RSA BSAFE® Crypto-C Micro Edition 4.1.4 Security Policy Level 1

This document is a non-proprietary Security Policy for the RSA BSAFE Crypto-C Micro Edition 4.1.4 (Crypto-C ME) cryptographic module from Dell Inc.

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Preface

This security policy describes how Crypto-C ME meets the relevant Level 1 and Level 3 security requirements of FIPS 140-2, and how to securely operate Crypto-C ME in a FIPS 140-2-compliant manner.

Federal Information Processing Standards Publication 140-2 - Security Requirements for Cryptographic Modules (FIPS 140-2) details the United States Government requirements for cryptographic modules. For more information about the FIPS 140-2 standard and validation program, see the FIPS 140-2 page on the NIST Web site.

References

This document deals only with operations and capabilities of the Crypto-C ME cryptographic module in the technical terms of a FIPS 140-2 cryptographic module security policy. More information about Crypto-C ME and the entire Dell product line is available at Dell Support:

Document Organization

This Security Policy explains the cryptographic module features and functionality relevant to FIPS 140-2, and comprises the following sections:

- This section, provides an overview and introduction to the Security Policy.
- Crypto-C ME Cryptographic Toolkit describes Crypto-C ME and how it meets FIPS 140-2 requirements.
- Secure Operation of Crypto-C ME specifically addresses the required configuration for the FIPS 140-2 mode of operation.
- Services lists the functions of Crypto-C ME.
- Acronyms and Definitions lists the acronyms and definitions used in this document.

Terminology

In this document, the term *cryptographic module*, refers to the Crypto-C ME FIPS 140-2 Security Level 1 validated cryptographic module.

1 Crypto-C ME Cryptographic Toolkit

Crypto-C ME is designed for different processors, and includes various optimizations. Assembly-level optimizations on key processors mean Crypto-C ME algorithms can be used at increased speeds on many platforms.

The Crypto-C ME software development toolkit is designed to enable developers to incorporate cryptographic technologies into applications. It helps to protect sensitive data as it is stored, using strong encryption techniques to ease integration with existing data models. Using Crypto-C ME in applications helps provide a persistent level of protection for data, lessening the risk of internal, as well as external, compromise.

Crypto-C ME offers a full set of cryptographic algorithms including asymmetric key algorithms, symmetric key block and stream algorithms, message digests, message authentication, and Pseudo Random Number Generator (PRNG) support. Developers can implement the full suite of algorithms through a single Application Programming Interface (API) or select a specific set of algorithms to reduce code size or meet performance requirements.

Note: When operating in a FIPS 140-2-approved manner, the set of available algorithms cannot be changed.

This section provides an overview of the cryptographic module and contains the following topics:

- Cryptographic Module
- Crypto-C ME Interfaces
- Roles, Services and Authentication
- Cryptographic Key Management
- Cryptographic Algorithms
- Self Tests.

1.1 Cryptographic Module

Crypto-C ME is classified as a multi-chip standalone cryptographic module for the purposes of FIPS 140-2. As such, Crypto-C ME must be tested on a specific operating system and computer platform. The cryptographic boundary includes Crypto-C ME running on selected platforms running selected operating systems while configured in “single user” mode. Crypto-C ME is validated as meeting all FIPS 140-2 Security Level 1 security requirements.

Crypto-C ME is packaged as a set of dynamically loaded shared libraries containing the module's entire executable code. The Crypto-C ME toolkit relies on the physical security provided by the hosting general purpose computer (GPC) in which it runs.

The following table lists the certification levels sought for Crypto-C ME for each section of the FIPS 140-2 specification.

Table 1 Certification Levels

Section of the FIPS 140-2 Specification	Level
Cryptographic Module Specification	3
Cryptographic Module Ports and Interfaces	1
Roles, Services, and Authentication	1
Finite State Model	1
Physical Security	N/A
Operational Environment	1
Cryptographic Key Management	1
EMI/EMC	1
Self-Tests	1
Design Assurance	3
Mitigation of Other Attacks	1
Overall	1

1.1.1 Laboratory Validated Operating Environments

For FIPS 140-2 validation, Crypto-C ME is tested by an accredited FIPS 140-2 testing laboratory on the following operating environments:

- SUSE Software Solutions®:
  - SUSE® Linux Enterprise Server 12 SP3 running on
    - VMware ESXi 6.0.0 running on a Dell PowerEdge™ R630 with Intel® Xeon® E5-2620, built with LSB 4.0 and gcc 4.4 (64-bit), with and without Intel AES-NI Processor Algorithm Accelerator (PAA).

1.1.2 Affirmation of Compliance for other Operating Environments

Affirmation of compliance is defined in Section G.5, "Maintaining validation compliance of software or firmware cryptographic modules," in Implementation Guidance for FIPS PUB 140-2 and the Cryptographic Module Validation Program. Compliance is maintained in all operational environments for which the binary executable remains unchanged.

The Cryptographic Module Validation Program (CMVP) makes no statement as to the correct operation of the module or the security strengths of the generated keys if the specific operational environment is not listed on the validation certificate.

Important: Dell affirms compliance of all patch and Service Pack levels with the same capabilities as the listed operating environments, unless noted otherwise.

For Crypto-C ME 4.1.4, Dell affirms compliance for the following operating environments:

- Canonical:
  - Ubuntu 18.04 LTS on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4.
  - Ubuntu 16.04 LTS on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4.
  - Ubuntu 14.04 LTS on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4.
- CentOS™ Project:
  - CentOS 8.0 on x86_64 (64-bit), built with Linux® Standard Base (LSB) 4.0 and gcc 4.4.
  - CentOS 7.9 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - CentOS 7.8 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - CentOS 7.7 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - CentOS 7.6 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - CentOS 6.10 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4.

- Dell™
  - PowerProtect™ Data Domain™ OS on x86_64 (64 bit), built with LSB 4.1 and gcc 4.8.3.
- Red Hat:
  - Enterprise Linux 8.1 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - Enterprise Linux 8.0 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - Enterprise Linux 7.9 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - Enterprise Linux 7.8 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - Enterprise Linux 7.7 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - Enterprise Linux 7.6 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - Enterprise Linux 6.10 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4.
- SUSE Software Solutions®:
  - SUSE® Linux Enterprise Server 15 SP2 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - SUSE Linux Enterprise Server 15 SP1 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - SUSE Linux Enterprise Server 15 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - SUSE Linux Enterprise Server 12 SP5, SP4, SP3, SP2 and SP1 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4
  - SUSE Linux Enterprise Server 11 SP4 on x86_64 (64-bit), built with LSB 4.0 and gcc 4.4.

1.1.3 Single Operator Mode

An Operator is an individual accessing the cryptographic module or a process operating the cryptographic module on behalf of the individual.

The operating system must enforce a single operator mode of operation, that is, concurrent operators are explicitly excluded.

Multi-user Operating Systems

For the following supported multi-user operating systems, the operating system and hardware enforce a single operator mode of operation by enforcing process isolation and CPU scheduling:

- Canonical Ubuntu
- CentOS Project CentOS
- Micro Focus SUSE
- Red Hat Enterprise Linux
- Dell PowerProtect DataDomain OS.

On these operating systems, running on a general purpose computer, dynamically loaded shared libraries, including the cryptographic module, are loaded into the address space of a process. Each instance of the cryptographic module functions entirely within the process space of the process containing the module.

The single operator for a given instance of the cryptographic module is the identity associated with the process containing the module. The operating system and hardware enforce process isolation including memory, where keys and intermediate key data are stored, and CPU scheduling. The writable memory areas of the cryptographic module, data and stack segments, are accessible only to the process containing the module.

The operating system is responsible for multitasking operations so that other processes cannot access the address space of the process containing the cryptographic module. Consequently, with the exception of privileged user accounts, no additional steps are required to restrict the operating system to a single operator mode of operation. That is, concurrent operators are explicitly excluded.

Privileged user accounts

Multi-user operating systems provide tracing and debugging utilities through which one process can control another, enabling the controller process to inspect and manipulate the internal state of its target process.

With the exception of privileged user accounts, root user/administrator user, the controller process must be running as the same user id as the target process for these utilities to work. This usage does not contravene the single operator mode of operation as both the controller and target processes are operating on behalf of a single operator.

Privileged user accounts are able to use tracing and debugging utilities to target a process with a different user id to the controlling process. An operator using this privilege to inspect or manipulate a process operating on behalf of another operator contravenes the single operator mode of operation.

To maintain the single operator mode of operation a privileged user must not use any of the system tracing and debugging utilities provided by the operating system.

In Unix-type operating systems the `ptrace` system call, the debugger `gdb`, `strace`, `ftrace` and `systemtrap` must not be used.

If necessary, the operating system can be configured to provide only a single operator. That is, login credentials for all user accounts, including privileged user accounts, can be provided to a single individual only.

Server environments

When the module is deployed in a server environment, the server application is the user of the module. The server application makes the calls to the module. Therefore, the server application is the single user of the module, even when the server application is serving multiple clients.

1.2 Crypto-C ME Interfaces

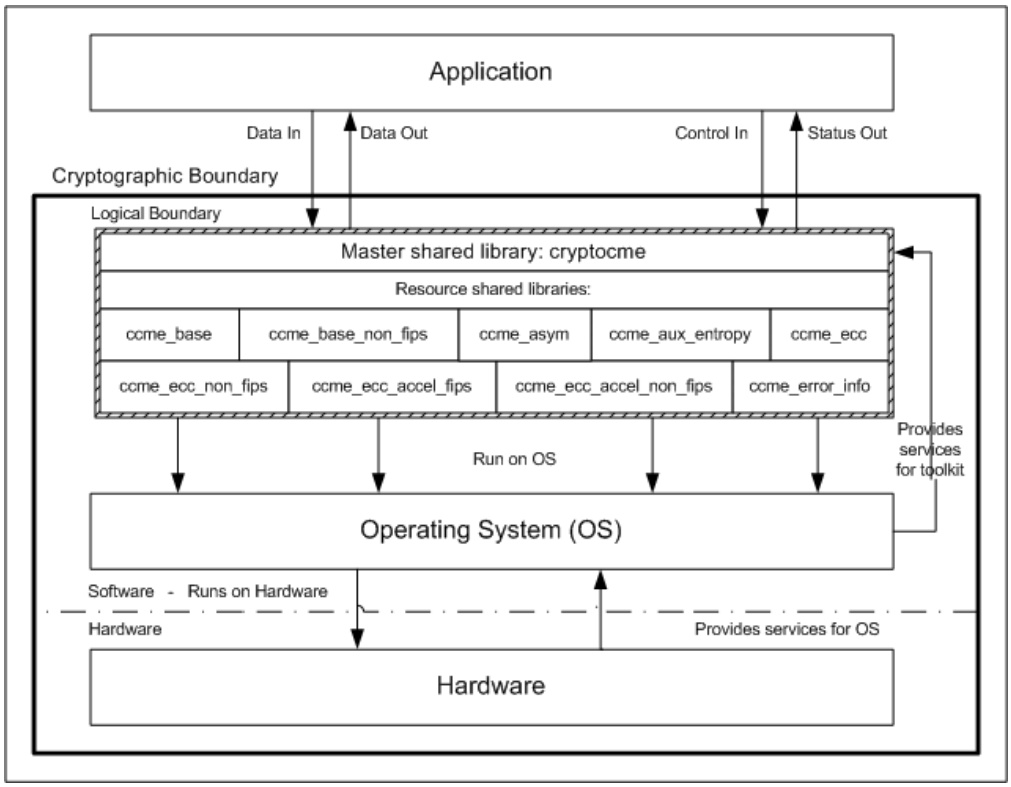
Crypto-C ME is validated as a multi-chip standalone cryptographic module. The physical cryptographic boundary of the module is the case of the general-purpose computer or mobile device, which encloses the hardware running the module. The physical interfaces for Crypto-C ME consist of the keyboard, mouse, monitor, CD-ROM drive, floppy drive, serial ports, USB ports, COM ports, and network adapter(s).

The logical boundary of the cryptographic module is the set of master and resource shared library files comprising the module:

- Master shared library:
  - `libcryptocme.so` on systems running a Linux operating system
- Resource shared libraries:
  - `libccme_base.so`, `libccme_base_non_fips.so`, `libccme_asym.so`, `libccme_aux_entropy.so`, `libccme_ecc.so`, `libccme_ecc_non_fips.so`, `libccme_ecc_accel_fips.so`, `libccme_ecc_accel_non_fips.so`, and `libccme_error_info.so` on systems running a Linux operating system.

The underlying logical interface to Crypto-C ME is the API, documented in the *RSA BSAFE Crypto-C Micro Edition Developers Guide*. Crypto-C ME provides for Control Input through the API calls. Data Input and Output are provided in the variables passed with the API calls, and Status Output is provided through the returns and error codes documented for each call. This is illustrated in the following diagram.

Figure 1 Crypto-C ME Logical Interfaces



1.3 Roles, Services and Authentication

Crypto-C ME meets all FIPS 140-2 Level 1 requirements for roles services and authentication, implementing both a Crypto User role and Crypto Officer role. As allowed by FIPS 140-2, Crypto-C ME does not support user identification or authentication for these roles. Only one role can be active at a time and Crypto-C ME does not allow concurrent operators. After loading, the cryptographic module is implicitly in the Crypto User role.

1.3.1 Crypto Officer Role

The Crypto Officer is responsible for installing and loading the cryptographic module. After the module is installed and operational, an operator can assume the Crypto Officer role by calling `R_PROV_FIPS140_assume_role()` with `R_FIPS140_ROLE_OFFICER`.

An operator assuming the Crypto Officer role can:

- Perform the full set of self tests.
- Call any Crypto-C ME function. For a complete list of functions available to the Crypto Officer, see Services.

1.3.2 Crypto User Role

A Crypto Officer can assume the Crypto User role by calling `R_PROV_FIPS140_assume_role()` with `R_FIPS140_ROLE_USER`.

An operator assuming the Crypto User role can use the entire Crypto-C ME API except for `R_PROV_FIPS140_self_tests_full()`, which is reserved for the Crypto Officer. For a complete list of Crypto-C ME functions, see Services.

1.4 Cryptographic Key Management

Cryptographic key management is concerned with generating keys, key assurance, storing keys, managing access to keys, protecting keys during use, and zeroizing keys when they are no longer required.

1.4.1 Key Generation

Crypto-C ME supports the generation of DSA, RSA, Diffie-Hellman (DH) and Elliptic Curve Cryptography (ECC) public and private keys. Crypto-C ME uses the CTR Deterministic Random Bit Generator (CTR DRBG) as the default pseudo-random number generator (PRNG) for asymmetric and symmetric keys.

When operating in a FIPS 140-2-approved manner, RSA keys can only be generated using the approved FIPS 186-4 RSA key generation method.

1.4.2 Key Assurance

Crypto-C ME supports validity assurance of asymmetric keys. Functions are available to test the validity of:

- ECC keys, and DSA keys and domain parameters, against FIPS 186-4
- RSA keys against FIPS 186-4 or SP 800-56B rev 2.

1.4.3 Key Storage

Crypto-C ME does not provide long-term cryptographic key storage. If a user chooses to store keys, the user is responsible for storing keys exported from the module.

The following table lists all keys and Critical Security Parameters (CSPs) in the module and where they are stored.

Table 2 Key Storage

Key or CSP	Generation/Input/Output	Storage
Hardcoded DSA public key	• Generated when the module is created • Cannot be output from the module.	Persistent storage embedded in the module binary
AES keys	• Entered in plaintext through the API or generated by an explicit API call • Output in plaintext through the API.	Volatile memory only (plaintext)
HMAC keys	• Entered in plaintext through the API or generated by an explicit API call • Output in plaintext through the API.	Volatile memory only (plaintext)
DH public/private keys	• Entered in plaintext through the API or generated by an explicit API call • Output in plaintext through the API.	Volatile memory only (plaintext)

Table 2 Key Storage (continued)

Key or CSP	Generation/Input/Output	Storage
ECC public/private keys	• Entered in plaintext through the API or generated by an explicit API call • Output in plaintext through the API.	Volatile memory only (plaintext)
RSA public/private keys	• Entered in plaintext through the API or generated by an explicit API call • Output in plaintext through the API.	Volatile memory only (plaintext)
DSA public/private keys	• Entered in plaintext through the API or generated by an explicit API call • Output in plaintext through the API.	Volatile memory only (plaintext)
CTR DRBG entropy	• Generated internally • Cannot be output from the module.	Volatile memory only (plaintext)
CTR DRBG V value	• Generated internally • Cannot be output from the module.	Volatile memory only (plaintext)
CTR DRBG key	• Generated internally • Cannot be output from the module.	Volatile memory only (plaintext)
CTR DRBG init_seed	• Generated internally • Cannot be output from the module.	Volatile memory only (plaintext)
HMAC DRBG entropy	• Generated internally • Cannot be output from the module.	Volatile memory only (plaintext)
HMAC DRBG V value	• Generated internally • Cannot be output from the module.	Volatile memory only (plaintext)
HMAC DRBG key	• Generated internally • Cannot be output from the module.	Volatile memory only (plaintext)
HMAC DRBG init_seed	• Generated internally • Cannot be output from the module.	Volatile memory only (plaintext)

CSP Usage:

- The hardcoded DSA public key is used to confirm the integrity of the module binaries during the module integrity POST.
- The DRBG CSPs (V value, key, `init_seed` and entropy) are all required for the correct operation of DRBG instances, as per SP 800-90A. The V value and the key represent the internal state of the DRBG. The `init_seed` is entropic data that is used to initialize the internal state of the DRBG.
- All other CSPs are loaded or generated by application calls to the module and are used in cryptographic operations performed by the application.

1.4.4 Key Access

An authorized operator of the module has access to all key data created during Crypto-C ME operation.

Note: The Crypto User and Crypto Officer roles have equal and complete access to all keys.

The following table lists the keys or CSPs with the different services provided by the toolkit, and the type of access to those keys or CSPs.

Table 3 Key and CSP Access

Key or CSP	Service Type	Type of Access
Asymmetric keys (RSA)	Asymmetric encryption and decryption	Read/Execute
Symmetric keys (AES)	Symmetric encryption and decryption	Read/Execute
Asymmetric keys (DSA, ECC, and RSA)	Digital signature and verification	Read/Execute
None	Message digest	N/A
HMAC keys	MAC	Read/Execute
CTR DRBG entropy, IV, key, and init_seed HMAC DRBG entropy, IV, key, and init_seed	Random number generation	Read/Write/ Execute
Symmetric keys (AES) MAC Keys (HMAC)	Key derivation	Write
Symmetric keys (AES) Asymmetric keys (DSA, RSA, DH, and ECC) MAC keys (HMAC)	Key generation	Write
Asymmetric keys (DSA, RSA, DH and ECC)	Key assurance	Read
Asymmetric keys (RSA, ECC)	Key establishment primitives	Read/Execute
Hardcoded DSA public key	Self-test	Read/Execute
None	Show status	N/A
All	Zeroization	Read/Write

1.4.5 Key Protection/Zeroization

All key data resides in internally allocated data structures and can be output only using the Crypto-C ME API. The operating system protects memory and process space from unauthorized access. The operator should follow the steps outlined in the *RSA BSAFE Crypto-C Micro Edition Developers Guide* to ensure sensitive data is protected by zeroizing the data from memory when it is no longer needed.

1.4.6 Key Wrapping

Crypto-C ME supports wrapping of raw key data, symmetric keys, and asymmetric keys using AES KW and AES KWP algorithms.

1.5 Cryptographic Algorithms

To achieve compliance with the FIPS 140-2 standard, only FIPS 140-2-approved or allowed algorithms can be used in an approved mode of operation.

Note: Crypto User Guidance on Algorithms provides algorithm-specific guidance on the use of the algorithms listed in this section.

1.5.1 FIPS 140-2-approved Algorithms

The following table lists the Crypto-C ME FIPS 140-2-approved algorithms, with appropriate standards and CAVP validation certificate numbers.

Table 4 Crypto-C ME FIPS 140-2-approved Algorithms

Algorithm Type	Algorithm and approved parameter/modulus/key sizes	Standard	Validation Certificate
Asymmetric Cipher	RSADP (RSA decryption primitive) component Modulus sizes: 2048 and 3072[1] bits	SP 800-56B rev 2	C584
Asymmetric Key	ECC		C584
	• Public Key Validation Curves: B-233, B-283, B-409, B-571, K-233, K-283, K-409, K-571, P-224, P-256, P-384, P-521	FIPS 186-4	
	• Key Pair Generation Curves: B-233, B-283, B-409, B-571, K-233, K-283, K-409, K-571, P-224, P-256, P-384, P-521	FIPS 186-4	
	FFC		
	• Domain Parameter Generation L = 2048, N = 224; L = 2048, N = 256; L = 3072, N = 256	FIPS 186-4	C584
	• Domain Parameter Validation L = 1024, N = 160	FIPS 186-2	C584
	• Domain Parameter Validation L = 1024, N = 160; L = 2048, N = 224; L = 2048, N = 256; L = 3072, N = 256	FIPS 186-4	C584
	• Key Pair Generation L = 2048, N = 224; L = 2048, N = 256; L = 3072, N = 256	FIPS 186-4	C584
	RSA		
	• Key Generation, Modulus sizes: 2048, 3072 bits	FIPS 186-4	C584
	• Key Validation, Modulus sizes: 2048, 3072 bits	SP 800-56B rev 2	VA

Table 4 Crypto-C ME FIPS 140-2-approved Algorithms (continued)

Algorithm Type	Algorithm and approved parameter/modulus/key sizes	Standard	Validation Certificate
Digital Signature	DSA • Signature Generation L = 2048, N = 224; L = 2048, N = 256; L = 3072, N = 256 • Signature Verification L = 1024, N = 160; L = 2048, N = 224; L = 2048, N = 256; L = 3072, N = 256	FIPS 186-4 FIPS 186-4	C584
	ECDSA • Signature and Signature Component Generation Curves: B-233, B-283, B-409, B-571, K-233, K-283, K-409, K-571, P-224, P-256, P-384, P-521 • Signature Verification Curves: B-163, B-233, B-283, B-409, B-571, K-163, K-233, K-283, K-409, K-571, P-192, P-224, P-256, P-384, P-521	FIPS 186-4 FIPS 186-4	C584
	RSA • Signature Generation Algorithms: X9.31, PKCS #1 V1.5, RSASSA-PSS Key (modulus) sizes: 2048, 3072 bits. • Signature Generation Algorithms: X9.31, PKCS #1 V1.5, RSASSA-PSS Key (modulus) sizes: 4096 bits. • Signature Verification Algorithms: X9.31, PKCS #1 V1.5, RSASSA-PSS Key (modulus) sizes: 1024, 2048, 3072 bits. • Signature Verification Algorithms: X9.31, PKCS #1 V1.5, RSASSA-PSS Key (modulus) sizes: 1024, 1536, 2048, 3072, 4096 bits. • RSASP1 (RSA signature primitive 1) component Key (modulus) sizes: 2048, 3072 [1] bits.	FIPS 186-4 FIPS 186-2 FIPS 186-4 FIPS 186-2 FIPS 186-4	C584
Key Agreement Primitives	ECC • Primitive CDH • Curves: B-233, B-283, B-409, B-571, K-233, K-283, K-409, K-571, P-224, P-256, P-384, P-521	SP 800-56A	C584
Key Derivation Functions (KDFs)	HMAC-based Extract-and-Expand KDF (HKDF): SHA-1, SHA-224, SHA-256, SHA-384, SHA-512, SHA3-224, SHA3-256, SHA3-384, SHA3-512	SP 800-56C	VA
	KBKDF, using pseudo-random functions: HMAC-based Feedback Mode[2], with: SHA-1, SHA-224, SHA-256, SHA-384, SHA-512	SP 800-108	C584
	Password-based Key Derivation Function 2 (PBKDF2) [3]	SP 800-132	VA[4]

Table 4 Crypto-C ME FIPS 140-2-approved Algorithms (continued)

Algorithm Type	Algorithm and approved parameter/modulus/key sizes	Standard	Validation Certificate
KDFs (continued)	TLS Pseudo-random Function (TLS PRF) - Component Test Protocol: TLS 1.0/1.1[5] TLS 1.2; SHA: SHA-256, SHA-384, SHA-512	SP 800-135 Rev. 1	C584
	X9.63 KDF - Component Test: SHA: SHA-224, SHA-256, SHA-384, SHA-512	ANSI X9.63, SP 800-135 Rev. 1	C584
Key Generation	Cryptographic Key Generation (CKG)	SP 800-133	VA
Key Wrap	AES in KW and KWP modes with 128, 192, and 256-bit key sizes	SP 800-38F	C584
MAC	GMAC: AES-128, AES-192, AES-256	SP 800-38D	C584
	HMAC SHA: SHA-1, SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, SHA-512/256	FIPS 198-1	C584
	HMAC SHA-3: SHA3-224, SHA3-256, SHA3-384, SHA3-512	FIPS 198-1	C584
Message Digest	SHA: SHA-1, SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, SHA-512/256	FIPS 180-4	C584
	SHA-3: SHA3-224, SHA3-256, SHA3-384, SHA3-512	FIPS 202	C584
Random Bit Generator	CTR DRBG AES-CTR mode with 128, 192, and 256-bit key sizes.	SP 800-90A Rev. 1	C584
	HMAC DRBG Modes SHA-1, SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, SHA-512/256 SHA3-224, SHA3-256, SHA3-384, SHA3-512	SP 800-90A Rev. 1 FIPS 202	C584
Symmetric Cipher	AES CBC, CFB 128-bit, ECB, OFB 128-bit, and CTR modes with 128, 192, and 256-bit key sizes	SP 800-38A	C584
	CCM modes with 128, 192, and 256-bit key sizes	SP 800-38C	
	GCM mode with automatic internally generated IV with 128, 192, and 256-bit key sizes	SP 800-38D	
	XTS mode with 128 and 256-bit key sizes.	SP 800-38E	

[1]A 3072-bit modulus is not tested by the CAVP but is approved for use in the FIPS 140-2 approved mode of operation. Dell affirms correct implementation of RSADP and RSASP1 with a 3072-bit modulus.

[2] As defined by the HKDF expand step,

[3]As defined in SP 800-132, PBKDF2 can be used in FIPS 140-2 approved mode of operation when used with FIPS 140-2-approved symmetric key and message digest algorithms. For more information, see Crypto User Guidance.

[4]Not yet tested by the CAVP, but is approved for use in FIPS 140-2 approved mode of operation. Dell affirms correct implementation of the algorithm.

[5]The TLS 1.0 and 1.1 KDF, documented in SP 800-135, are only allowed when the conditions detailed in the Crypto User Guidance are satisfied.

1.5.2 FIPS 140-2-allowed Algorithms

The following table lists the Crypto-C ME FIPS 140-2-allowed algorithms, with appropriate standards.

Table 5 Crypto-C ME FIPS 140-2-allowed Algorithms

Algorithm Type	Algorithm	Standard
Key Encapsulation	RSA PKCS #1 v1.5 key decryption Modulus sizes: 2048 to 15360 in increments of 256 bits	IG D.9 RFC 2313
Message Digest	MD5[1] • As part of an approved key transport scheme, for example, TLS 1.0, where no security is provided by the MD5 algorithm.	SP 800-135 Rev. 1 RFC 2246 RFC 4346
Random Number	Non-deterministic Random Number Generator (NDRNG) Entropy source to seed the random number generator.	IG G.13

[1]MD5 is allowed in the FIPS140-2 approved mode of operation for a purpose that is not security relevant or is redundant to an approved cryptographic algorithm. See section 4.2.1 of SP 800-135 Rev. 1 and IG 1.23

1.5.3 Non-FIPS 140-2-approved Algorithms

The following table lists the algorithms that are not FIPS 140-2-approved.

Table 6 Crypto-C ME non-FIPS 140-2-approved Algorithms

Algorithm Type	Algorithm
Asymmetric Key	ECAES, ECIES
	FFC • Key Pair Validation (SP 800-56A) L = 2048, N = 224; L = 2048, N = 256; L = 3072, N = 256 • DH Key Pair Generation (IEEE P-1363) 2048 bits <= L <= 8192 bits and N >= 224 bits
Key Agreement Primitives	ECC • Primitives: ECDH (IG D.8, SECG SEC 1) • Curves: B-233, B-283, B-409, B-571, K-233, K-283, K-409, K-571, P-224, P-256, P-384, P-521
	FFC • Primitive: DH (SP 800-56A, IG D.8, IEEE P-1363) • Domain parameter-size sets: L=2048, N=224; L=2048, N=256

Table 6 Crypto-C ME non-FIPS 140-2-approved Algorithms (continued)

Algorithm Type	Algorithm
Key Agreement Schemes	ECC (SP 800-56A) • Schemes: Full Unified Model, Ephemeral Unified Model, One-Pass Unified Model, One-Pass Diffie-Hellman Model and Static Unified Model • Curves: P-224, P-256, P-384, P-521
	FFC (SP 800-56A) • Schemes: dhHybrid1, dhEphem, dhHybridOneFlow, dhOneFlow and dhStatic • Domain parameter-size sets: L=2048, N=224; L=2048, N=256
Key Derivation Function	SCrypt PBKDF1 Shamir's Secret Share
Key Transport Schemes	KTS-OAEP, KTS-OAEP-Party_V-confirmation, KTS-KEM-KWS, KTS-KEM-KWS-Party_V-confirmation (SP 800-56B) Modulus sizes: 2048 and 3072-bit
Key Wrap	RSA-OAEP and RSA-KEM-KWS (SP 800-56B) Modulus sizes: 2048 and 3072-bit.
Message Digest	MD2, MD4
MAC	HMAC-MD5
Random Number	Non-approved RNG (FIPS 186-2) Non-approved RNG (OTP).
Symmetric Cipher	AES in CFB 64-bit, CTS, and BPS[1] ARIA DES, Triple-DES (two-key), Triple-DES (three key), DESX, DES40, DES in BPS mode Camellia GOST RC2, RC4, RC5 SEED.

[1]For format-preserving encryption (FPE).

For more information about using Crypto-C ME in a FIPS 140-2-compliant manner, see Secure Operation of Crypto-C ME.

1.6 Self Tests

Crypto-C ME performs a number of power-up and conditional self-tests to ensure proper operation.

If a power-up self-test fails for one of the resource libraries, all cryptographic services for the library are disabled. Services for a disabled library can only be re-enabled by reloading the FIPS 140-2 module. If a conditional self-test fails, the operation fails but no services are disabled.

For self-test failures (power-up or conditional) the library notifies the user through the returns and error codes for the API.

1.6.1 Power-up Self-test

Crypto-C ME implements the following power-up self-tests:

- AES in CCM, GCM, GMAC, and XTS mode Known Answer Tests (KATs) (encrypt/decrypt)
- SHA-1,
  SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, SHA-512/256,
  SHA3-224, SHA3-256, SHA3-384, and SHA3-512 KATs
- HMAC SHA-1,
  HMAC SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, SHA-512/256,
  HMAC SHA3-224, SHA3-256, SHA3-384, and SHA3-512 KATs
- ANSI X9.63 KDF |
  HKDF
  Single-step KDF
  TLS 1.0/1.1 PRF, TLS 1.2 PRF KATs
- RSA sign/verify KATs
- RSA pair-wise consistency test
- DSA pair-wise consistency test
- ECDSA pair-wise consistency test
- DH, ECDH and ECDHC conditional tests
- PRNG (CTR DRBG and HMAC DRBG) KATs
- Software integrity test using DSA signature verification.

Power-up self-tests are executed automatically when the module loads into memory.

1.6.2 Conditional Self-tests

Crypto-C ME performs two conditional self-tests:

- A pair-wise consistency test each time Crypto-C ME generates a DH, DSA, RSA, or ECC public/private key pair.
- A Continuous Random Number Generation (CRNG) test each time the toolkit produces random data, as per the FIPS 140-2 standard. The CRNG test is performed on all approved and non-approved PRNGs (CTR DRBG, HMAC DRBG, NDRNG (Entropy), non-approved RNG (FIPS 186-2) and non-approved RNG (OTP)).
- DRBG tests are run during instantiation, random generation, and re-seeding by the toolkit.

1.6.3 Mitigation of Other Attacks

The following table describes the mechanisms employed to mitigate against attacks which might prevent proper operation of the module.

Table 7 Mitigation of Other Attacks

Attack	Mitigation Mechanism
Timing Attack on RSA	Blinding
Padding Oracle Attack on PKCS #1	Constant time padding operation

Blinding:

RSA key operations implement blinding, a reversible way of modifying the input data, so as to make the RSA operation immune to timing attacks. Blinding has no effect on the algorithm other than to mitigate attacks on the algorithm. Blinding is implemented through blinding modes, and the following options are available:

- Blinding mode off.
- Blinding mode with no update, where the blinding value is constant for each operation.
- Blinding mode with full update, where a new blinding value is used for each operation.

RSA signing operations implement a verification step after private key operations. This verification step, which has no effect on the signature algorithm, is in place to prevent potential faults in optimized Chinese Remainder Theorem (CRT) implementations. For more information, see Modulus Fault Attacks Against RSA-CRT Signatures.

Constant time padding operation:

RSA PKCS#1 v1.5 encryption padding operations are implemented in constant time in order to make the operation immune to timing attacks. For more information, see Chosen Ciphertext Attacks Against Protocols Based on the RSA Encryption Standard PKCS #1.

2 Secure Operation of Crypto-C ME

This section provides an overview of how to securely operate Crypto-C ME in compliance with the FIPS 140-2 standards.

Note: The module operates as a Validated Cryptographic Module only when the rules for secure operation are followed.

2.1 Crypto User Guidance

This section provides guidance to the module user to ensure that the module is used in a FIPS 140-2 compliant way.

Section 2.1.1 provides algorithm-specific guidance. The requirements listed in this section are not enforced by the module and must be ensured by the module user.

Section 2.1.2 provides guidance on obtaining assurances for Digital Signature Applications.

Section 2.1.3 provides guidance on obtaining assurances for Key Transport Applications.

Section 2.1.3 provides information about the minimum length of passwords.

Section 2.1.4 provides general crypto user guidance.

2.1.1 Crypto User Guidance on Algorithms

The following guidance is provided for Crypto Users operating in the FIPS 140-2 approved mode.

The Crypto User must use only those algorithms approved or allowed for use in a FIPS 140-2 approved mode of operation. These algorithms are listed in:

- Table 4, Crypto-C ME FIPS 140-2-approved Algorithms
- Table 5, Crypto-C ME FIPS 140-2-allowed Algorithms.

For:

- Key Agreement:
  - For ECC based DH key agreement schemes:
    - Curves with:
      - at least 112 bits of security strength are **allowed**
      - less than 112 bits of security strength are **not allowed**.

        - The key establishment methodology provides:
            - between 112 bits and 256 bits of encryption strength when using **approved** domain parameter size sets, as listed in Table 4.
            - between 112 and 256 bits of encryption strength when curves that are **allowed**.
            - less than 112 bits of encryption strength when using curves that are **not allowed**.
- Key Transport/Wrapping:
    - For key wrapping using AES:
        - The key establishment methodology provides between 128 and 256 bits of encryption strength.
    - For RSA Key Transport/Wrapping schemes:
        - There are no RSA key transport or key wrapping algorithms available in the module's approved mode of operation.
- Digital Signatures.
    - An approved DRBG must be used for digital signature generation.
    - Keys used for digital signature generation and verification shall not be used for any other purpose.
    - SHA1 is **disallowed** for the generation of digital signatures.
    - For DSA:
        - When generating domain parameters, generation shall comply with FIPS 186-4 by specifying the algorithm identifier `R_CR_ID_DSA_PARAMETER_GENERATION` when creating the `R_CR` object.
        - There are no *non-approved but allowed* domain parameter set sizes. See Table 4 for approved domain parameter set sizes.
    - For ECDSA:
        - In addition to the approved named curves listed in Table 4, curves with the domain parameters generated in compliance with the rules specified in Section 6.1.1 of FIPS 186-4 are **approved** for signature verification.

          The domain parameters can be specified by name, or can be explicitly defined

          The use of these curves is also approved for signature generation if the key size is at least 224 bits.
        - There are no *non-approved but allowed* curves.
    - For RSA based schemes:
        - The length of an RSA key pair for digital signature generation must be greater than or equal to 2048 bits. For digital signature verification, the length must be greater than or equal to 2048 bits, however 1024 bits is

allowed for legacy-use only. RSA keys shall have a public exponent of an odd number, equal to or greater than 65537.

- For RSASSA-PSS:
  - If the length of the RSA modulus in bits is 1024 bits, and the output length of the **approved** hash function output block is 512 bits, then the length of the salt (`sLen`) shall be `0<=sLen<=hLen - 2`

    where `hLen` is the length of the hash function output block, in bytes or octets
  - Otherwise, the length of the salt shall be `0 <=sLen<=hLen`.

- KDFs:
  - For HKDF:
    - A FIPS 140-2 approved HMAC must be used.
    - A particular key-derivation key must only be used for a single key-expansion step. For more information see SP 800-56C Rev. 1
    - The derived key must be used only as a secret key.
    - The derived key shall not be used as a key stream for a stream cipher.
    - When selecting an HMAC hash, the output block size must be equal to or greater than the desired security strength of the derived key.
  - For PBKDF2:
    - Passwords must be generated using a cryptographically secure random password generator that employs an approved DRBG.
    - The minimum password length depends on the character set chosen.

      For examples, see Information on Minimum Password Length.
    - The length of the randomly-generated portion of the salt shall be at least 16 bytes. For more information see SP 800-132.
    - The iteration count shall be selected as large as possible, a minimum of 10,000 iterations is recommended.

      See section 5.1.1.2, *Memorized Secret Verifiers*, of SP 800-63B.
    - The maximum key length is `(232 -1)*b`, where `b` is the digest size of the hash function.
    - The key derived using PBKDF2 can be used as referred to in SP 800-132, Section 5.4, option 1 and 2.
    - Keys generated using PBKDF2 shall only be used in data storage applications.
  - For Single-step KDF:
    - A FIPS 140-2 approved HMAC must be used.
  - For TLS 1.0, 1.1 and 1.2 Key Derivation:

- The TLS 1.0 and 1.1 KDF is allowed only when the following conditions are satisfied:
  - The KDF is performed in the context of the TLS protocol
  - SHA-1 and HMAC are as specified in FIPS 180-4 and FIPS 198-1, respectively.
- The TLS 1.2 KDF, is allowed only when the following conditions are satisfied:
  - The KDF is performed in the context of the TLS protocol
  - HMAC is as specified in FIPS 198-1
  - P_HASH uses either SHA-256, SHA-384 or SHA-512.

For more information, see SP 800-135 Rev. 1.

The TLS protocols have not been tested by the CAVP and CMVP.

- MAC:
  - The key length for an HMAC generation or verification must be equal to or greater than 112 bits.
  - For HMAC verification, a key length greater than or equal to 80 and less than 112 is allowed for **legacy-use**.
- Random Bit Generator:
  - Only FIPS 140-2 Approved DRBGs may be used for generation of keys, asymmetric and symmetric.
  - When using an approved DRBG, the number of bits of entropy input must be equivalent to or greater than the security strength of the keys the caller wishes to generate. For example, a 256-bit or higher entropy input when generating 256-bit AES keys.
  - When using an Approved DRBG to generate keys or FFC domain parameters, the requested security strength of the DRBG must be at least as great as the security strength of the key or domain parameters being generated. That means that an Approved DRBG with an appropriate strength must be used.

    For more information about requesting the DRBG security strength, see the **API Reference Information > Pseudo-random Number Generation** section in the *RSA BSAFE Crypto-C Micro Edition Developers Guide*.

    For further information, see **Table 3: Hash functions that can be used to provide the targeted security strengths** in SP 800-57 Part 1 Rev. 4.
  - As the module does not modify the output of an Approved DRBG, any generated symmetric keys or seed values are created directly from the output of the Approved DRBG.
- Symmetric Cipher:
  - When using GCM feedback mode for symmetric encryption, the authentication tag length and authenticated data length may be specified as input parameters, but the IV must not be specified. It must be generated internally. IV generation operates in one of two ways:

- In regular use, the generated IV is fully random, generated by an approved PRNG, with a default length of 96 bits. No special considerations are required provided the system has sufficient entropy.
- When used for TLS 1.2 protocol GCM cipher suites, as in RFC 5288, the four-byte salt derived from the TLS handshake process must be input using the identifier `R_CR_INFO_ID_CIPHER_PARTIAL_IV` during cipher initialization. This is used as the first four bytes of IV. The remaining eight bytes of IV, referred to as `nonce_explicit` in RFC 5288, are generated deterministically by the module using an 64-bit global counter within the module. The module uses the current system time to initialize the counter when it is first used. The module user must ensure the system time is valid to prevent repetition of IVs.

– In case the power to the module is lost and then restored, a new key must be used for AES GCM encryption/decryption.

– AES in XTS mode is approved only for hardware storage applications.

  The two keys concatenated to create the single double-length key must be checked to ensure they are different. This is the default for the module.

  If the check is turned off by calling `R_CR_set_info()` with `R_CR_INFO_ID_CIPHER_XTS_KEY_CHECK`, AES in XTS mode is not FIPS 140-2-approved.

– The following restrictions apply to the use of Triple-DES. For:

  - Two-key Triple-DES and Three-key Triple_DES:
    - The use of Triple-DES for encryption is **disallowed**.
    - Decryption using Triple-DES is allowed for **legacy-use**

      The user should determine the risk of accepting the decrypted information when processing more than 2^{20} blocks of data encrypted using Triple-DES.

    For more information about the use of Triple-DES, see SP 800-131A Rev 1.

2.1.2 Crypto User Guidance on Obtaining Assurances for Digital Signature Applications

The module provides support for the FIPS 186-4 standard for digital signatures. The following gives an overview of the assurances required by FIPS 186-4. SP 800-89 provides the methods to obtain these assurances.

The tables below describe the FIPS 186-4 requirements for signatories and verifiers and the corresponding module capabilities and recommendations.

Table 8 Signatory Requirements

FIPS 186-4 Requirement	Module Capabilities and Recommendations
Obtain appropriate DSA and ECDSA parameters when using DSA or ECDSA.	The generation of DSA parameters is in accordance with the FIPS 186-4 standard for the generation of probable primes. For ECDSA, use the NIST recommended curves as defined in section 2.1.1.
Obtain assurance of the validity of those parameters.	The module provides the API R_CR_validate_key() to validate DSA parameters for probable primes as described in FIPS 186-4. For ECDSA, use the NIST recommended curves as defined in section 2.1.1.
Obtain a digital signature key pair that is generated as specified for the appropriate digital signature algorithm.	The module generates the digital signature key pair according to the required standards. Choose a FIPS-Approved DRBG like HMAC DRBG to generate the key pair.
Obtain assurance of the validity of the public key.	The module provides the API R_CR_validate_key() to explicitly validate the public key according to SP 800-89.
Obtain assurance that the signatory actually possesses the associated private key.	The module verifies the signature created using the private key, but all other assurances are outside the scope of the module.

Table 9 Verifier Requirements

FIPS 186-4 Requirement	Module Capabilities and Recommendations
Obtain assurance of the signatory's claimed identity.	The module verifies the signature created using the private key, but all other assurances are outside the scope of the module.
Obtain assurance of the validity of the domain parameters for DSA and ECDSA.	The module provides the API R_CR_validate_key()to validate DSA parameters for probable primes as described in FIPS 186-4. For ECDSA, use the NIST recommended curves as defined in section 2.1.1.
Obtain assurance of the validity of the public key.	The module provides the API R_CR_validate_key() to explicitly validate the public key according to SP 800-89.

Table 9 Verifier Requirements (continued)

FIPS 186-4 Requirement	Module Capabilities and Recommendations
Obtain assurance that the claimed signatory actually possessed the private key that was used to generate the digital signature at the time that the signature was generated.	Outside the scope of the module.

2.1.3 Information on Minimum Password Length

Key Derivation Threat Model:

If an adversary has access to 1 million Graphics Processing Units (GPUs), each of which can process 1,000 million hashes per second, they can perform 6×10^{16} hashes per minute.

For PBKDF2, with an iteration count of 10,000, where each iteration involves a HMAC that requires at least 2 hashes, the adversary has a 1 in 100,000 chance of brute forcing a password in one minute if the password search space has 3×10^{17} entries.

For the roles database the adversary must not have more than a 1 in 1,000,000 chance of guessing the PIN in a single attempt. This can be prevented by having at least 20 random bits in the PIN.

To comply with both roles database requirements the PIN must have a minimum of 73 random bits.

Minimum Password Length:

The minimum length (L) of a password generated using a cryptographically secure random password generator to provide a search space of S entries depends on the size (N) of the character set:

$L = \lceil \log_2 S / \log_2 N \rceil$

The following table provides examples for a password used by PBKDF2:
$S = 4.32 \times 10^{20}$

Character Set	N	L
Case sensitive (a-z, A-Z)	52	13
Case sensitive alpha numeric	62	12
All ASCII printable characters except space	94	11

2.1.4 General Crypto User Guidance

Crypto-C ME users should take care to zeroize CSPs when they are no longer needed. For more information on clearing sensitive data, see section 1.4.5 and the relevant API documentation in the *RSA BSAFE Crypto-C Micro Edition Developer Guide*.

2.2 Roles

If a user of Crypto-C ME needs to operate the toolkit in different roles, then the user must ensure all instantiated cryptographic objects are destroyed before changing from the Crypto User role to the Crypto Officer role, or unexpected results could occur. The following table lists the roles in which a user can operate:

Table 10 Services Authorized for Roles

Role	Authorized Services
Crypto Officer R_FIPS140_ROLE_OFFICER	All services.
Crypto User R_FIPS140_ROLE_USER	All services except R_PROV_FIPS140_self_tests_full().

The complete list of the functionality available is outlined in Services.

2.3 Modes of Operation

The following table lists the available mode filters to determine the mode Crypto-C ME operates in and the algorithms allowed.

Table 11 Crypto-C ME Mode Filters

Mode	Description
R_MODE_FILTER_FIPS140	FIPS 140-2-approved. Implements FIPS 140-2 mode and provides the cryptographic algorithms listed in Table 4. The default pseudo-random number generator (PRNG) is CTR DRBG.
R_MODE_FILTER_FIPS140_SSL	FIPS 140-2-approved if used with TLS protocol implementations. Implements FIPS 140-2 SSL mode and provides the same algorithms as R_LIB_CTX_MODE_FIPS140, plus the MD5 message digest algorithm. This mode can be used in the context of the key establishment phase in the TLS 1.0 and TLS 1.1 protocol. For more information, see Section D.2, "Acceptable Key Establishment Protocols," in Implementation Guidance for FIPS PUB 140-2 and the Cryptographic Module Validation Program. The implementation guidance disallows the use of the SSLv2 and SSLv3 versions. Cipher suites including non-FIPS 140-2- approved algorithms are unavailable. This mode allows implementations of the TLS protocol to operate Crypto-C ME in a FIPS 140-2-compliant manner with CTR DRBG as the default PRNG.
R_MODE_FILTER_JCMVP	Not FIPS 140-2-approved. Implements Japan Cryptographic Module Validation Program (JCMVP) mode and provides the cryptographic algorithms approved by the JCMVP.
R_MODE_FILTER_JCMVP_SSL	Not FIPS 140-2-approved. Implements JCMVP SSL mode and provides the cryptographic algorithms approved by the JCMVP, plus the MD5 message digest algorithm.

In each mode of operation, the complete set of services, which are listed in this Security Policy, are available to both the Crypto Officer and Crypto User roles (with the exception of `R_PROV_FIPS140_self_tests_full()`, which is always reserved for the Crypto Officer).

Note: Cryptographic keys must not be shared between modes. For example, a key generated FIPS 140-2 mode must not be shared with an application running in a non-FIPS 140-2 mode.

2.4 Operating Crypto-C ME

Crypto-C ME operates in an unrestricted mode on startup, providing access to all cryptographic algorithms available from the FIPS 140-2 provider set against the library context. To restrict the module to a specific set of algorithms, call `R_LIB_CTX_set_mode()` with one of the mode filters listed in listed in Table 11.

After setting Crypto-C ME into a FIPS 140-2-approved mode, only the algorithms listed in Table 4 are available to operators.

To disable FIPS 140-2 mode, call `R_LIB_CTX_set_mode()` with `NULL` to put Crypto-C ME back into an unrestricted mode.

To retrieve the current Crypto-C ME FIPS 140-2 mode, call `R_LIB_CTX_get_mode()`.

To run self-tests on the FIPS 140-2 module the application must ensure that there are no cryptographic operations using the module.

`R_PROV_FIPS140_self_tests_full()` is restricted to operation by the Crypto Officer.

The user of Crypto-C ME links with the `ccme_core` and `ccme_fipsprov` static libraries for their platform. At run time, `ccme_fipsprov` loads the `cryptocme` master shared library, which then loads all of the resource shared libraries. For more information, see **Get Stated with Crypto-C ME > About Your Binary Installation > Installed Library Files** in the *RSA BSAFE Crypto-C Micro Edition Developers Guide*.

The current Crypto-C ME role is determined by calling `R_LIB_CTX_get_info()` with `R_LIB_CTX_INFO_ID_ROLE`. The role is changed by calling `R_PROV_FIPS140_assume_role()` with one of the information identifiers listed in Table 10.

2.5 Startup Self-tests

To operate in a FIPS 140-2-compliant manner, Crypto-C ME executes self-tests when the module is first loaded.

2.6 Deterministic Random Number Generator

In all modes of operation, Crypto-C ME provides the CTR DRBG as the default deterministic random number generator (DRNG).

Users can choose to use an approved DRNG other than the default, including the HMAC DRBG implementations, when creating a cryptographic object and setting this object against the operation requiring random number generation (for example, key generation).

Crypto-C ME also includes a non-approved NDRNG (Entropy) used to generate seed material for the DRNGs.

2.6.1 DRNG Seeding

In the FIPS 140-2 validated library, Crypto-C ME implements DRNGs that can be called to generate random data. The quality of the random data output from these DRNGs depends on the quality of the supplied seeding (entropy).

The DRNG is seeded with an amount of entropy that depends upon the security strength of the DRNG mode, up to a maximum of 256 bits of security strength.

DRBG Mode	Entropy Obtained (bits)
CTR DRBG	
CTR -AES-256	256
HMAC DRBG	
HMAC-SHA1	128
HMAC-SHA224	192
HMAC-SHA256	256
HMAC-SHA384	256
HMAC-SHA512	256
HMAC-SHA512-224	192
HMAC-SHA512-256	256
HMAC-SHA3-224	192
HMAC-SHA3-256	256
HMAC-SHA3-384	256
HMAC-SHA3-512	256

Crypto-C ME provides internal entropy collection, for example, from high precision timers, where possible. On platforms with limited internal sources of entropy, it is strongly recommended to collect entropy from external sources.

Additional entropy sources can be added to an application either by:

- Replacing internal entropy by calling `R_CR_set_info()` with `R_CR_INFO_ID_RAND_ENT_CB` and the parameters for an application-defined entropy collection callback function.
- Adding to internal entropy by calling `R_CR_entropy_resource_init()` to initialize an entropy resource structure and then adding this to the library context by calling `R_LIB_CTX_add_resource()`.

For more information about these functions, see the *RSA BSAFE Crypto-C Micro Edition Developers Guide*.

Note: If entropy from external sources is added to an application using `R_CR_set_info()` with `R_CR_INFO_ID_RAND_ENT_CB` or `R_CR_entropy_resource_init()`, no assurances are made about the minimum strength of generated keys.

For more information about seeding DRNGs, see “Randomness Requirements for Security” in RFC 4086 and SP 800-90A Rev. 1.

3 Services

The following is the list of services provided by Crypto-C ME.

An operator assuming the Crypto User role can use the entire Crypto-C ME API except for `R_PROV_FIPS140_self_tests_full()`, which is reserved for the Crypto Officer.

For more information about individual functions, see the *RSA BSAFE Crypto-C Micro Edition Developers Guide*.

```
R_ALG_PARAMS_asym_from_binary()
R_ALG_PARAMS_cipher_from_binary()
R_ALG_PARAMS_ctrl()
R_ALG_PARAMS_digest_from_binary()
R_ALG_PARAMS_free()
R_ALG_PARAMS_from_binary()
R_ALG_PARAMS_get_binary()
R_ALG_PARAMS_get_info()
R_ALG_PARAMS_kdf_from_binary()
R_ALG_PARAMS_keywrap_from_binary()
R_ALG_PARAMS_new()
R_ALG_PARAMS_new_from_R_CR()
R_ALG_PARAMS_peek_error()
R_ALG_PARAMS_peek_error_string()
R_ALG_PARAMS_pop_error()
R_ALG_PARAMS_pop_error_string()
R_ALG_PARAMS_ref_inc()
R_ALG_PARAMS_set_info()
R_ALG_PARAMS_signature_from_binary()
R_ALG_PARAMS_signature_get_info()
R_ALG_PARAMS_to_binary()
R_ALG_signature_info()
R_BASE64_decode()
R_BASE64_decode_checked()
R_BASE64_decode_checked_ef()
R_BASE64_decode_ef()
R_BASE64_encode()
R_BASE64_encode_checked()
R_BASE64_encode_checked_ef()
R_BASE64_encode_ef()
R_BIO_append_filename()
R_BIO_cb_cmd_to_string()
R_BIO_cb_post()
R_BIO_cb_pre()
R_BIO_CB_return()
R_BIO_clear_flags()
R_BIO_clear_retry_flags()
R_BIO_copy_next_retry()
R_BIO_ctrl()
R_BIO_debug_cb()
R_BIO_dump()
R_BIO_dump_format()
R_BIO_dup_chain()
R_BIO_dup_chain_ef()
R_BIO_eof()
R_BIO_f_buffer()
R_BIO_f_null()
R_BIO_f_prefix()
R_BIO_find_type(
R_BIO_flags_to_string()
R_BIO_flush()
R_BIO_free()
R_BIO_free_all()
R_BIO_get_app_data()
R_BIO_get_buffer_num_lines()
R_BIO_get_cb()
R_BIO_get_cb_arg()
R_BIO_get_close()
R_BIO_get_flags()
R_BIO_get_fp()
R_BIO_get_info_cb()
R_BIO_get_mem_data()
R_BIO_get_retry_BIO()
R_BIO_get_retry_flags()
R_BIO_get_retry_reason()
R_BIO_gets()
R_BIO_method_name()
R_BIO_method_type()
R_BIO_new()
R_BIO_new_ef()
R_BIO_new_file()
R_BIO_new_file_ef()
R_BIO_new_file_w()
R_BIO_new_file_w_ef()
R_BIO_new_fp()
R_BIO_new_fp_ef()
R_BIO_new_init()
R_BIO_new_init_ef()
R_BIO_new_mem()
R_BIO_new_mem_ef()
R_BIO_open_file()
R_BIO_open_file_w()
R_BIO_pending()
R_BIO_pop()
R_BIO_print_hex()
R_BIO_printf()
```

```
R_BIO_push()
R_BIO_puts()
R_BIO_read()
R_BIO_read_filename()
R_BIO_reference_inc()
R_BIO_reset()
R_BIO_retry_type()
R_BIO_rw_filename()
R_BIO_s_file()
R_BIO_s_mem()
R_BIO_s_null()
R_BIO_seek()
R_BIO_set()
R_BIO_set_app_data()
R_BIO_set_bio_cb()
R_BIO_set_buffer_read_data()
R_BIO_set_buffer_size()
R_BIO_set_cb()
R_BIO_set_cb_arg()
R_BIO_set_cb_recursive()
R_BIO_set_close()
R_BIO_set_flags()
R_BIO_set_fp()
R_BIO_set_info_cb()
R_BIO_set_mem_eof_return()
R_BIO_set_read_buffer_size()
R_BIO_set_retry_read()
R_BIO_set_retry_small_buffer()
R_BIO_set_retry_special()
R_BIO_set_retry_write()
R_BIO_set_write_buffer_size()
R_BIO_should_io_special()
R_BIO_should_read()
R_BIO_should_retry()
R_BIO_should_small_buffer()
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R_GBL_ERR_STATE_peek_last_error()
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R_PKEY_dup()
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R_PKEY_from_binary()
R_PKEY_from_binary_ef()
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R_PKEY_from_file()
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R_PKEY_get_info()
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R_PKEY_public_from_file()
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R_PKEY_public_to_file()
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R_PKEY_SEARCH_free()
R_PKEY_SEARCH_init()
R_PKEY_SEARCH_new()
R_PKEY_SEARCH_next()
R_PKEY_set_info()
R_PKEY_store()
R_PKEY_to_binary()
R_PKEY_to_bio()
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R_PROV_FIPS140_set_info()
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R_PROV_FIPS140_STATUS_to_string()
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R_PROV_PKCS11_get_driver_name()
R_PROV_PKCS11_get_driver_path()
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R_PROV_PKCS11_get_driver_version()
R_PROV_PKCS11_get_flags()
R_PROV_PKCS11_get_info()
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R_PROV_PKCS11_get_slot_firmware_version()
R_PROV_PKCS11_get_slot_flags()
R_PROV_PKCS11_get_slot_hardware_version()
R_PROV_PKCS11_get_slot_ids()
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R_PROV_PKCS11_get_token_flags()
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R_PROV_PKCS11_set_info()
R_PROV_PKCS11_set_login_cb()
R_PROV_PKCS11_set_quirks()
R_PROV_PKCS11_set_slot_info()
R_PROV_PKCS11_set_token_login_pin()
R_PROV_PKCS11_set_user_pin()
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R_SELECT_get_info()
R_SELECT_new()
R_SELECT_set_info()
R_SKEY_delete()
R_SKEY_dup()
R_SKEY_dup_ef()
R_SKEY_free()
R_SKEY_generate()
R_SKEY_get_info()
R_SKEY_load()
R_SKEY_new()
R_SKEY_new_ef()
R_SKEY_SEARCH_add_filter()
R_SKEY_SEARCH_free()
R_SKEY_SEARCH_init()
R_SKEY_SEARCH_new()
R_SKEY_SEARCH_next()
R_SKEY_set_info()
R_SKEY_store()
R_STACK_cat()
R_STACK_clear()
R_STACK_clear_arg()
R_STACK_data()
R_STACK_delete()
R_STACK_delete_all()
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R_STACK_delete_ptr()
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R_time_cmp()
R_TIME_CTX_free()
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R_TIME_CTX_new_ef()
R_TIME_dup()
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R_time_export()
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R_TIME_export_timestamp()
R_TIME_free()
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R_time_from_int()
R_time_get_cmp_func()
R_time_get_export_func()
R_time_get_func()
R_time_get_import_func()
R_time_get_offset_func()
R_time_import()
R_TIME_import()
R_TIME_import_timestamp()
R_TIME_new()
R_time_new()
R_time_new_ef()
R_TIME_new_ef()
R_TIME_offset()
R_time_offset()
R_time_set_cmp_func()
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R_time_set_export_func()
R_time_set_func()
R_time_set_import_func()
R_time_set_offset_func()
R_time_size()
R_TIME_time()
R_time_to_int()
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4 Acronyms and Definitions

The following table lists and describes the acronyms and definitions used throughout this document.

Table 12 Acronyms and Definitions

Term	Definition
AES	Advanced Encryption Standard. A fast symmetric key algorithm with a 128-bit block, and keys of lengths 128, 192, and 256 bits. Replaces DES as the US symmetric encryption standard.
API	Application Programming Interface.
BPS	Brier, Peyrin and Stern. An encryption mode of operation used with the AES and Triple-DES symmetric key algorithms for format-preserving encryption (FPE).
Attack	Either a successful or unsuccessful attempt at breaking part or all of a cryptosystem. Various attack types include an algebraic attack, birthday attack, brute force attack, chosen ciphertext attack, chosen plaintext attack, differential cryptanalysis, known plaintext attack, linear cryptanalysis, middle person attack and timing attack.
Camellia	A symmetric key algorithm with a 128-bit block, and keys of lengths 128, 192, and 256 bits. Developed jointly by Mitsubishi and NTT.
CAVP	Cryptographic Algorithm Validation Program (CAVP) provides validation testing of FIPS-approved and NIST-recommended cryptographic algorithms and their individual components.
CBC	Cipher Block Chaining. A mode of encryption in which each ciphertext depends upon all previous ciphertexts. Changing the Initialization Vector (IV) alters the ciphertext produced by successive encryptions of an identical plaintext.
CFB	Cipher Feedback. A mode of encryption producing a stream of ciphertext bits rather than a succession of blocks. In other respects, it has similar properties to the CBC mode of operation.
CMVP	Cryptographic Module Validation Program
CRNG	Continuous Random Number Generation.
CSP	A Critical Security Parameters is security related information, such as keys or passwords, whose disclosure or modification can compromise security.
CTR	Counter mode of encryption, which turns a block cipher into a stream cipher. It generates the next keystream block by encrypting successive values of a counter.
CTR DRBG	Counter mode Deterministic Random Bit Generator.

Table 12 Acronyms and Definitions (continued)

Term	Definition
CTS	Cipher text stealing mode of encryption, which enables block ciphers to be used to process data not evenly divisible into blocks, without the length of the ciphertext increasing.
DES	Data Encryption Standard. A symmetric encryption algorithm with a 56-bit key with eight parity bits. See also Triple-DES.
DESX	A variant of the DES symmetric key algorithm intended to increase the complexity of a brute force attack.
Diffie-Hellman	The Diffie-Hellman (DH) asymmetric key exchange algorithm. There are many variants, but typically two entities exchange some public information (for example, public keys or random values) and combines them with their own private keys to generate a shared session key. As private keys are not transmitted, eavesdroppers are not privy to all of the information comprising the session key.
DSA	Digital Signature Algorithm. An asymmetric algorithm for creating digital signatures.
DRBG	Deterministic Random Bit Generator.
EC	Elliptic Curve.
ECAES	Elliptic Curve Asymmetric Encryption Scheme.
ECB	Electronic Codebook. A mode of encryption, which divides a message into blocks and encrypts each block separately.
ECC	Elliptic Curve Cryptography (ECC): the public-key cryptographic methods using operations in an elliptic curve group. ECC keys are used in several algorithms including ECDSA, ECDH and ECDHC. An individual ECC key must not be used for multiple purpose, for example, signing and key agreement.
ECDH	Elliptic Curve Diffie-Hellman key agreement algorithm. This algorithm uses a key-agreement primitive that does not employ the elliptic curve's cofactor.
ECDHC	Elliptic Curve Diffie-Hellman with Cofactor key agreement algorithm. This algorithm employs the CDH primitive.
ECDSA	Elliptic Curve Digital Signature Algorithm.
ECIES	Elliptic Curve Integrated Encryption Scheme.
Encryption	The transformation of plaintext into an apparently less readable form (called ciphertext) through a mathematical process. The ciphertext can be read by anyone who has the key and decrypts (undoes the encryption) the ciphertext.

Table 12 Acronyms and Definitions (continued)

Term	Definition
FFC	Finite Field Cryptography (FFC): the public-key cryptographic methods using operations in a multiplicative group of a finite field. FFC keys are use in algorithms including DSA and Diffie-Hellman.
FIPS	Federal Information Processing Standards.
FIPS 180-4	Federal Information Processing Standards Publication: Secure Hash Standard (SHS).
FIPS 186-2	Federal Information Processing Standards Publication:
FIPS 186-4	Federal Information Processing Standards Publication: Digital Signature Standard (DSS).
FIPS 198-1	Federal Information Processing Standards Publication: The Keyed-Hash Message Authentication Code (HMAC).
FIPS 202	Federal Information Processing Standards Publication: SHA-3 Standard: Permutation-Based Hash and Extendable-Output Functions.
FPE	Format-preserving encryption. Encryption where the ciphertext output is in the same format as the plaintext input. For example, encrypting a 16-digit credit card number produces another 16-digit number.
GCM	Galois/Counter Mode. A mode of encryption combining the Counter mode of encryption with Galois field multiplication for authentication.
GMAC	Galois Message Authentication Code. An authentication only variant of GCM.
GOST	GOST symmetric key encryption algorithm developed by the USSR government. There is also the GOST message digest algorithm.
HKDF	HMAC-based Extract-and Expand KDF. HKDF is a two-step key derivation function, where the first step, extraction, transforms a shared secret into a key-derivation key. The second step, expansion, uses the key-derivation key to derive an output key
HMAC	Keyed-Hashing for Message Authentication Code.
HMAC DRBG	HMAC Deterministic Random Bit Generator.
IG	Implementation Guidance for FIPS 140-2 and the Cryptographic Module Validation Program.
IV	Initialization Vector. Used as a seed value for an encryption or MAC operation.
JCMVP	Japan Cryptographic Module Validation Program.
KAT	Known Answer Test.

Table 12 Acronyms and Definitions (continued)

Term	Definition
Key	A string of bits used by cryptographic algorithms. There are a variety of cryptographic key types. These keys might be used for operations such as encryption or decryption, cryptographic signing or verification, or key agreement. Some types of keys are intended to be kept secret, and other keys are intended to be public.
Key wrapping	A method of encrypting key data for protection on untrusted storage devices or during transmission over an insecure channel.
L	The bit length of the prime field size.
MAC	Message Authentication Code.
MD2	A message digest algorithm, which hashes an arbitrary-length input into a 16-byte digest.
MD4	A message digest algorithm, which hashes an arbitrary-length input into a 16-byte digest.
MD5	A message digest algorithm, which hashes an arbitrary-length input into a 16-byte digest. Designed as a replacement for MD4.
N	The bit length of the subprime field size.
NDRNG	Non-deterministic random number generator.
NIST	National Institute of Standards and Technology. A division of the US Department of Commerce (formerly known as the NBS) which produces security and cryptography-related standards.
OFB	Output Feedback. A mode of encryption in which the cipher is decoupled from its ciphertext.
OS	Operating System.
P_HASH	A function that uses the HMAC-HASH as the core function in its construction. Specified in RFC 2246 and RFC 5246.
PBKDF1	Password-based Key Derivation Function 1. A method of password-based key derivation defined in RFC 2988, which applies a message digest, MD2, MD5, or SHA-1, to derive the key. PBKDF1 is not recommended for new applications because the message digest algorithms used have known vulnerabilities, and the derived keys are limited in length.
PBKDF2	Password-based Key Derivation Function 2. A method of password-based key derivation, originally defined in RFC 2988, which applies a Message Authentication Code (MAC) algorithm to derive the key. In RFC 2988 the PRF used by PBKDF2 is specified as SHA-1. SP 800-132 approves PBKDF2 where the PRF may be any FIPS approved hash function. In this document PBKDF2 represents the expanded specification provided in SP 800-132.
PC	Personal Computer.

Table 12 Acronyms and Definitions (continued)

Term	Definition
PRF	PseudoRandom Function
Private Key	The secret key in public key cryptography. Primarily used for decryption but also used for encryption with digital signatures.
PRNG	Pseudo-random Number Generator.
Public Key	TBA
RC2	Block cipher developed by Ron Rivest as an alternative to the DES. It has a block size of 64 bits and a variable key size. It is a legacy cipher and RC5 should be used in preference.
RC4	Symmetric algorithm designed by Ron Rivest using variable length keys (usually 40-bit or 128-bit).
RC5	Block cipher designed by Ron Rivest. It is parameterizable in its word size, key length, and number of rounds. Typical use involves a block size of 64 bits, a key size of 128 bits, and either 16 or 20 iterations of its round function.
RFC 2246	The TLS Protocol.
RFC 2313	PKCS #1: RSA Encryption.
RFC 2998	PKCS #5: Password-Based Cryptography Specification.
RFC 4086	Randomness Requirements for Security.
RFC 4346	The Transport Layer Security (TLS) Protocol.
RFC 5246	The Transport Layer Security (TLS) Protocol.
RFC 5488	AES Galois Counter Mode (GCM) Cipher Suites for TLS.
RNG	Random Number Generator.
RSA	Public key (asymmetric) algorithm providing the ability to encrypt data and create and verify digital signatures. RSA stands for Rivest, Shamir, and Adleman, the developers of the RSA public key cryptosystem.
SEED	SEED symmetric key encryption algorithm developed by the Korean Information Security Agency.
SHA	Secure Hash Algorithm. An algorithm, which creates a unique hash value for each possible input. SHA takes an arbitrary input, which is hashed into a 160-bit digest.
SHA-1	A revision to SHA to correct a weakness. It produces 160-bit digests. SHA-1 takes an arbitrary input, which is hashed into a 20-byte digest.

Table 12 Acronyms and Definitions (continued)

Term	Definition
SHA-2	The NIST-mandated successor to SHA-1, to complement the Advanced Encryption Standard. It is a family of hash algorithms (SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, and SHA-512/256), which produce digests of 224, 256, 384, 512, 224, and 256 bits respectively.
SHA-3	SHA-3 is a family of hash algorithms which include SHA-3-224, SHA-3-256, SHA-3-384 and SHA-3-512 bits. It is an alternative to SHA-2, as no significant attacks on SHA-2 are currently known.
SEED	A symmetric key algorithm developed by the Korean Information Security Agency.
SP 800-38A	NIST Special Publication 800-38A: Recommendation for Block 2001 Edition Cipher Modes of Operation Methods and Techniques.
SP 800-38C	NIST Special Publication 800-38C: Recommendation for Block Cipher Modes of Operation: The CCM Mode for Authentication and Confidentiality.
SP 800-38D	NIST Special Publication 800-38D: Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC.
SP 800-38E	NIST Special Publication 800-38E: Recommendation for Block Cipher Modes of Operation: The XTS-AES Mode for Confidentiality on Storage Devices.
SP 800-38F	NIST Special Publication 800-38F: Recommendation for Block Cipher Modes of Operation: Methods for Key Wrapping.
SP 800-56A	NIST Special Publication 800-56A Revision 2: Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Logarithm Cryptography.
SP 800-56B	NIST Special Publication 800-56B Revision 2: Recommendation for Pair-Wise Key Establishment Using Integer Factorization Cryptography.
SP 800-56C	NIST Special Publication 800-56C Revision 1: Recommendation for Key-Derivation Methods in Key-Establishment Schemes.
SP 800-57 Part 1 Rev. 4	NIST Special Publication 800-57 Part 1 Revision 4: Recommendation for Key Management.
SP 800-67 Rev. 2	NIST Special Publication 800-67 revision 2: Recommendations for The Triple Data Encryption Block Cipher.
SP 800-89	NIST Special Publication 800-89: Recommendation for Obtaining Assurances for Digital Signature Applications.
SP 800-90A Rev. 1	NIST Special Publication 800-90A Revision 1: Recommendation for Random Number Generation Using Deterministic Random Bit Generators.
SP 800-108	NIST Special Publication 800-108: Recommendation for Key Derivation Using Pseudorandom Functions (Revised).

Table 12 Acronyms and Definitions (continued)

Term	Definition
SP 800-131A	NIST Special Publication 800-131A Revision 1 Transitions: Recommendation for Transitioning the Use of Cryptographic Algorithms and Key Lengths
SP 800-132	NIST Special Publication 800-132: Recommendation for Password-Based Key Derivation
SP 800-133	NIST Special Publication 800-133: Recommendation for Cryptographic Key Generation.
SP 800-135 Rev. 1	NIST Special Publication 800-135 Revision 1: Recommendation for Existing Application-Specific Key Derivation Functions.
Triple-DES	A variant of DES. A symmetric encryption algorithm which uses three 56-bit keys with eight parity bits each.
XTS	XEX-based Tweaked Codebook mode with ciphertext stealing. A mode of encryption used with AES.

5 Change Summary

June 2022	Removed references to Operating Environments that are no longer validated. Moved Triple-DES and RSA key-wrapping/transport to *Non-FIPS 140-2-approved Algorithms* table.
March 2022	Moved non-compliant DH Key Pair Generation to *Non-FIPS 140-2-approved Algorithms* table. Table 5, Crypto-C ME FIPS 140-2-allowed Algorithms Table 6, Crypto-C ME non-FIPS 140-2-approved Algorithms
October 2021	Updated the vendor affirmed platforms. Affirmation of Compliance for other Operating Environments Moved non-compliant SP 800-56A references, according to FIPS 140-2 Implementation Guidance D.1 - Revision 2. Key Assurance Crypto User Guidance on Algorithms Table 3, Key and CSP Access Table 4, Crypto-C ME FIPS 140-2-approved Algorithms Table 5, Crypto-C ME FIPS 140-2-allowed Algorithms