitelisting
18	Secure Wireless	SWS	Wireless Architecture, Bluetooth Security, NFC Security, Zigbee Security, ZWave Security, LoRaWAN Security, Cellular Security, Satellite Security, WiFi Security, Wireless Availability
19	Training	TRN	Administrator Training, User Training
20	Vulnerability Management	VLN	Responsible Disclosure Program, Vulnerability Scanning, Updates, and Patches
21	Security Testing	SET	Assessment Scoping and Planning, Penetration Testing, Red Teaming, Third-Party Assessments, Bug Bounty, IoT Applications and Services (Internally Developed)

Control ID (Column D): The control identification (ID) is the official identifier of a specific security control. The ID (e.g., "RSM-01") allows controls to be referenced elsewhere by their position in the framework.

CCM Domain (Column E): Security controls in the framework are associated, or mapped, in this column to the domains of the CSA Cloud Controls Matrix (CCM). When the IoT security control is derived or linked to a CCM control, one or more entries are identified. The associated controls involve partial to complete coverage of the control specifications in each framework.

Control Specification (Column F): Specifications are written as mitigations or countermeasures addressing specific risk areas for an IoT system. For usability, each control is separated into a simplified action to address unique IoT environments.

IoT System Risk Impact Levels (Columns G, H, I)



Columns G through I: This information enables the initial tailoring of security controls to a user's unique environment. Before beginning the process of tailoring individual security controls, users should review two U.S. Department of Commerce publications: "Standards for Security Categorization of Federal Information and Information Systems" *(FIPS 199)*[1] and "Minimum Security Requirements for Federal Information and Information Systems" *(FIPS 200)*[2]. Those publications categorize risk impact levels as "low," "moderate," or "high" in three areas: confidentiality, integrity, and availability.

Confidentiality (Column G): Some data in an IoT system, such as personal privacy and proprietary information, necessitates restricted access using various security controls to remain appropriately confidential. To evaluate components of an IoT system's confidentiality risk, it is necessary to estimate the potential impact (low, moderate, or high) if system data were made public or compromised by an attacker.

Integrity (Column H): To protect data integrity, an enterprise must guard against improper data modification or destruction and ensure information authenticity. To evaluate integrity risks of an IoT system, assess the impact (low, moderate, or high) if system data were destroyed or inappropriately modified.

Availability (Column I): To assess the degree to which system information must remain accessible in a timely and reliable manner, evaluate the potential system risks if it became inoperable for any duration.

To assess whether specific risks regarding confidentiality, integrity, and availability of system data is low, moderate, or high, consult the information in the *FIPS 199* publication called "POTENTIAL IMPACT DEFINITIONS FOR SECURITY OBJECTIVES."

After determining these risk impact levels, the IoT Security Controls Framework can identify all needed security controls for a specific environment.

1 FIPS 199: "Standards for Security Categorization of Federal Information and Information Systems," Federal Information Processing Standards Publication, Computer Security Division, U.S. Department of Commerce; February 2004. https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.199.pdf

2 FIPS 200: "Minimum Security Requirements for Federal Information and Information Systems," Federal Information Processing Standards Publication, Computer Security Division, U.S. Department of Commerce; March 2006. https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.200.pdf

Note that when an impact level is high, all available security controls should be applied—including those for low, moderate, and high-risk levels. When an impact level is moderate, apply all controls for moderate and low-risk levels.

Below are examples of three impact ratings and the necessary corresponding controls.

Type of Security Risk	Risk Impact Level	Necessary Security Controls
Confidentiality	High	High, Moderate, and Low
Integrity	Moderate	Moderate and Low
Availability	Low	Low Only

Figure 2 - CIA Examples

Supplemental Control Guidance (Columns J, K)

J	K
Additional Direction	**References**

Additional Direction (Column J): When assessing or implementing any of the individual security protocols in the IoT Security Controls Framework, be sure to view this supplementary information detailing special requirements, explanations of terms, helpful operating tips, and more.

References (Column K): Consult this section for professional source information, such as government publications, regulatory information, and other references necessary to understand and implement a control specification fully.

Implementation Guidance (Columns L, M, N)

L	M	N
Implementation Guidance		
Control Type	***Man Auto Semi***	***Freq***

When implementing an enterprise security plan, use the "Implementation Guidance" section to determine control types for unique environments (Column J). This insight will include how organizations can implement the controls (Column K) and the frequency with which each security control measure should be enacted (Column L).

Types of Security Controls (Column L)

The IoT Framework security controls are classified into three types, based on when, where, and how the measures work to increase security.

Preventive controls: Stop something from happening (i.e., limiting physical access to a room through a locked door or require higher-level biometric identification protocols).

Detective controls: Identify and then characterize incidents. Examples include researching an inventory discrepancy after a physical count, recording video, and using motion sensors to detect trespassing.

Corrective controls: Mitigate damage caused by security incidents. For example, use a fire extinguisher to limit fire damage or ensure the availability of a duplicate data center if a primary data center crashes.

Control Implementation Guidance (Column M)

Security controls are implemented in three ways, depending on the level of automation.

Manual controls: A human performs manual controls. For example, in a risk management process review, someone evaluates the process to confirm it has been executed in accordance with policy.

Automatic controls: A system performs automatic controls without human intervention. For example, in a user access check, a user logs in with a username and password. The system then verifies the combination before granting access.

Semi-automatic controls: Semi-automatic controls combine automated and manual efforts. For example, in a physical inventory, items are counted, and the results are compared to a system-generated list. Differences are then reconciled through an investigation, which may involve paper and electronic records.

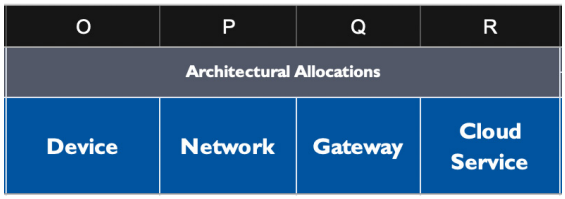
Control Frequency (Column N)

Some organizations require more frequent controls based on internal risk priorities or regulatory compliance requirements. The following frequencies are recommended for different situations (depending on individual enterprise needs).

- Annually
- Quarterly
- Monthly
- Weekly
- Daily
- Event: Control performed irregularly (e.g., a software update)
- Continuously: Control performed many times per day (e.g., user access)

Device, Network, Gateway, and Cloud Services (O, P, Q, R)

The IoT Framework guides the application of architectural element controls in an IoT system. These architectural elements represent standard layers within an IoT architecture, as shown in the below figure.



Implementers should consult these document sections to determine if controls are applicable at each layer. Each column describes opportunities to create trust boundaries within IoT architecture. Discrete controls should be applied at each layer.

Device (Column O)

Controls applied directly at the device layer that focuses on the data processed, stored, and/or generated by the device. A generic IoT device will incorporate sensors, actuators, and potentially a minimal user interface. The device may also be capable of collecting and storing events or security logs, using configuration files that must be integrity-protected.

Network (Column P)

At the network layer, components such as wireless access points (WAPs) support device Wi-Fi connectivity. Other network components may include key management servers that support protocols such as ZigBee. Additionally, network security controls may consist of zero trust designs, virtual local area network (VLAN) segmentation, firewalling, and intrusion detection. Consider data encryption and integrity protection as data traverses an IoT network.

Gateway (Column Q)

The gateway represents a high potential IoT network entry point for threat actors. The gateway may have additional security controls applied that exceed what devices typically implement.

Cloud Services (Column R)

Most IoT devices require cloud environments to operate. Devices may send data directly to the cloud or be managed through a cloud service. Data transmitted to the cloud must be protected during transit and persistently within cloud provider storage volumes. In some cases, anonymity protections must be applied within the cloud to ensure identities cannot be linked to IoT data.

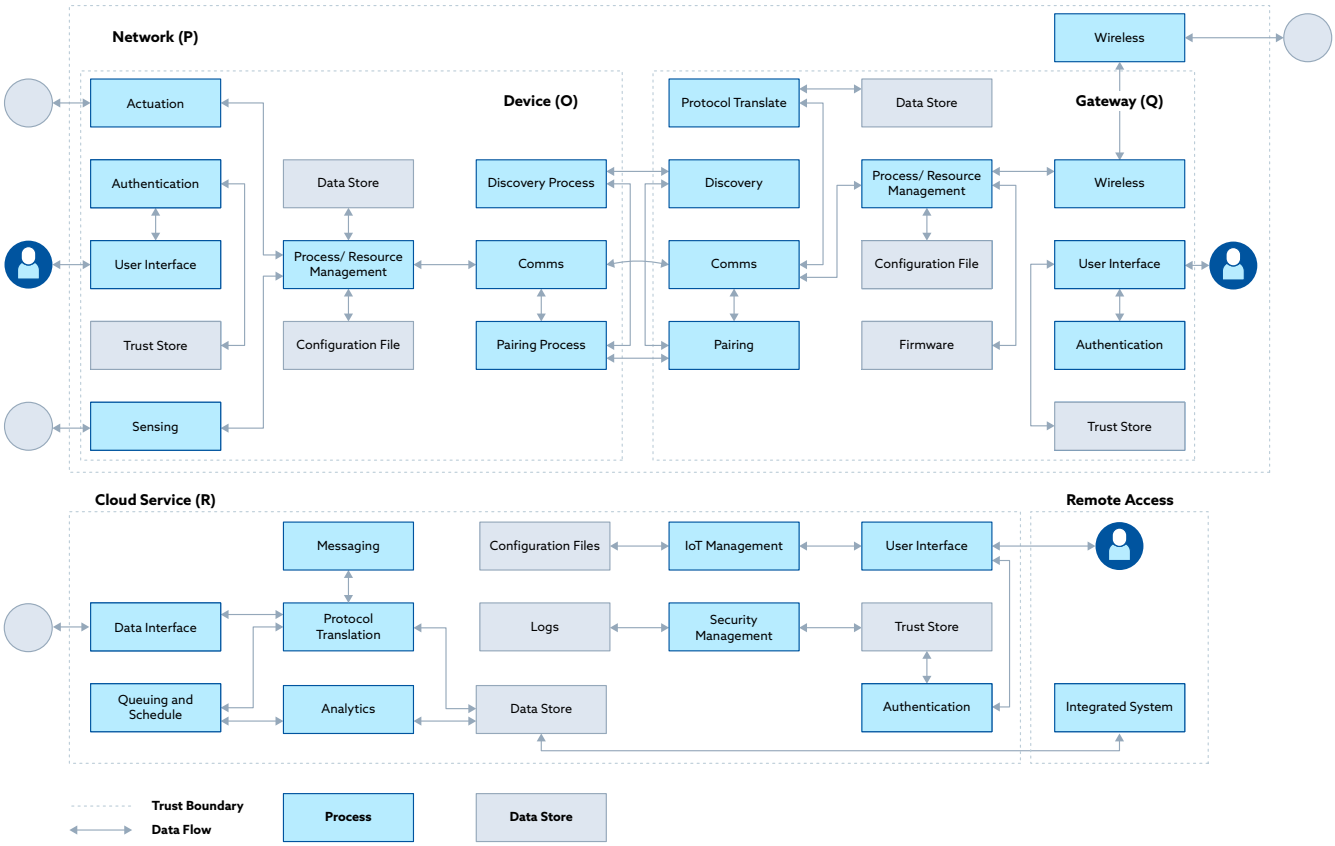


Figure 3 - Data flow between architectural elements

Additional Resources

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