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FIPS 140-2 Non-Proprietary Security Policy

Oracle Linux 8 NSS Cryptographic Module

FIPS 140-2 Level 1 Validation

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1. Introduction

1.1 Overview

This document is the Security Policy for the Oracle Linux 8 NSS Cryptographic Module by Oracle Corporation. This Security Policy specifies the security rules under which the module shall operate to meet the requirements of FIPS 140-2 Level 1. It also describes how the Oracle Linux 8 NSS Cryptographic Module functions in order to meet the FIPS 140-2 requirements, and the actions that operators must take to maintain the security of the module.

This Security Policy describes the features and design of the Oracle Linux 8 NSS Cryptographic Module using the terminology contained in the FIPS 140-2 specification. FIPS 140-2, Security Requirements for Cryptographic Module specifies the security requirements that will be satisfied by a cryptographic module utilized within a security system protecting sensitive but unclassified information. The NIST/CCCS Cryptographic Module Validation Program (CMVP) validates cryptographic module to FIPS 140-2. Validated products are accepted by the Federal agencies of both the USA and Canada for the protection of sensitive or designated information.

1.2 Document Organization

The FIPS 140-2 Submission Package contains:

- Oracle Linux 8 NSS Cryptographic Module Non-Proprietary Security Policy
- Other supporting documentation as additional references

With the exception of this Non-Proprietary Security Policy, the FIPS 140-2 Validation Documentation is proprietary to Oracle and is releasable only under appropriate non-disclosure agreements. For access to these documents, please contact Oracle.



2. Oracle Linux 8 NSS Cryptographic Module

2.1 Functional Overview

The Oracle Linux 8 NSS Cryptographic Module (hereafter referred to as the “module”) is a set of libraries designed to support cross-platform development of security-enabled applications. Applications built with the Oracle Linux 8 NSS Cryptographic Module can support SSL v3, TLS, IKE, PKCS #5, PKCS #7, PKCS #11 (version 3.0), PKCS #12, S/MIME, X.509 v3 certificates, and other security standards supporting FIPS 140-2 validated cryptographic algorithms. It combines a vertical stack of Oracle Linux components intended to limit the external interface each separate component may provide. The Oracle Linux 8 NSS Cryptographic Module is distributed with the Oracle Linux open-source distributions. The module provides a C-language Application Program Interface (API) for use by other processes that require cryptographic functionality.

Oracle Linux 8 NSS Cryptographic Module supports 2 types of cryptographic implementations:

- a) NSS in Native C Programming Language; and
- b) AES-NI for X86 processors.

2.2 FIPS 140-2 Validation Scope

The following table shows the security level for each of the eleven sections of the validation. See Table 1 below.

Security Requirements Section	Level
Cryptographic Module Specification	1
Cryptographic Module Ports and Interfaces	1
Roles and Services and Authentication	2
Finite State Machine 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

Table 1: FIPS 140-2 Security Requirements

3. Cryptographic Module Specification

3.1 Definition of the Cryptographic Module

The Oracle Linux 8 NSS Cryptographic Module with version R8-8.4.0 is defined as a software only multi-chip standalone module as defined by the requirements within FIPS PUB 140-2. The logical cryptographic boundary of the module consists of shared library files and their integrity check signature files, which are delivered through the Package Manager (RPM) as listed below:

- nss-softokn RPM file with version [nss-softokn-3.53.1-17.el8_3.x86_64.rpm](#) or [nss-softokn-3.53.1-17.el8_3.aarch64.rpm](#) which contains the following files:
 - /usr/lib64/libnssdbm3.chk (64 bits)
 - /usr/lib64/libnssdbm3.so (64 bits)
 - /usr/lib64/libsoftokn3.chk (64 bits)
 - /usr/lib64/libsoftokn3.so (64 bits)

- nss-softokn-freebl RPM file with version [nss-softokn-freebl-3.53.1-17.el8_3.x86_64.rpm](#) or [nss-softokn-freebl-3.53.1-17.el8_3.aarch64.rpm](#), which contains the following files:
 - /lib64/libfreeblpriv3.chk (64 bits)
 - /lib64/libfreeblpriv3.so (64 bits)

Figure 1 shows the logical block diagram of the module executing in memory on the host system.

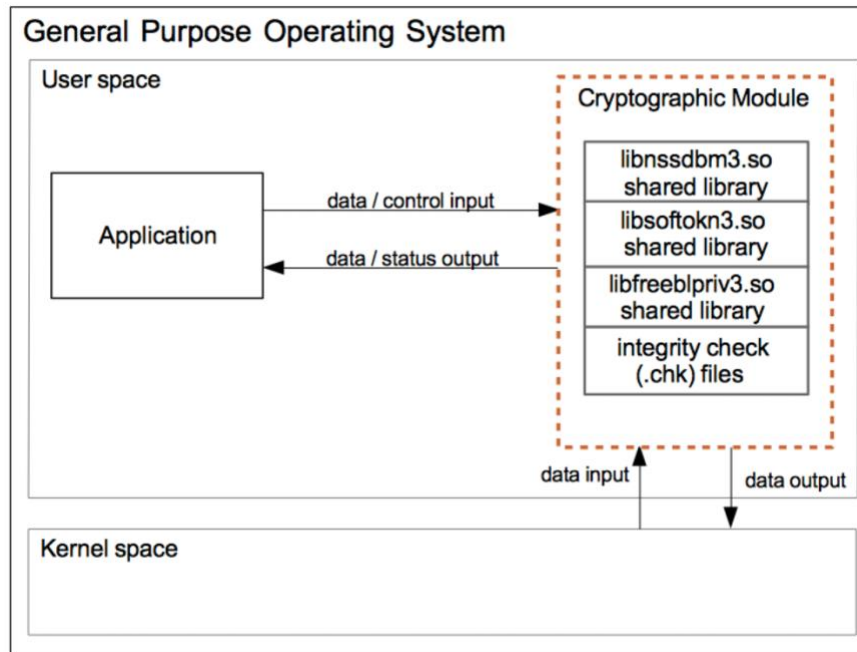


Figure 1: Oracle Linux 8 NSS Logical Cryptographic Boundary

3.2 Definition of the Physical Cryptographic Boundary

The physical cryptographic boundary of the module is defined as the hard enclosure of the host system on which it runs. See Figure 2 below. No components are excluded from the requirements of FIPS PUB 140-2.

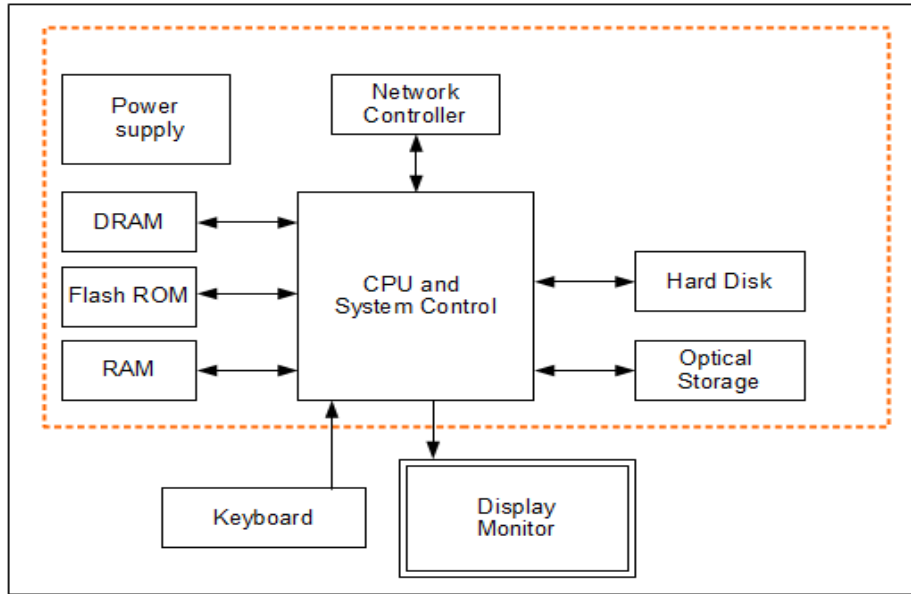


Figure 2: Oracle Linux 8 NSS Hardware Block Diagram

3.3 Approved or Allowed Security Functions

The module supports two modes of operation: FIPS Approved mode and non-Approved mode.

When the module is powered on, the power-up self-tests are executed automatically without any operator intervention. If the power-up self-tests complete successfully, the module will be in FIPS Approved mode by default. In Approved mode, only Approved algorithms (as listed in Table 2) and non-approved but Allowed algorithms (as listed in Table 3) can be used.

Approved Security Functions		Certificate
Symmetric Algorithms		
AES	Generic C: AES in CBC, ECB, CTR, GCM Modes (e/d; Key Sizes 128, 192, 256 for all modes)	A 1623
	AESNI: AES in CBC, ECB, CTR, GCM Modes (e/d; Key Sizes 128, 192, 256 for all modes)	A 1624
	Generic C CTS: AES in CBC-CS1 mode (d/e; Key Sizes 128, 192, 256)	A 1629
	Generic C CMAC: Generation/Verification (Key Sizes 128, 192, 256) MAC: 128	A 1626
	AESNI KW: AES-KW (d/e; Key Sizes 128, 192, 256) AES-KWP (d/e; Key Sizes 128, 192, 256)	A 1627
	Generic C KW: AES-KW (d/e; Key Sizes 128, 192, 256) AES-KWP (d/e; Key Sizes 128, 192, 256)	A 1625

Approved Security Functions		Certificate
Triple-DES (3-Key) ¹	Generic C: Triple-DES in CBC and ECB Modes (e/d; KO 1 for all modes)	A 1623
Cryptographic Key Generation (CKG)		
CKG	NIST SP 800-133rev2 Asymmetric and Symmetric Cryptographic Key Generation	(Vendor Affirmed)
Secure Hash Standard (SHS)		
SHS	Generic C: SHA-1, SHA-224, SHA-256, SHA-384, SHA-512	A 1623
Data Authentication Code		
HMAC	Generic C: HMAC-SHA-1, HMAC-SHA-224, HMAC-SHA-256, HMAC-SHA-384, HMAC-SHA-512	A 1623
Asymmetric Algorithms		
RSA	Generic C: FIPS 186-4: PKCS 1.5 (Key Gen, Sig Gen, Sig Ver); Modulus Sizes 2048, 3072, 4096 with hash sizes SHA-256, SHA-384, SHA-512; (SHA-1 allowed for Sig Ver operations supported)	A 1623
DSA	Generic C: FIPS 186-4: Key Gen, PQG Gen, PQG Ver, Sig Gen, Sig Ver; Modulus Sizes 2048, 3072, with hash sizes SHA-224, SHA-256, SHA-384, SHA-512; (Modulus size 1024 and SHA-1 allowed for PQG Ver and Sig Ver operations only)	A 1623
ECDSA	Generic C: FIPS 186-4: Key Gen, Key Ver, Sig Gen, Sig Ver; Curves P-256, P-384, P-521 with hash sizes SHA-224, SHA-256, SHA-384, SHA-512; (SHA-1 allowed for Sig Ver operations only)	A 1623
Random Number Generation		
DRBG	Generic C: Hash_Based DRBG: (SHA-256)	A 1623
Key Establishment Scheme (NIST SP 800-56Ar3)		
KAS-FFC-SSC-SP800-56Ar3	Generic C: KAS-FFC-SSC SP 800-56Ar3: dhEphem scheme, Domain Parameter Generation and Mod P Methods (ffdhe2048, ffdhe3072, ffdhe4096, ffdhe6144, ffdhe8192, MODP-2048, MODP-3072, MODP-4096, MODP-6144, MODP-8192) KAS role: initiator, responder	A 1623
KAS-ECC-SSC-SP800-56Ar3	Generic C: KAS-ECC-SSC SP 800-56Ar3: ephemeralUnified scheme for KAS-ECC-SSC (Curves P-256, P-384, P-521). KAS role: initiator, responder	

¹ 3-Key Triple-DES key shall not be used to encrypt more than 2¹⁶ 64-bit blocks of data.

Approved Security Functions		Certificate
Safe Primes Key Generation	<p>Generic_C:</p> <p>Safe Primes Key Generation:</p> <p>Safe Prime Groups: ffdhe2048, ffdhe3072, ffdhe4096, ffdhe6144, ffdhe8192, MODP-2048, MODP-3072, MODP-4096, MODP-6144, MODP-8192</p>	
RSA Key Transport Scheme (SP 800-56Br2)		
KTS-RSA	<p>Generic_C:</p> <p>Function: partialVal; Modulo: 2048, 3072, 4096, 6144, 8192;</p> <p>Key Generation Methods: rsakpg1-basic;</p> <p>Scheme: KTS-OAEP-basic;</p> <p>KAS Role: initiator, responder;</p> <p>Key Transport Method Hash Algorithms: SHA2-224, SHA2-256, SHA2-384, SHA2-512</p>	A 1623
Key Derivation Using Pseudo Random Functions (SP 800-108)		
KBKDF	<p>Generic_C:</p> <p>KDF Mode: Counter and Feedback</p> <p>MAC Modes: HMAC-SHA-1, HMAC-SHA2-224, HMAC-SHA2-256, HMAC-SHA2-384, HMAC-SHA2-512</p>	A 1623
Key Derivation (NIST SP 800-135)		
KDF IKE (CVL)	<p>IKE KDF:</p> <p>IKEv1, IKEv2 (SHA 1, 256, 384, 512)</p>	A 1628
KDF TLS (CVL)	<p>Generic_C:</p> <p>TLS 1.0, TLS 1.1, TLS 1.2 with SHA-256, SHA-384, SHA-512</p>	A 1623
KDA HKDF	<p>TLS v1.3:</p> <p>HKDF: (NIST SP 800-56Cr1 with HMAC-SHA (224, 256, 384, 512))</p>	A 1622
Password Based Key Derivation Function (PBKDF)		
PBKDF	<p>Generic_C:</p> <p>PBKDF with HMAC-SHA-1, HMAC-SHA-224, HMAC-SHA-256, HMAC-SHA-384, HMAC-SHA-512</p>	A 1623
Key Transport Scheme (KTS)		
KTS	<p>AESNI KW:</p> <p>AES-KW (d/e; Key Sizes 128 , 192, 256)</p> <p>AES-KWP (d/e; Key Sizes 128, 192, 256)</p>	A 1627
	<p>Generic C KW:</p> <p>AES-KW (d/e; Key Sizes 128 , 192, 256)</p> <p>AES-KWP (d/e; Key Sizes 128, 192, 256)</p>	A 1625
	AES-GCM key wrapping with 128, 192 and 256 bit keys	A 1623 A 1624
	AES-CBC with 128 and 256 bit keys and HMAC-SHA-1, HMAC-SHA-224, HMAC-SHA-256, HMAC-SHA-384, or HMAC-SHA-512 key wrapping.	A 1623 (AES & HMAC) A 1624 (AES)
	Triple-DES CBC with 192 bit key and HMAC-SHA-1, HMAC-SHA-224, HMAC-SHA-256, HMAC-SHA-384, or HMAC-SHA-512 key wrapping.	A 1623
Entropy		

Approved Security Functions		Certificate
ENT (NP)	NIST SP 800-90B	N/A

Table 2: FIPS Approved Security Functions

Note: No parts of the TLS protocol except the KDF with cert #A 1623 and #A 1622 have been reviewed or tested by CMVP or CAVP. Also, no parts of the IKE protocol except the KDF with cert #A 1628 have been reviewed or tested by CMVP or CAVP.

3.4 Non-Approved but Allowed Security Functions

The following are considered non-Approved but allowed security functions:

Algorithm	Usage
RSA PKCS#1-v1.5 Key Wrapping with key sizes greater than 2048-bit up to 16384 bits	Key wrapping using PKCS#1-v1.5 padding scheme method, key establishment methodology provides between 112 and 256 bits of encryption strength.
MD5 (no security claimed per IG 1.23)	Message digest used in TLS only.

Table 3: Non-Approved but Allowed Security Functions

3.5 Non-Approved Security Functions

The following algorithms are considered non-Approved. Using any of these algorithms will put the module in the non-Approved mode implicitly. The services associated with these non-Approved algorithms are specified in Section 7.3.

Algorithm	Usage
AES-GCM	With counter IV generation With random IV generation using less than 96 bits With external IV generation
Camellia	Encryption/Decryption
ChaCha20-Poly1305	Authenticated Encryption/Decryption
SEED	Encryption/Decryption
DES	Encryption/Decryption
RC2	Encryption/Decryption
RC4	Encryption/Decryption
RC5	Encryption/Decryption
SEED	Encryption/Decryption
Two-Key Triple-DES	Encryption/Decryption, key wrapping using two-key Triple-DES
MD2	Hashing
MD5	Hashing
DSA with non-compliant key size	DSA key pair generation with key size less than 2048 bits.
	DSA signature generation with key size less than 2048 bits.
	DSA signature generation with SHA-1.

Algorithm	Usage
	DSA signature verification with key size less than 1024 bits.
RSA with non-compliant key size	RSA key pair generation with key size less than 2048 bits.
	RSA Signature generation with SHA-1
	RSA signature generation with key size less than 2048 bits
	RSA signature verification with key size less than 1024 bits.
	RSA key wrapping with key size less than 2048 bits.
RSA PSS	Signature Generation/Verification
ECDSA with non-compliant hash size	ECDSA signature generation using SHA-1
Diffie-Hellman with non-compliant key size	Diffie-Hellman shared secret computation with key size less than 2048 bits.
Diffie-Hellman keys generated with domain parameters other than safe primes.	Shared secret computation
J-PAKE	Key agreement
EC with Edwards 25519 Curve	Key management
Key Wrapping	non-SP 800-38F AES and Triple-DES Key wrapping
PBKDF (non-compliant with SP800-132)	Key derivation

Table 4: Non-Approved and Disallowed Functions

4. Module Ports and Interfaces

The module FIPS 140 interfaces can be categorized as follows:

- Data Input Interface
- Data Output Interface
- Control Input interface
- Status Output Interface

As a software-only module, the module does not have physical ports. For the purpose of FIPS 140-2 validation, the physical ports of the module are interpreted to be the physical ports of the hardware platform on which it runs. The logical interface is a C-language Application Program Interface (API) following the PKCS #11 specification, the database files in kernel file system, and environment variables.

The module uses different function arguments for input and output to distinguish between data input, control input, data output, and status output, to disconnect the logical paths followed by data/control entering the module and data/status exiting the module. The module doesn't use the same buffer for input and output. After the module is done with an input buffer that holds security related information, it always zeroizes the buffer so that if the memory is later reused as an output buffer, no sensitive information can be inadvertently leaked.

Table 5 below shows the mapping of interfaces as per FIPS 140-2 standard.

FIPS 140-2 Interface	Module Interfaces
Data Input	API input parameters and database files in kernel file system
Data Output	API output parameters and database files in kernel file system
Control Input	API function calls and environment variables
Status Output	API return codes and status parameters

Table 5: Mapping of FIPS 140-2 Logical Interfaces

4.1 PKCS #11

The logical interfaces of the module consist of the PKCS #11 (Cryptoki) API. The API itself defines the module's logical boundary, i.e., all access to the module is through this API. The functions in the PKCS #11 API are listed in Table 8.

4.2 Inhibition of Data Output

All data output via the data output interface is inhibited when the NSS cryptographic module is performing self-tests or in the Error state.

- During self-tests: All data output via the data output interface is inhibited while self-tests are executed.
- In Error state: The Boolean state variable `sftk_fatalError` tracks whether the NSS cryptographic module is in the Error state. Most PKCS #11 functions, including all the functions that output data via the data output interface, check the `sftk_fatalError` state variable and, if it is true, return the `CKR_DEVICE_ERROR` error code immediately. Only the functions that shut down and restart the module, reinitialize the module, or output status information can be invoked in the Error state. These functions are `FC_GetFunctionList`, `FC_Initialize`, `FC_Finalize`, `FC_GetInfo`, `FC_GetSlotList`, `FC_GetSlotInfo`, `FC_GetTokenInfo`, `FC_InitToken`, `FC_CloseSession`, `FC_CloseAllSessions`, and `FC_WaitForSlotEvent`.



4.3 Disconnecting the Output Data Path from the Key Processes

During key generation and key zeroization, the module may perform audit logging, but the audit records do not contain sensitive information. The module does not return the function output arguments until the key generation or key zeroization is finished. Therefore, the logical paths used by output data exiting the module are logically disconnected from the processes/threads performing key generation and key zeroization.



5. Physical Security

The module is comprised of software only and thus does not claim any physical security.

6. Operational Environment

6.1 Tested Environments

The module operates in a modifiable operational environment under the FIPS 140-2 definition. The module was tested on the following environments with and without PAA (i.e., AES-NI):

Operating Environment	Processor	Hardware
Oracle Linux 8.4 64-bit	Intel® Xeon® Platinum 8167M	Oracle Server X7-2C
Oracle Linux 8.4 64-bit	AMD EPYC™ 7551	Oracle Server E1-2C
Oracle Linux 8.4 64-bit	Ampere®Altra® Neoverse-N1	Oracle Server A1-2C

Table 6: Tested Operating Environment

6.2 Vendor Affirmed Environments

The following platforms have not been tested as part of the FIPS 140-2 level 1 certification. However, Oracle “vendor affirms” that these platforms are equivalent to the tested and validated platforms. Additionally, Oracle affirms that the module will function the same way and provide the same security services on any of the systems listed below.

Operating Environment	Hardware
Oracle Linux 8 64-bit	Oracle X Series Servers
Oracle Linux 8 64-bit	Oracle E Series Servers
Oracle Linux 8 64-bit	Oracle A Series Servers

Table 7: Vendor Affirmed Operational Environments

Note: CMVP makes no statement as to the correct operation of the module or the security strengths of the generated keys when so ported if the specific operational environment is not listed on the validation certificate.

6.3 Operational Environment Policy

The operating system is restricted to a single operator (concurrent operators are explicitly excluded).

The application that makes calls to the module is the single user of the module, even when the application is serving multiple clients.

In operational mode, the ptrace system call, the debugger gdb, and strace shall be not used. In addition, other tracing mechanisms offered by the Linux environment, such as ftrace or systemtap, shall not be used.

7. Roles, Services and Authentication

This section defines the roles, services, and authentication mechanisms and methods with respect to the applicable FIPS 140-2 requirements.

7.1 Roles

The module implements a Crypto Officer (CO) role and a User role:

- The CO role is supported for the installation and initialization of the module. Also, the CO role can access other general-purpose services (such as message digest and random number generation services) and status services of the module. The CO does not have access to any service that utilizes the secret or private keys of the module. The CO must control the access to the module both before and after installation, including management of physical access to the computer, executing the module code as well as management of the security facilities provided by the operating system.
- The User role has access to all cryptographically secure services which use the secret or private keys of the module. It is also responsible for the retrieval, updating and deletion of keys from the private key database.

7.2 FIPS Approved Operator Services and Descriptions

The module has a set of API functions denoted by FC_xxx as listed in Table 8. Among the module's API functions, only FC_GetFunctionList is exported and therefore callable by its name. All the other API functions must be called via the function pointers returned by FC_GetFunctionList. It returns a CK_FUNCTION_LIST structure containing function pointers named C_xxx such as C_Initialize and C_Finalize. The C_xxx function pointers in the CK_FUNCTION_LIST structure returned by FC_GetFunctionList point to the FC_xxx functions.

The following convention is used to describe API function calls. Here FC_Initialize is used as an example:

- When “call FC_Initialize” is mentioned, the technical equivalent of “call the FC_Initialize function via the C_Initialize function pointer in the CK_FUNCTION_LIST structure returned by FC_GetFunctionList” is implied.

The module supports Crypto-Officer services which require no operator authentication, and User services which require operator authentication. Crypto-Officer services do not require access to the secret and private keys and other CSPs associated with the user. The message digesting services are available to Crypto-Officer only when CSPs are not accessed. User services which access CSPs (e.g., FC_GenerateKey, FC_GenerateKeyPair) require operator authentication.

Table 8 lists all the services available in FIPS Approved mode. Please refer to Table 2 and Table 3 for the Approved or allowed cryptographic algorithms supported by the module.

U	CO	Service Name	Function	Service Description	Keys and CSP(s)	Access
	X	Get Function List	FC_GetFunctionList	Return a pointer to the list of function pointers for the operational mode	None	N/A
	X	Module Initialization	FC_InitToken	Initialize or re-initialize a token	User password and all keys	Z
	X		FC_InitPIN	Initialize the user's password, i.e., set the user's initial password	User password	W
	X	General Purpose	FC_Initialize	Initialize the module library	None	N/A
	X		FC_Finalize	Finalize (shut down) the module library	All keys	Z
	X		FC_GetInfo	Obtain general information about the module library	None	N/A
	X	Slot and Token Management	FC_GetSlotList	Obtain a list of slots in the system	None	N/A
	X		FC_GetSlotInfo	Obtain information about a particular slot	None	N/A
	X		FC_GetTokenInfo	Obtain information about the token (This function provides the Show Status service)	None	N/A
	X		FC_GetMechanismList	Obtain a list of mechanisms (cryptographic algorithms) supported by a token	None	N/A
	X		FC_GetMechanismInfo	Obtain information about a particular mechanism	None	N/A
X			FC_SetPIN	Change the user's password	User password	R, W
	X	Session Management	FC_OpenSession	Open a connection (session) between an application and a particular token	None	N/A
	X		FC_CloseSession	Close a session	All keys for the session	Z
	X		FC_CloseAllSessions	Close all sessions with a token	All keys	Z
	X		FC_GetSessionInfo	Obtain information about the session (This function provides the Show Status service)	None	N/A
	X		FC_GetOperationState	Save the state of the cryptographic operations in a session (This function is only implemented for message digest operations)	None	N/A
	X		FC_SetOperationState	Restore the state of the cryptographic operations in a session (This function is only implemented for message digest operations)	None	N/A
X			FC_Login	Log into a token	User Password	R, W, X
X			FC_Logout	Log out from a token	None	N/A
X		Object Management	FC_CreateObject	Create a new object	Key	W

U	CO	Service Name	Function	Service Description	Keys and CSP(s)	Access
X			FC_CopyObject	Create a copy of an object	Original Key, new key ⁴	R, W
X			FC_DestroyObject	Destroy an object	Key	Z
X			FC_GetObjectSize	Obtain the size of an object in bytes	Key	R
X			FC_GetAttributeValue	Obtain an attribute value of an object	Key	R
X			FC_SetAttributeValue	Modify an attribute value of an object	Key	W
X			FC_FindObjectsInit	Initialize an object search operation	None	N/A
X			FC_FindObjects	Continue an object search operation	Keys matching the search criteria	R
X			FC_FindObjectsFinal	Finish an object search operation	None	N/A
X			Encryption and Decryption	FC_EncryptInit	Initialize an encryption operation	AES/Triple-DES key
X		FC_Encrypt		Encrypt single-part data	AES/Triple-DES key	R
X		FC_EncryptUpdate		Continue a multiple-part encryption operation	AES/Triple-DES key	R
X		FC_EncryptFinal		Finish a multiple-part encryption operation	AES/Triple-DES key	R
X		FC_DecryptInit		Initialize a decryption operation	AES/Triple-DES key	R
X		FC_Decrypt		Decrypt single-part encrypted data	AES/Triple-DES key	R
X		FC_DecryptUpdate		Continue a multiple-part decryption operation	AES/Triple-DES key	R
X		FC_DecryptFinal		Finish a multiple-part decryption operation	AES/Triple-DES key	R
	X	Message Digest	FC_DigestInit	Initialize a message digesting operation	None	N/A
	X		FC_Digest	Digest single-part data	None	N/A
	X		FC_DigestUpdate	Continue a multiple-part digesting operation	None	N/A
X			FC_DigestKey	Continue a multiple-part message-digesting operation by digesting the value of a secret key as part of the data already digested	HMAC Key	R
	X		FC_DigestFinal	Finish a multiple-part digesting operation	None	N/A
X		Signature Generation and Verification	FC_SignInit	Initialize a signature operation	DSA/ECDSA/RSA private key, HMAC key	R
X			FC_Sign	Sign single-part data	DSA/ECDSA/RSA private key, HMAC key	R
X			FC_SignUpdate	Continue a multiple-part signature operation	DSA/ECDSA/RSA private key, HMAC key	R

⁴ 'Original key' and 'New key' are the secret keys or public/private key pairs.

U	CO	Service Name	Function	Service Description	Keys and CSP(s)	Access
X			FC_SignFinal	Finish a multiple-part signature operation	DSA/ECDSA/RSA private key, HMAC key	R
X			FC_SignRecoverInit	Initialize a signature operation, where the data can be recovered from the signature	DSA/ECDSA/RSA private key	R
X			FC_SignRecover	Sign single-part data, where the data can be recovered from the signature	DSA/ECDSA/RSA private key	R
X			FC_VerifyInit	Initialize a verification operation	DSA/ECDSA/RSA public key, HMAC key	R
X			FC_Verify	Verify a signature on single-part data	DSA/ECDSA/RSA public key, HMAC key	R
X			FC_VerifyUpdate	Continue a multiple-part verification operation	DSA/ECDSA/RSA public key, HMAC key	R
X			FC_VerifyFinal	Finish a multiple-part verification operation	DSA/ECDSA/RSA public key, HMAC key	R
X			FC_VerifyRecoverInit	Initialize a verification operation, where the data is recovered from the signature	DSA/ECDSA/RSA public key	R
X			FC_VerifyRecover	Verify a signature on single-part data, where the data is recovered from the signature	DSA/ECDSA/RSA public key	R
X			Dual Function Cryptographic Operations	FC_DigestEncryptUpdate	Continue a multiple-part digesting and encryption operation	AES/Triple-DES key
X		FC_DecryptDigestUpdate		Continue a multiple-part decryption and digesting operation	AES/Triple-DES key	R
X		FC_SignEncryptUpdate		Continue a multiple-part signing and encryption operation	DSA/ECDSA/RSA private key, HMAC key, AES/Triple-DES key	R
X		FC_DecryptVerifyUpdate		Continue a multiple-part decryption and verify operation	DSA/ECDSA/RSA public key, HMAC key, AES/Triple-DES key	R
X		Key Management	FC_GenerateKey	Generate a secret key (Also used by TLS to generate a pre-master secret)	AES/Triple-DES/HMAC key	W
				Derive a key from a password or passphrase using PBKDF	Password or passphrase PBKDF derived key	R W
			FC_GenerateKeyPair	Generate a public/private key pair (This function performs the pair-wise consistency tests)	DSA/ECDSA/RSA key pair, Diffie-Hellman/EC Diffie-Hellman key pair	W

U	CO	Service Name	Function	Service Description	Keys and CSP(s)	Access	
			FC_WrapKey	Wrap (encrypt) a key using one of the following mechanisms: (1) SP 800-38F AES Key wrapping (2) RSA encryption	Wrapping Key ⁵ , Key to be wrapped ⁶	R	
			FC_UnwrapKey	Unwrap (decrypt) a key using one of the following mechanisms: (1) SP 800-38F AES Key unwrapping (2) RSA decryption	Unwrapping key ⁷	R	
					Unwrapped key ⁸	W	
			FC_DeriveKey	Shared secret computation	Diffie-Hellman and EC Diffie-Hellman key pairs	R	
					KAS-FFC-SS and KAS-ECC-SSC shared secrets	W	
				TLS derived key from TLS master secret which is derived from TLS premaster secret using TLS KDF	TLS pre-master secret	R	
					TLS master secret	R, W	
					TLS and HKDF derived key ⁹	W	
				Derive a key from KAS-FFC-SSC/KAS-ECC-SSC shared secret using HKDF	Derive keys from IKE shared secret using IKE KDF.	IKE shared secret (from KAS-FFC-SSC/KAS-ECC-SSC)	R
						IKE derived keys	W
						IKE SA Tunnel Encryption Keys IKE SA Tunnel Integrity Keys IPsec SA Tunnel Encryption Keys IPsec SA Tunnel Integrity Keys	W
			Derive keys from a key derivation key using KBKDF	Key derivation key, KBKDF derived key	W		
	X	Random Number Generation	FC_SeedRandom	Mix in additional seed material to the random number generator	Entropy input string, seed, DRBG V and C values	R, W	

⁵ 'Wrapping key' corresponds to the secret key or public key used to wrap another key.

⁶ 'Key to be wrapped' is the key that is wrapped by the 'wrapping key'.

⁷ 'Unwrapping key' corresponds to the secret key or private key used to unwrap another key.

⁸ 'Unwrapped key' is the plaintext key that has not been wrapped by a 'wrapping key'.

⁹ 'Derived key' is the key obtained by a key derivation function which takes the 'TLS master secret' as input.

U	CO	Service Name	Function	Service Description	Keys and CSP(s)	Access
			FC_GenerateRandom	Generate random data (This function performs the continuous random number generator test)	Random data, DRBG V and C values	R, W
	X	Parallel Function Management	FC_GetFunctionStatus	A legacy function, which simply returns the value 0x00000051 (function not parallel)	None	N/A
			FC_CancelFunction	A legacy function, which simply returns the value 0x00000051 (function not parallel)	None	N/A
	X	Self-Tests	N/A	The self-tests are performed automatically when loading the module	DSA 2048-bit public key for module integrity test	R
	X	Show Status	N/A	Via exit codes	N/A	N/A
X		Zeroization	FC_DestroyObject	All CSPs are automatically zeroized when freeing the cipher handle	All secret or private keys and password	Z
	X		FC_InitToken			
			FC_Finalize			
			FC_CloseSession			
			FC_CloseAllSessions			

Table 8: FIPS Approved Operator Services and Descriptions

R – Read, W – Write, X – Execute, Z – Zeroize

Note: The message digesting functions (except FC_DigestKey) that do not use any keys of the module can be accessed by the Crypto-Officer role and do not require authentication to the module. The FC_DigestKey API function computes the message digest (hash) of the value of a secret key, so it is available only to the User role.

7.3 Non-FIPS Approved Services and Descriptions

Table 9 lists all the services available in non-Approved mode with API function and the non- Approved algorithm that the function may invoke. Please note that the functions are the same as the ones listed in **Table 8**, but the underneath non-Approved algorithms are invoked. Please also refer to Table 4 for the non-Approved algorithms. If any service invokes the non-Approved algorithms, then the module will enter non-Approved mode implicitly.

Service Name	Function	Non-Approved Algorithm Invoked
Encryption and Decryption	FC_EncryptInit	AES-GCM listed in Table 4, Camellia, ChaCha20-Poly 1305 (authenticated), DES, RC2, RC4, RC5, SEED, Two-Key Triple-DES
	FC_Encrypt	
	FC_EncryptUpdate	
	FC_EncryptFinal	

Service Name	Function	Non-Approved Algorithm Invoked		
	FC_DecryptInit	AES-GCM listed in Table 4, Camellia, ChaCha20-Poly 1305 (authenticated), DES, RC2, RC4, RC5, SEED, Two-Key Triple-DES		
	FC_Decrypt			
	FC_DecryptUpdate			
	FC_DecryptFinal			
Message Digest	FC_DigestInit	MD2, MD5		
	FC_Digest			
	FC_DigestUpdate			
	FC_DigestKey			
	FC_DigestFinal			
Signature Generation and Verification	FC_SignInit	DSA signature generation with non-compliant key size < 2048, DSA signature generation with SHA-1, RSA PSS, RSA signature generation with non-compliant key sizes < 2048, RSA signature generation with SHA-1, ECDSA signature generation using SHA-1		
	FC_Sign			
	FC_SignUpdate			
	FC_SignFinal			
	FC_SignRecoverInit			
	FC_SignRecover			
	FC_VerifyInit	DSA signature verification with non-compliant key sizes < 1024, RSA PSS, RSA signature verification with non-compliant key sizes < 1024		
	FC_Verify			
	FC_VerifyUpdate			
	FC_VerifyFinal			
	FC_VerifyRecoverInit			
	FC_VerifyRecover			
	Dual Function Cryptographic Operations		FC_DigestEncryptUpdate	AES-GCM listed in Table 4, MD2, MD5, Camellia, DES, RC2, RC4, RC5, SEED, Two-Key Triple-DES
			FC_DecryptDigestUpdate	AES-GCM listed in Table 4, Camellia, DES, RC2, RC4, RC5, SEED, MD2, MD5, Two-Key Triple-DES
FC_SignEncryptUpdate		DSA signature generation with non-compliant key sizes < 2048, DSA signature generation with SHA-1, RSA PSS, RSA signature generation with non-compliant key sizes < 2048, RSA signature generation with SHA-1, ECDSA signature generation with SHA-1, AES-GCM listed in Table 4, Camellia, DES, RC2, RC4, RC5, SEED, Two-key Triple-DES		
FC_DecryptVerifyUpdate		DSA signature verification with non-compliant key sizes < 1024, RSA PSS, RSA signature verification with non-compliant key sizes < 1024, AES-GCM listed in Table 4, Camellia, DES, RC2, RC4, RC5, SEED, Two-key Triple-DES		
Key Management	FC_GenerateKey	Derive a key from a password or passphrase using PBKDF (non-compliant with SP800-132)		
	FC_GenerateKeyPair	DSA key pair generation with non-compliant key sizes < 2048, RSA key pair generation with non-compliant key sizes < 2048		

Service Name	Function	Non-Approved Algorithm Invoked
	FC_WrapKey	Triple-DES key wrapping (encrypt) using Two-key or Three-key Triple-DES, RSA key wrapping (encrypt) with non-compliant key sizes < 2048, non-SP 800-38F AES key wrapping (encrypt)
	FC_UnwrapKey	Triple-DES key wrapping (decrypt) using Two-key or Three-key Triple-DES, RSA key wrapping (decrypt) with non-compliant key sizes < 2048, non-SP 800-38F AES key unwrapping (decrypt)
	FC_DeriveKey	Diffie-Hellman shared secret computation with noncompliant key sizes < 2048
		Diffie-Hellman keys generated with domain parameters other than safe primes.
		EC with Edwards 25519 Curve
		J-PAKE key agreement

Table 9: Non-FIPS Approved Operator Services and Descriptions

7.4 Operator Authentication

7.4.1 Role Assumption

The CO role is implicitly assumed by an operator while installing the module by following the instructions in Section 10.1 and while performing other CO services on the module.

The module implements a password-based Role based authentication for the User role as defined by FIPS 140-2. To perform any security services under the User role, an operator must log into the module and complete an authentication procedure using the password information unique to the User role operator. The password is passed to the module via the API function as an input argument and won't be displayed. The return value of the function is the only feedback mechanism, which does not provide any information that could be used to guess or determine the User's password. The password is initialized by the CO role as part of module initialization and can be changed by the User role operator.

If a User-role service is called before the operator is authenticated, it returns the CKR_USER_NOT_LOGGED_IN error code. The operator must call the FC_Login function to provide the required authentication.

Once a password has been established for the module, the user is allowed to use the security services if and only if the user is successfully authenticated to the module. Password establishment and authentication are required for the operation of the module. When the module is powered off, the result of previous authentication will be cleared and the user needs to be re-authenticated.

7.4.2 Strength of Authentication Mechanism

The module imposes the following requirements on the password. These requirements are enforced by the module on password initialization or change.



- The password must be at least seven characters long.
- The password must consist of characters from three or more character classes. We define five character classes: digits (0-9), ASCII lowercase letters (a-z), ASCII uppercase letters (AZ), ASCII non-alphanumeric characters (space and other ASCII special characters such as '\$', '!'), and non-ASCII characters (Latin characters such as 'e', 's'; Greek characters such as 'Ω', 'θ'; other non-ASCII special characters such as '.'). If an ASCII uppercase letter is the first character of the password, the uppercase letter is not counted toward its character class. Similarly, if a digit is the last character of the password, the digit is not counted toward its character class.

To estimate the maximum probability that a random guess of the password will succeed, we assume that:

- The characters of the password are independent with each other.
- The password contains the smallest combination of the character classes, which are five digits, one ASCII lowercase letter and one ASCII uppercase letter. The probability to guess every character successfully is $(1/10)^5 * (1/26) * (1/26) = 1/67,600,000$.

Since the password can contain seven characters from any three or more of the aforementioned five character classes, the probability that a random guess of the password will succeed is less than or equals to $1/67,600,000$, which is smaller than the required threshold $1/1,000,000$.

After each failed authentication attempt, the NSS cryptographic module inserts a one-second delay before returning to the caller, allowing at most 60 authentication attempts during a one-minute period. Therefore, the probability of a successful random guess of the password during a one-minute period is less than or equals to $60 * 1/67,600,000 = 0.089 * (1/100,000)$, which is smaller than the required threshold $1/100,000$.

8. Key and CSP Management

The following keys, cryptographic key components and other critical security parameters are contained in the module.

CSP Name	Generation	Entry/Output	Storage	Zeroization
AES Key (128, 192, 256 bits)	NIST SP 800-90A DRBG	Encrypted through key wrapping using FC_UnwrapKey for input and FC_WrapKey for output	Application memory or key database	Automatically zeroized when freeing the cipher handle
Triple-DES Key (192 bits)	NIST SP 800-90A DRBG	Encrypted through key wrapping using FC_UnwrapKey for input and FC_WrapKey for output	Application memory or key database	Automatically zeroized when freeing the cipher handle
DSA Private Key (2048 and 3072 bits)	Public and private keys are generated using the FIPS 186-4 key generation method via the FC_GenerateKeyPair function; random values are obtained from the SP800-90A DRBG.	Encrypted through key wrapping using FC_UnwrapKey for input and FC_WrapKey for output	Application memory or key database	Automatically zeroized when freeing the cipher handle
ECDSA Private Key (P-256, P-384, P-521)	Public and private keys are generated using the FIPS 186-4 key generation method via the FC_GenerateKeyPair function; random values are obtained from the SP800-90A DRBG.	Encrypted through key wrapping using FC_UnwrapKey for input and FC_WrapKey for output	Application memory or key database	Automatically zeroized when freeing the cipher handle
RSA Private Key (2048, 3072, 4096 bits)	Public and private keys are generated using the FIPS 186-4 key generation method via the FC_GenerateKeyPair function; random values are obtained from the SP800-90A DRBG.	Encrypted through key wrapping using FC_UnwrapKey for input and FC_WrapKey for output	Application memory or key database	Automatically zeroized when freeing the cipher handle

CSP Name	Generation	Entry/Output	Storage	Zeroization
HMAC Key (≥ 112 bits)	NIST SP 800-90A DRBG	Encrypted through key wrapping using FC_UnwrapKey for input and FC_WrapKey for output	Application memory or key database	Automatically zeroized when freeing the cipher handle
DRBG Entropy Input String	Obtained from CPU jitter source	N/A	Application memory	Automatically zeroized when freeing DRBG handle
DRBG seed, V and C values	Derived from entropy input	N/A	Application memory	Automatically zeroized when freeing DRBG handle
TLS Pre-Master Secret	Use of SP 800-90A DRBG or DH/ECDH shared secret computation. Generated by TLS client as output from DRBG when using RSA key exchange.	Entry: if received by module as TLS server, wrapped with server's public RSA key; otherwise no entry. Output: if generated by module as TLS client, wrapped with server's public RSA key; otherwise, no output.	Application memory or key database	Automatically zeroized when freeing the cipher handle
TLS Master Secret	Derived from TLS pre-master secret By using key derivation	N/A	Application memory or key database	Automatically zeroized when freeing the cipher handle
TLS derived keys	TLS derived keys Generated during the TLS v1.0/1.1 and v1.2 KDFs from TLS master-secret	Encrypted through key wrapping using FC_WrapKey	Application memory or key database	Automatically zeroized when freeing the cipher handle
HKDF derived keys	Derived SP800-56Crev1 HKDF KDF mechanisms	Encrypted through key wrapping using FC_WrapKey	Application memory or key database	Automatically zeroized when freeing the cipher handle
Diffie-Hellman public and private keys	Public and private keys are generated using the SP800-56ARev3 Safe Primes key generation method via the FC_GenerateKeyPair function; random values are obtained from the SP800-90A DRBG.	Encrypted through key wrapping using FC_UnwrapKey for input and FC_WrapKey for output	Application memory or key database	Automatically zeroized when freeing the cipher handle

CSP Name	Generation	Entry/Output	Storage	Zeroization
KAS-ECC-SSC public and private keys	Public and private keys are generated using the FIPS 186-4 key generation method via the FC_GenerateKeyPair function; random values are obtained from the SP800-90A DRBG.	Encrypted through key wrapping using FC_UnwrapKey for input and FC_WrapKey for output	Application memory or key database	Automatically zeroized when freeing the cipher handle
KAS-FFC-SSC shared secret	Generated during shared secret computation via FC_DeriveKey.	Shared secret is output in plaintext form.	Application memory or key database	Automatically zeroized when freeing the cipher handle
KAS-ECC-SSC shared secret	Generated during shared secret computation via FC_DeriveKey.	Shared secret is output in plaintext form.	Application memory or key database	Automatically zeroized when freeing the cipher handle
PBKDF password	N/A	API input parameter	Application memory or key database	Automatically zeroized when freeing the cipher handle
PBKDF derived key	Derived using SP800-132 PBKDF mechanisms	Encrypted for output using FC_WrapKey	Application memory or key database	Automatically zeroized when freeing the cipher handle
KBKDF derived key	Derived SP800-108 KBKDF KDF mechanisms.	Encrypted for output using FC_WrapKey	Application memory or key database	Automatically zeroized when freeing the cipher handle
Key derivation key for KBKDF	Input key used for KBKDF function.	API input parameter	Application memory or key database	Automatically zeroized when freeing the cipher handle
IKE SA tunnel encryption keys	SP 800-135 IKE KDF	Encrypted for output using FC_WrapKey	Ephemeral	Close of IKE SA or termination of Pluto IKE Daemon zeroizes the CSP
IKE SA tunnel integrity keys	SP 800-135 IKE KDF	Encrypted for output using FC_WrapKey	Ephemeral	Close of IKE SA or termination of Pluto IKE Daemon zeroizes the CSP
IKE derived keys	Generated during the IKEv1 and IKEv2 KDFs	Keys are output in plaintext form.	Application memory or key database	Automatically zeroized when freeing the cipher handle

CSP Name	Generation	Entry/Output	Storage	Zeroization
IPsec SA Tunnel Encryption Keys	SP 800-135 IKE KDF	Encrypted for output using FC_WrapKey	Ephemeral	Zeroized from the module's memory when passed to the kernel after establishment of the SA
IPsec SA Tunnel Integrity Keys	SP 800-135 IKE KDF	Encrypted for output using FC_WrapKey	Ephemeral	Zeroized from the module's memory when passed to the kernel after establishment of the SA
User Passwords	N/A (supplied by the calling application)	N/A (input through API parameter)	Application memory or key database in salted form	Automatically zeroized when the module is reinitialized or overwritten when the user changes its password

Table 10: CSP Table

8.1 Random Number Generation

The module employs the Deterministic Random Bit Generator (DRBG) based on [SP 800-90A] for the random number generation. The DRBG supports the Hash_DRBG mechanism with SHA-256. The module uses CPU jitter as a noise source provided by the operational environment which is within the module's physical boundary but outside of the module's logical boundary. The source is compliant with [SP 800-90B] and marked as ENT on the certificate. The entropy source provides at least 230 bits of entropy and the following caveat applies: The module generates keys whose strength are modified by available entropy. Lastly, the module performs the DRBG health tests as defined in section 11.3 of [SP 800-90A].

8.2 Key/CSP Storage

The module employs the cryptographic keys and CSPs in the FIPS Approved mode of operation as listed in Table 10. The module does not perform persistent storage for any keys or CSPs. Note that the private key database (provided with the files key3.db/key4.db) mentioned in Table 10 is within the module's physical boundary but outside its logical boundary.

8.3 Key/CSP Zeroization

The application that uses the module is responsible for appropriate zeroization of the key material. The module provides zeroization methods to clear the memory region previously occupied by a plaintext secret key, private key or password. A plaintext secret or private key gets zeroized when it is passed to an FC_DestroyObject call. All plaintext secret and private keys must be zeroized when the module is shut down (with an FC_Finalize call), reinitialized (with an FC_InitToken call), or when the session is closed (with an FC_CloseSession or FC_CloseAllSessions call). All zeroization is to be performed by storing the value 0 into every byte of the memory region that is previously occupied by a plaintext secret key, private key or password. Zeroization is performed in a time that is not sufficient to compromise plaintext secret or private keys and password.

8.4 Key/CSP Generation

The module provides an SP 800-90A-compliant Deterministic Random Bit Generator (DRBG) for creation of symmetric keys, key components of asymmetric keys, and random number generation.

The key generation methods implemented in the module for Approved services in FIPS mode is compliant with [SP 800-133].

For generating RSA, DSA and ECDSA keys the module implements asymmetric key generation services compliant with [FIPS 186-4]. A seed (i.e. the random value) used in asymmetric key generation is directly obtained from the [SP 800-90A] DRBG.

The public and private keys used in the EC Diffie-Hellman shared secret computation schemes are generated internally by the module using ECDSA key generation compliant with [FIPS 186-4] and [SP 800-56Ar3]. The Diffie-Hellman shared secret computation scheme is also compliant with [SP 800-56Ar3], and generates keys using safe primes defined in RFC 7919 and RFC 3526, as described in the next section.

8.5 Key Agreement/Key Transport

The module provides KAS-FFC-SSC and KAS-ECC-SSC compliant with SP 800-56Arev3, in accordance with scenario X1 (1) of IG D.8. The module provides support for Diffie-Hellman and EC Diffie-Hellman key agreement schemes compliant with SP800-56Arev3 by offering separate services for shared secret computation and the key derivation using the SP800-135 TLS KDF (for use within the TLS protocol), so that the user application can implement the key agreement.

For Diffie-Hellman, the module supports the use of safe primes defined in RFC 7919 for domain parameters and key generation, which are used in TLS key exchange.

- TLS (RFC7919)
 - ffdhe2048 (ID = 256)
 - ffdhe3072 (ID = 257)
 - ffdhe4096 (ID = 258)
 - ffdhe6144 (ID = 259)
 - ffdhe8192 (ID = 260)

The module also supports the use of safe primes defined in RFC 3526, which are part of the Modular Exponential (MODP) Diffie-Hellman groups that can be used for Internet Key Exchange (IKE). Note that the module only implements key generation and shared secret computation of safe primes, and no other part of the IKE protocol (with the exception of the IKE KDF, which is separately implemented).

- IKEv2 (RFC3526)
 - MODP-2048 (ID=14)
 - MODP-3072 (ID=15)
 - MODP-4096 (ID=16)
 - MODP-6144 (ID=17)

- MODP-8192 (ID=18)

According to Table 2: Comparable strengths in [SP 800-57], the key sizes of AES, Triple-DES, RSA, Diffie-Hellman and EC Diffie-Hellman provide the following security strength in FIPS mode of operation:

- Diffie-Hellman shared secret computation provides between 112 and 200 bits of encryption strength.
- EC Diffie-Hellman shared secret computation provides between 128 and 256 bits of encryption strength.
- RSA key wrapping with PKCS#1-v1.5 provides between 112 and 256 bits of encryption strength considering the use of keys equal to or larger than 2048 bits up to 16384 bits; Allowed per IG D.9
- AES key wrapping with KW, KWP and GCM; KTS (AES Certs. #A1623, #A1624, #A1625 and #A1627; key establishment methodology provides between 128 and 256 bits of encryption strength).
- AES key wrapping with AES CBC and HMAC; KTS (AES Certs. #A1623 and #A1624 and HMAC Certs. #A1623; key establishment methodology provides 128 or 256 bits of encryption strength).
- Triple-DES Key wrapping with Triple-DES CBC and HMAC; KTS (Triple-DES Cert. #A1623 and HMAC Certs. #A1623; key establishment methodology provides 112 bits of encryption strength).
- RSA key wrapping with OAEP; KTS-RSA (Cert. #A1623; key establishment methodology provides between 112 and 200 bits of encryption strength).

8.6 Key Derivation

The module supports the following key derivation methods according to [SP 800-135]:

- KDF for the TLS protocol, used as pseudo-random functions (PRF) for TLSv1.0/1.1 and TLSv1.2.
- HKDF for the TLS protocol TLSv1.3.
- KDF for the IKE protocol.

The module supports the following key derivation methods according to [SP 800-108]:

- Key Based Key Derivation Function (KBKDF).

The module also supports password-based key derivation (PBKDF). The implementation is compliant with option 1a of [SP 800-132]. Keys derived from passwords or passphrases using this method can only be used in storage applications.

9. Self-Tests

FIPS 140-2 requires that the module perform self-tests to ensure the integrity of the module, and the correctness of the cryptographic functionality at start up. In addition, conditional tests are required during operational stage of the module. All of these tests are listed and described in this section.

9.1 Power-Up Self-Tests

All the power-up self-tests are performed automatically by initializing or re-initializing the module without requiring any operator intervention. During the power-up self-tests, no cryptographic operation is available and all input or output is inhibited. Once the power-up self-tests are completed successfully, the module enters operational mode and cryptographic operations are available. If any of the power-up self-tests fail, the module enters the Error state. In Error state, all output is inhibited and no cryptographic operation is allowed. The module returns the error code `CKR_DEVICE_ERROR` to the calling application to indicate the Error state. The module needs to be reinitialized in order to recover from the Error state. The following table provides the lists of Known-Answer Test (KAT) and Integrity Test as the power up self-tests:

Algorithm	Test
AES	KATs for ECB and CBC, modes: encryption and decryption are tested separately
AES-GCM	KAT for encryption and decryption
Triple-DES	KATs for ECB and CBC modes: encryption and decryption are tested separately
KAS-FFC-SSC	Primitive "Z" Computation KAT with 2048-bit key
DSA	KAT: signature generation and verification are tested separately
KAS-ECC-SSC	Primitive "Z" Computation KAT with P-256 curve
ECDSA	KAT: signature generation and verification are tested separately
RSA	KAT: encryption and decryption are tested separately KAT: signature generation and verification are tested separately
SHA	KAT: SHA-1, SHA-224, SHA-256, SHA-384, SHA-512
HMAC	KAT: HMAC-SHA-1, HMAC-SHA-224, HMAC-SHA-256, HMAC-SHA-384, HMAC-SHA-512
CMAC	KAT: AES-CMAC KAT
PBKDF KDF	KAT: Using SHA-256
TLS KDF	KAT: TLS 1.0 PRF KAT and TLS 1.2 KAT using SHA-224, SHA-256, SHA-384 and SHA-512
HKDF KDF	KAT: HKDF KAT using SHA-256, SHA-384 and SHA-512
IKE KDF	KAT: SP800-135 IKE PRF using SHA-1, SHA-256, SHA-384 and SHA-512.
KBKDF KDF	KAT: Counter KDF and HMAC-SHA256
DRBG	KAT of Hash_DRBG with SHA-256
DRBG	DRBG health tests as specified in section 11.3 of NIST SP 800-90Ar1
Module Integrity	DSA signature verification with 2048 bits key and SHA-256

Table 11: Power-On Self-Tests

The power-up self-tests can be performed on demand by reinitializing the module.

9.2 Conditional Self-Tests

The following table provides the lists of Pairwise Consistency Test (PCT) and Continuous Random Number Generation Test (CRNGT) as the conditional self-tests. If any of the conditional test fails, the module enters the Error state. It returns the error code CKR_DEVICE_ERROR to the calling application to indicate the Error state. The module needs to be reinitialized in order to recover from the Error state.

Algorithm	Test
DSA	PCT for DSA key generation
ECDSA	PCT for ECDSA key generation
RSA	PCT for RSA key generation
DRBG	CRNGT

Table 12: Conditional Self-Tests

10. Crypto-Officer and User Guidance

10.1 Crypto-Officer Guidance

The version of the RPM containing the validated module is stated in section 3.1 above. The RPM package of the Module shall be installed by standard tools recommended for the installation of Oracle packages on an Oracle Linux system (for example, yum, RPM, and the RHN remote management tool). The integrity of the RPM is automatically verified during the installation of the Module and the Crypto Officer shall not install the RPM file if the [Oracle Linux Yum Server](#) indicates an integrity error. The RPM files listed in section 3 are signed by Oracle and during installation; Yum performs signature verification which ensures as secure delivery of the cryptographic module. If the RPM packages are downloaded manually, then the CO should run ‘rpm –K <rpm-file-name>’ command after importing the builder’s GPG key to verify the package signature. In addition, the CO shall also verify the hash of the RPM package to confirm a proper download.

Recommended method

The system-wide cryptographic policies package (crypto-policies) contains a tool that completes the installation of cryptographic modules and enables self-checks in accordance with the requirements of Federal Information Processing Standard (FIPS) Publication 140-2. We call this step “FIPS enablement”. The tool named fips-mode-setup installs and enables or disables all the validated FIPS modules and it is the recommended method to install and configure an Oracle Linux 8 system.

1. Ensure that the OL8 x86_64 or aarch64 system is configured with "BaseOS Latest", "AppStream Latest" and "Security Validation (Update 8)" yum repositories enabled:


```
# yum-config-manager --enable ol8_baseos_latest ol8_appstream ol8_u4_security_validation
```

Note: If system is configured with the Unbreakable Linux Network (ULN) depending on the architecture make sure enabled channels [ol8_x86_64_baseos_latest, ol8_x86_64_appstream, ol8_x86_64_u4_security_validation] for x86_64 or [ol8_aarch64_baseos_latest, ol8_aarch64_appstream, ol8_aarch64_u4_security_validation] for aarch64.
2. Install nss-sofotkn RPM file e.g for x86_64 or aarch use yum command:


```
# yum install nss-sofotkn-3.53.1-17.el8\_3.x86\_64 or nss-sofotkn-3.53.1-17.el8\_3.aarch64
```
3. Install nss-sofotkn-freebl RPM file from the yum/ULN:


```
# yum install nss-sofotkn-freebl-3.53.1-17.el8\_3.x86\_64 or nss-sofotkn-freebl-3.53.1-17.el8\_3.aarch64
# yum update nss-sofotkn-freebl
```
4. Switch the system to FIPS enablement in Oracle Linux 8:


```
# fips-mode-setup --enable
Setting system policy to FIPS
FIPS mode will be enabled.
Reboot the system for the setting to take effect.
```
5. Restart your system:


```
# reboot
```
6. After the restart, you can check the current state:


```
# fips-mode-setup --check
FIPS mode is enabled.
```

Note: As a side effect of the enablement procedure the fips-mode-enable tool also changes the system wide cryptographic policy level to a level named “FIPS”, this level helps applications by changing configuration defaults to approved algorithms.

10.1.1 AES NI Support and Manual Method

According to the NSS FIPS 140-2 Security Policy, the NSS module supports the AES-NI Intel processor instruction set as an approved cipher. The AES-NI instruction set is used by the Module.

In case you configured a full disk encryption using AES, you may use the AES-NI support for a higher performance compared to the software-only implementation.

Verify that your processor offers the AES-NI instruction set by calling the following command:

```
cat /proc/cpuinfo | grep aes
```

If the command returns a list of properties, including the “aes” string, your CPU provides the AES-NI instruction set. If the command returns nothing, AES-NI is not supported.

The recommended method automatically performs all the necessary steps. The following steps can be done manually but are not recommended and are not required if the systems have been installed with the fips-mode-setup tool:

- Create a file named /etc/system-fips, the contents of this file are never checked
- Ensure to invoke the command ‘fips-finish-install --complete’ on the installed system
- Ensure that the kernel boot line is configured with the fips=1 parameter set
- Reboot the system

NOTE: If /boot or /boot/efi resides on a separate partition, the kernel parameter boot=<boot partition> must be supplied. The partition can be identified with the command "df | grep boot". For example:

```
$ df | grep boot
```

<u>Filesystem</u>	<u>1K-blocks</u>	<u>Used</u>	<u>Available</u>	<u>Use%</u>	<u>Mounted on</u>
/dev/sda1	233191	30454	190296	14%	/boot

The partition of the /boot file system is located on /dev/sda1 in this example.

Therefore, the parameter boot=/dev/sda1 needs to be appended to the kernel command line in addition to the parameter fips=1.

10.1.1 Access to Audit Data

The module may use the Unix syslog function and the audit mechanism provided by the operating system to audit events. Auditing is turned off by default. Auditing capability shall be turned on as part of the initialization procedures by setting the environment variable NSS_ENABLE_AUDIT to 1. The Crypto-Officer shall also configure the operating system's audit mechanism.

The module uses the syslog function to audit events, so the audit data are stored in the system log. Only the root user can modify the system log. On some platforms, only the root user can read the system log; on other platforms, all users can read the system log. The system log is usually under the /var/log directory. The exact location of the system log is specified in the /etc/syslog.conf file. The module uses the default user facility and the info, warning, and err severity levels for its log messages.

The module can also be configured to use the audit mechanism provided by the operating system to audit events. The audit data would then be stored in the system audit log. Only the root user can read or modify the system audit log. To turn on this capability it is necessary to create a symbolic link from the library file `/usr/lib64/libaudit.so.0` to `/usr/lib64/libaudit.so.1.0.0` (on 64-bit platforms).

10.2 User Guidance

In order to run the module in FIPS-Approved mode, only the FIPS Approved or allowed services listed in Table 8 with the validated or allowed cryptographic algorithms/security functions listed in Table 2 and Table 3 shall be used.

The following module initialization steps shall be followed before starting to use the NSS module:

- Set the environment variable `NSS_ENABLE_AUDIT` to 1 before using the module with an application.
- Use the application to get the function pointer list using the API “`FC_GetFunctionList`”.
- Use the API `FC_Initialize` to initialize the module and ensure that it returns `CKR_OK`. A return code other than `CKR_OK` means the module is not initialized correctly, and in that case, the module shall be reset and initialized again.
- For the first login, provide a NULL password and login using the function pointer `C_Login`, which will in-turn call `FC_Login` API of the module. This is required to set the initial NSS User password.
- Now, set the initial NSS User role password using the function pointer `C_InitPIN`. This will call the module's API `FC_InitPIN` API. Then, logout using the function pointer `C_Logout`, which will call the module's API `FC_Logout`.
- The NSS User role can now be assumed on the module by logging in using the User password. And the Crypto-Officer role can be implicitly assumed by performing the Crypto-Officer services as listed in Section 7.2.

The module can be configured to use different private key database formats: `key3.db` or `key4.db`. “`key3.db`” format is based on the Berkeley DataBase engine and should not be used by more than one process concurrently. “`key4.db`” format is based on SQL DataBase engine and can be used concurrently by multiple processes. Both databases are considered outside the module's logical boundary and all data stored in these databases is considered stored in plaintext. The interface code of the module that accesses data stored in the database is considered part of the cryptographic boundary.

Secret and private keys, plaintext passwords and other security-relevant data items are maintained under the control of the cryptographic module. Secret and private keys shall be passed to the calling application in encrypted (wrapped) form with `FC_WrapKey` and entered from calling application in encrypted form with `FC_UnwrapKey`. The key transport methods allowed for this purpose in FIPS Approved mode are SP 800-38F based AES key wrapping and RSA key wrapping using the corresponding Approved modes and key sizes. *Note:* If the secret and private keys passed to the calling application are encrypted using a symmetric key algorithm, the encryption key may be derived from a password. In such a case, they should be considered to be in plaintext form.

Automated key transport methods shall use `FC_WrapKey` and `FC_UnwrapKey` to output or input secret and private keys from or to the module.

All cryptographic keys used in the FIPS Approved mode of operation shall be generated in the FIPS Approved mode or imported while running in the FIPS Approved mode.

10.2.1 Triple-DES keys

According to IG A.13, the same Triple-DES key shall not be used to encrypt more than 2^{16} 64-bit blocks of data. Encrypting greater than 2^{16} blocks will result in the module operating in non-Approved mode implicitly. It is the User's responsibility to ensure the module's compliance with this requirement.

10.2.2 Key derivation using SP 800-132 PBKDF

The module provides password-based key derivation (PBKDF), compliant with SP 800-132. The module supports option 1a from section 5.4 of [SP 800-132], in which the Master Key (MK) or a segment of it is used directly as the Data Protection Key (DPK).

In accordance with [SP 800-132], the following requirements shall be met.

- Derived keys shall only be used in storage applications. The Master Key (MK) shall not be used for other purposes. The length of the MK or DPK shall be of 112 bits or more.
- A portion of the salt, with a length of at least 128 bits, shall be generated randomly using the SP 800-90A DRBG,
- The iteration count shall be selected as large as possible, as long as the time required to generate the key using the entered password is acceptable for the users. The minimum value shall be 1000.
- Passwords or passphrases, used as an input for the PBKDF, shall not be used as cryptographic keys.
- The length of the password or passphrase shall be of at least 20 characters, and shall consist of lower-case, upper-case and numeric characters. The probability of guessing the value is estimated to be $1/62^{20} = 10^{-36}$, which is less than 2^{-112} .

The calling application shall also observe the rest of the requirements and recommendations specified in [SP 800-132].

10.2.3 AES-GCM IV

The AES GCM IV generation is in compliance with the [RFC 5288] and shall only be used for the TLS protocol version 1.2 to be compliant with [FIPS 140-2_IG] IG A.5, provision 1 ("TLS protocol IV generation"); The counter portion of the IV is set by the module within its cryptographic boundary. This counter portion i.e., nonce_explicit part of the IV does not exhaust the maximum number of possible values for a given session key. In case the module's power is lost and then restored, the key used for the AES GCM encryption or decryption shall be redistributed.

The module also complies with IG A.5, provision 2. The GCM random IV is generated by using the approved Hash_DRBG and the user must ensure that the IV length is at least 96 bits.

When a GCM IV is used for decryption, the responsibility for the IV generation lies with the party that performs the AES GCM encryption.

10.3 Handling Self-Test Errors

When the module enters the Error state, it needs to be reinitialized to resume normal operation. Reinitialization is accomplished by calling FC_Finalize followed by FC_Initialize.

11. Mitigation of Other Attacks

The module is designed to mitigate the following attacks.

Attack	Mitigation Mechanism	Specific Limit
Timing attacks on RSA	<p>RSA blinding Timing attack on RSA was first demonstrated by Paul Kocher in 1996 [15], who contributed the mitigation code to our module. Most recently Boneh and Brumley [16] showed that RSA blinding is an effective defense against timing attacks on RSA.</p>	None.
Cache-timing attacks on the modular exponentiation operation used in RSA and DSA	<p>Cache invariant modular exponentiation This is a variant of a modular exponentiation implementation that Colin Percival [17] showed to defend against cache-timing attacks</p>	This mechanism requires intimate knowledge of the cache line sizes of the processor. The mechanism may be ineffective when the module is running on a processor whose cache line sizes are unknown.
Arithmetic errors in RSA signatures	<p>Double-checking RSA signatures Arithmetic errors in RSA signatures might leak the private key. Ferguson and Schneier [18] recommend that every RSA signature generation should verify the signature just generated.</p>	None.

Table 13: Mitigation of Other Attacks

Acronyms, Terms and Abbreviations

Term	Definition
AES	Advanced Encryption Standard
AES-NI	Intel Advanced Encryption Standard New Instructions
CBC	Cipher Block Chaining
CMVP	Cryptographic Module Validation Program
CCCS	Canadian Centre for Cyber Security
CKG	Cryptographic Key Generation
CMAC	Cipher-Based Message Authentication Code
CRNGT	Continuous Random Number Generator Test
CSP	Critical Security Parameter
CTR	Counter Block Chaining
CTS	Ciphertext Stealing
CVL	Component Validation List
DES	Data Encryption Standard
DSA	Digital Signature Algorithm
ECB	Electronic Code Book
ECDSA	Elliptic Curve Digital Signature Algorithm
DRBG	Deterministic Random Bit Generator
GCM	Galois/Counter Mode
HMAC	(Keyed) Hash Message Authentication Code
IKE	Internet Key Exchange
MAC	Message Authentication Code
KAT	Known Answer Test
KDF	Key Derivation Function
NIST	National Institute of Standards and Technology
NSS	Network Security Services
PBKDF	Password Based Key Derivation Function
PCT	Pairwise Consistency Test
PKCS	Public-Key Cryptographic Standard
PUB	Publication
RSA	Rivest, Shamir, Addleman
SHA	Secure Hash Algorithm
TLS	Transport Layer Security

Table 14: Acronyms

References

The FIPS 140-2 standard, and information on the CMVP, can be found at <http://csrc.nist.gov/groups/STM/cmvp/index.html>. More information describing the module can be found on the Oracle web site at <https://www.oracle.com/linux/>.

This Security Policy contains non-proprietary information. All other documentation submitted for FIPS 140-2 conformance testing and validation is "Oracle - Proprietary" and is releasable only under appropriate non-disclosure agreements.

- [1] FIPS 140-2 Standard, <http://csrc.nist.gov/groups/STM/cmvp/standards.html>
- [2] FIPS 140-2 Implementation Guidance, <https://csrc.nist.gov/CSRC/media/Projects/cryptographic-module-validation-program/documents/fips140-2/FIPS1402IG.pdf>
- [3] FIPS 140-2 Derived Test Requirements, <https://csrc.nist.gov/CSRC/media/Projects/Cryptographic-Module-Validation-Program/documents/fips140-2/FIPS1402DTR.pdf>
- [4] FIPS 197 Advanced Encryption Standard, <https://csrc.nist.gov/publications/detail/fips/197/final>
- [5] FIPS 180-4 Secure Hash Standard, <https://csrc.nist.gov/publications/detail/fips/180/4/final>
- [6] FIPS 198-1 The Keyed-Hash Message Authentication Code (HMAC), <https://csrc.nist.gov/publications/detail/fips/198/1/final>
- [7] FIPS 186-4 Digital Signature Standard (DSS), <https://csrc.nist.gov/publications/detail/fips/186/4/final>
- [8] NIST SP 800-38A, Recommendation for Block Cipher Modes of Operation: Methods and Techniques, <https://csrc.nist.gov/publications/detail/sp/800-38a/final>
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- [10] NIST SP 800-38F, Recommendation for Block Cipher Modes of Operation: Methods for Key Wrapping, <https://csrc.nist.gov/publications/detail/sp/800-38f/final>
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- [14] NIST SP 800-90A, Recommendation for Random Number Generation Using Deterministic Random Bit Generators, <https://csrc.nist.gov/publications/detail/sp/800-90a/rev-1/final>
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- [18] C. Percival, "Cache Missing for Fun and Profit", <http://www.daemonology.net/papers/htt.pdf>
- [19] N. Ferguson and B. Schneier, Practical Cryptography, Sec. 16.1.4 "Checking RSA Signatures", p. 286, Wiley Publishing, Inc., 2003.