Microsoft Windows

FIPS 140 Validation

Microsoft Windows Server 2019

Microsoft Azure Stack Edge

Microsoft Azure Stack Hub

Microsoft Azure Stack Edge Rugged

Non-Proprietary

Security Policy Document

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Version History

Version	Date	Summary of changes
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1.1	September 20, 2022	Updates in response to NIST feedback
1.2	January 13, 2023	Updates in response to NIST feedback
1.3	September 8, 2023	Updates in response to NIST feedback, updated bounded module certificates
1.4	November 6, 2023	Updates in response to NIST feedback

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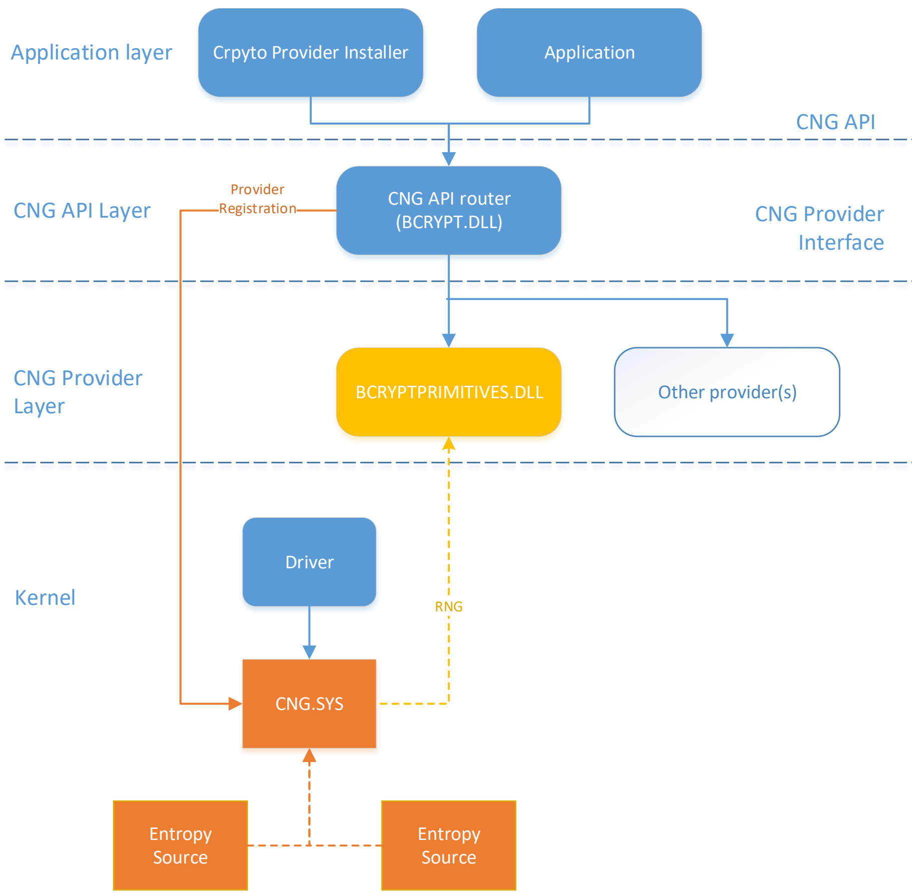
1 Introduction

Microsoft Kernel Mode Cryptographic Primitives Library is a kernel-mode cryptographic module that provides cryptographic services through the Microsoft CNG (Cryptography, Next Generation) API to Windows Server kernel components.

Kernel Mode Cryptographic Primitives Library also provides cryptographic provider registration and configuration services to both user and kernel mode components. See Non-Security Relevant Configuration Interfaces for more information. For the purpose of this validation, the Kernel Mode Cryptographic Primitives Library is classified as a Software-Hybrid cryptographic module because the validated platforms all implement the AES-NI instruction set.

The relationship between Kernel Mode Cryptographic Primitives Library and other components is shown in the following diagram:



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1.1 List of Cryptographic Module Binary Executables

The Kernel Mode Cryptographic Primitives Library consists of the following binaries:

- CNG.SYS

The Windows builds covered by this validation are:

- Windows Server 2019 build 10.0.17763.10021 and 10.0.17763.10127

1.2 Validated Platforms

The editions covered by this validation are:

- Windows Server 2019 Datacenter Core

The Kernel Mode Cryptographic Primitives Library component listed in Section 1.1 was validated using the combination of computers and Windows operating system editions specified in the table below.

All the computers for Windows Server listed in the table below are all 64-bit Intel architecture and implement the AES-NI instruction set but not the SHA Extensions.

Table 1 Validated Platforms

Computer	Windows Server 2019 Datacenter Core	Processor Image
Microsoft Azure Stack Edge - Dell XR2 - Intel Xeon Silver 4114	√	intel 2nd Gen Intel® Xeon® Scalable Processor wikichip.org
Microsoft Azure Stack Hub - Dell PowerEdge R640 - Intel Xeon Gold 6230	√	intel 2nd Gen Intel® Xeon® Scalable Processor wikichip.org
Microsoft Azure Stack Hub - Dell PowerEdge R840 - Intel Xeon Platinum 8260	√	

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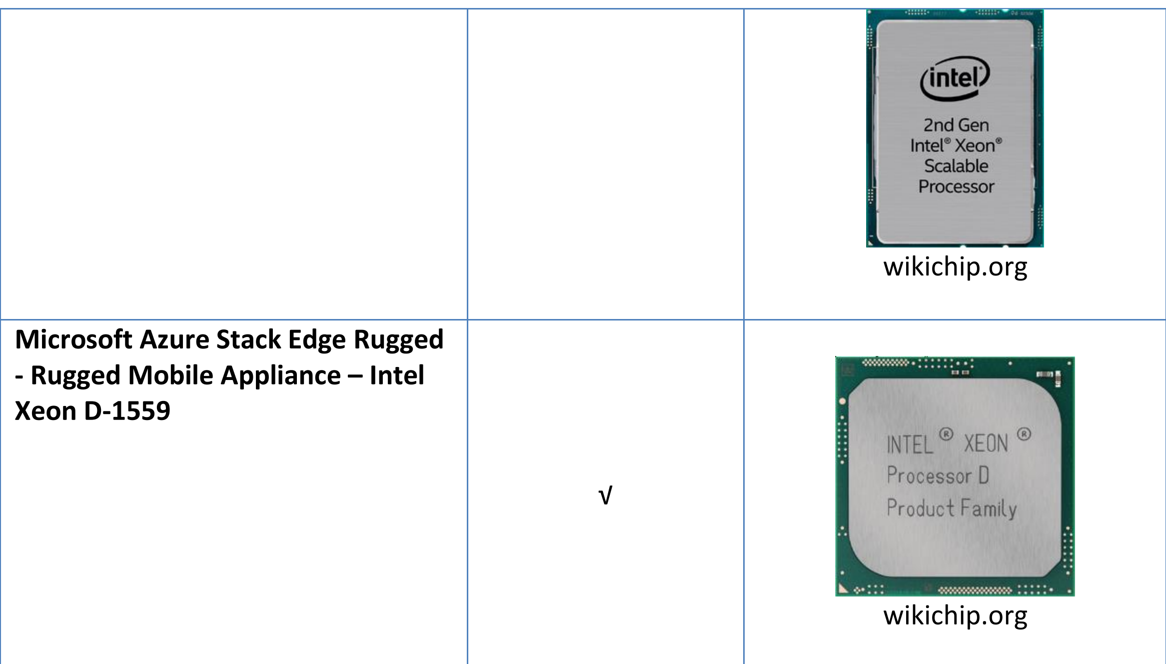

		wikichip.org
Microsoft Azure Stack Edge Rugged - Rugged Mobile Appliance – Intel Xeon D-1559	√	wikichip.org

1.3 Configure Windows to use FIPS-Approved Cryptographic Algorithms

Use the FIPS Local/Group Security Policy setting or a Mobile Device Management (MDM) to enable FIPS-Approved mode for Kernel Mode Cryptographic Primitives Library.

The Windows operating system provides a group (or local) security policy setting, “System cryptography: Use FIPS compliant algorithms for encryption, hashing, and signing”.

Consult the MDM documentation for information on how to enable FIPS-Approved mode. The Policy CSP - Cryptography includes the setting **AllowFipsAlgorithmPolicy**.

Changes to the Approved mode security policy setting do not take effect until the computer has been rebooted.

2 Cryptographic Module Specification

Kernel Mode Cryptographic Primitives Library is a multi-chip standalone module that operates in FIPS-Approved mode during normal operation of the computer and Windows operating system and when Windows is configured to use FIPS-approved cryptographic algorithms as described in Configure Windows to use FIPS-Approved Cryptographic Algorithms.

In addition to configuring Windows to use FIPS-Approved Cryptographic Algorithms, third-party applications and drivers installed on the Windows platform must not use any of the non-approved algorithms implemented by this module. As a general-purpose cryptographic library, it is the operator's responsibility to configure services or applications which use cryptographic services to specify only FIPS-

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Approved algorithms, if that is required by their local security policy. Windows will not operate in an Approved mode when the operators chooses to use a non-Approved algorithm or service.

The following configurations and modes of operation will cause Kernel Mode Cryptographic Primitives Library to operate in a non-approved mode of operation:

- Boot Windows in Debug mode
- Boot Windows with Driver Signing disabled

2.1 Cryptographic Boundary

The software-hybrid cryptographic boundary for Kernel Mode Cryptographic Primitives Library consists of disjoint software and hardware components within the same physical boundary of the host platform. The software components are defined as the binary CNG.SYS, and the hardware components are the CPUs running on each host platform.

2.2 FIPS 140-2 Approved Algorithms

Kernel Mode Cryptographic Primitives Library implements the following FIPS-140-2 Approved algorithms:[1]

Table 2 Approved Algorithms

Algorithm	Windows Server 2019 build 10.0.17763.10021	Windows Server 2019 build 10.0.17763.10127
FIPS 180-4 SHS SHA-1, SHA-256, SHA-384, and SHA-512	#C1577	#C2044
FIPS PUB 198-1 HMAC-SHA-1[2] and HMAC-SHA-256	#C1577	#C2044
FIPS 197 AES-128, AES-192, and AES-256 in ECB, CBC, CFB8, CFB128, and CTR modes (Generate Symmetric Key)	#C1577	#C2044
NIST SP 800-38B and SP 800-38C AES-128, AES-192, and AES-256 in CCM and CMAC modes (Generate Symmetric Key)	#C1577	#C2044
NIST SP 800-38D AES-128, AES-192, and AES-256 GCM decryption and GMAC (Generate Symmetric Key)	#C1577	#C2044
NIST SP 800-38E XTS-AES XTS-128 and XTS-256[3] (Generate Symmetric Key)	#C1577	#C2044

[1] This module may not use some of the capabilities described in each CAVP certificate.

[2] For HMAC, only key sizes that are >= 112 bits in length are used by the module in FIPS mode.

[3] AES XTS must be used only to protect data at rest and the caller needs to ensure that the length of data encrypted does not exceed 2^{20} AES blocks.

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FIPS 186-4 RSA PKCS#1 (v1.5) and RSA-SSA-PSS digital signature generation and verification with 1024[4], 2048, and 3072 moduli; supporting SHA-1[5], SHA-256, SHA-384, and SHA-512 (Generate Asymmetric Key / Signature)	#C1577	#C2044
FIPS 186-4 RSA key-pair generation with 2048 and 3072 moduli[6] (Generate Asymmetric Key / Signature)	#C1577	#C2044
FIPS 186-4 ECDSA key pair generation and verification, signature generation and verification with the following NIST curves: P-256, P-384, P-521[6] (Generate Asymmetric Key / Signature)	#C1577	#C2044
FIPS 186-4 DSA Key Generation, PQG Generation and Verification[6] (used only for KAS-FFC key generation)	#C1577	#C2044
KAS – SP 800-56A Diffie-Hellman Key Agreement; Finite Field Cryptography (FFC) with parameter FB (p=2048, q=224) and FC (p=2048, q=256); key establishment methodology provides 112 bits of encryption strength	#C1577	#C2044
KAS – SP 800-56A EC Diffie-Hellman Key Agreement; Elliptic Curve Cryptography (ECC) with parameter EC (P-256 w/ SHA-256), ED (P-384 w/ SHA-384), and EE (P-521 w/ SHA-512); key establishment methodology provides between 128 and 256-bits of encryption strength	#C1577	#C2044
NIST SP 800-56B RSADP mod 2048 (CVL)	#C1577	#C2044
NIST SP 800-90A AES-256 counter mode DRBG	#C1577	#C2044
NIST SP 800-67r1 Triple-DES (3 key encryption / decryption) in ECB, CBC, CFB8 and CFB64 modes	#C1577	#C2044
NIST SP 800-108 Key Derivation Function (KDF) CMAC-AES (128, 192, 256), HMAC (SHA1, SHA-256, SHA-384, SHA-512)	#C1584	#C2050

[4] RSA 1024 is only applicable for signature verification.
[5] SHA-1 is only acceptable for legacy signature verification.
[6] The module generates at least 256-bits of entropy before generating keys.

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NIST SP 800-38F AES Key Wrapping (KW) (128, 192, and 256) (Distributing Keys)	#C1584	#C2050
NIST SP 800-38F KTS – key establishment methodology provides between 128 and 256 bits of encryption strength	AES Certificate #C1584	AES Certificate #C2050
NIST SP 800-135 IKEv1, IKEv2 and TLS KDF primitives (CVL)[7]	#C1577	#C2044
NIST SP 800-132 KDF (also known as PBKDF) with HMAC (SHA-1, SHA-256, SHA-384, SHA-512) as the pseudo-random function (Derivation of Keys)	Vendor Affirmed	Vendor Affirmed
NIST SP 800-133r2 (sections 5.1,5.2, 6.1, and 6.2) Cryptographic Key Generation[6]	Vendor Affirmed	Vendor Affirmed

2.3 Non-Approved Algorithms

Kernel Mode Cryptographic Primitives Library implements the following non-Approved algorithms.

Non-Approved algorithms allowed in the Approved mode of operation:

- SHA-1 hash, only for the use of legacy digital signature verification. Any use outside of legacy digital signature verification is disallowed.
- MD5 and HMAC-MD5 (allowed in TLS and EAP-TLS, with no security claimed, per FIPS 140-2 IG 1.23, example scenario 2a).
- A non-deterministic random number generator (NDRNG). The NDRNG provides entropy input to the DRBG.
- ECDH (non-compliant) with the following curves and strengths, which are allowed in FIPS mode per FIPS 140-2 IG A.2:
    - brainpoolP224r1 (112 bits)
    - brainpoolP224t1 (112 bits)
    - brainpoolP256r1 (128 bits)
    - brainpoolP256t1 (128 bits)

[7] This cryptographic module supports the TLS, IKEv1, and IKEv2 protocols with SP 800-135 rev 1 KDF primitives, however, the protocols have not been reviewed or tested by the NIST CAVP and CMVP.

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- brainpoolP320r1 (160 bits)
- brainpoolP320t1 (160 bits)
- brainpoolP384r1 (192 bits)
- brainpoolP384t1 (192 bits)
- brainpoolP512r1 (256 bits)
- brainpoolP512t1 (256 bits)
- nistP224 (112 bits)
- numsP256t1 (128 bits)
- numsP384t1 (192 bits)
- numsP512t1 (256 bits)
- secP224k1 (112 bits)
- secP224r1 (112 bits)
- secP256k1 (128 bits)
- secP256r1 (128 bits)
- secP384r1 (192 bits)
- secP521r1 (256 bits)
- wtls12 (112 bits)
- x962P239v1 (120 bits)
- x962P239v2 (120 bits)
- x962P239v3 (120 bits)
- x962P256v1 (128 bits)
- Curve25519 (128 bits)

Non-Approved algorithms disallowed in the Approved mode of operation:

- Non-compliant NIST SP 800-67r1 Triple-DES (2 key legacy-use decryption)
- Non-compliant ANSI X9.63 and X9.42 key derivation.
- Non-compliant NIST SP 800-56A Key Agreement using Finite Field Cryptography (FFC) with parameter FA (p=1024, q=160). The key establishment methodology provides 80 bits of encryption strength instead of the Approved 112 bits of encryption strength listed above (non-compliant).
- NIST SP 800-38D AES-128, AES-192, and AES-256 GCM encryption (non-compliant).
- SHA-1 hash for digital signature generation.
- If HMAC-SHA1 is used, key sizes less than 112 bits (14 bytes) are disallowed for usage in HMAC generation, as per SP 800-131A (non-compliant).
- RSA 1024-bits for digital signature generation (non-compliant).
- RC2, RC4, MD2, and MD4.
- 2-Key -DES encryption.
- DES in ECB, CBC, CFB8 and CFB64 modes.
- Legacy CAPI KDF (proprietary).
- RSA encrypt/decrypt (non-compliant).
- ECDH (non-compliant) with the following curves and strengths:
  - brainpoolP192r1 (96 bits)
  - brainpoolP192t1 (96 bits)
  - ec192wapi (96 bits)

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- nistP192 (96 bits)
- secP160k1 (80 bits)
- secP160r1 (80 bits)
- secP160r2 (80 bits)
- secP192k1 (96 bits)
- secP192r1 (96 bits)
- wtls7 (80 bits)
- wtls9 (80 bits)
- x962P192v1 (96 bits)
- x962P192v2 (96 bits)
- x962P192v3 (96 bits)
- brainpoolP160r1 (80 bits)

2.4 FIPS 140-2 Approved Algorithms from Bounded Modules

A bounded module is a FIPS 140 module which provides cryptographic functionality that is relied on by a downstream module. As described in the Integrity Chain of Trust section, Kernel Mode Cryptographic Primitives Library depends on the following modules and algorithms:

The Windows OS Loader for Windows Server version 1809 build 10.0.17763.10021 (module certificate #4545) provides:

- CAVP certificates #C1586 (Windows Server) for FIPS 186-4 RSA PKCS#1 (v1.5) digital signature verification with 2048 moduli; supporting SHA-256
- CAVP certificates #C1577 (Windows Server) for FIPS 180-4 SHS SHA-256

The Windows OS Loader for Windows Server version 1809 build 10.0.17763.10127 (module certificate #4545) provides:

- CAVP certificates #C2052 (Windows Server) for FIPS 186-4 RSA PKCS#1 (v1.5) digital signature verification with 2048 moduli; supporting SHA-256
- CAVP certificates #C2044 (Windows Server) for FIPS 180-4 SHS SHA-256

2.5 Cryptographic Bypass

Cryptographic bypass is not supported by Kernel Mode Cryptographic Primitives Library.

2.6 Hardware Components of the Cryptographic Module

The physical boundary of the module is the physical boundary of the computer that contains the module. The following diagram illustrates the hardware components of the Kernel Mode Cryptographic Primitives Library module:

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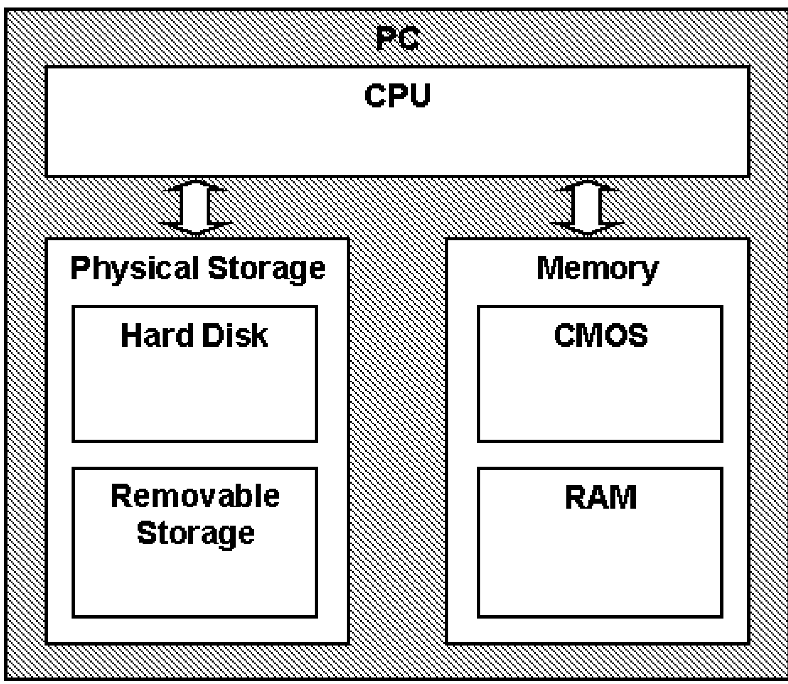

Note: The CPU provides Processor Algorithm Accelerator (PAA)

3 Cryptographic Module Ports and Interfaces

The Kernel Mode Cryptographic Primitives Library module implements a set of algorithm providers for the Cryptography Next Generation (CNG) framework in Windows. Each provider in this module represents a single cryptographic algorithm or a set of closely related cryptographic algorithms. These algorithm providers are invoked through the CNG algorithm primitive functions, which are sometimes collectively referred to as the CNG API. For a full list of these algorithm providers, see https://msdn.microsoft.com/en-us/library/aa375534.aspx

The Kernel Mode Cryptographic Primitives Library module is accessed through one of the following logical interfaces:

1. Kernel applications requiring cryptographic services use the BCrypt APIs detailed in Services.
2. Entropy sources supply random bits to the random number generator through the entropy interfaces.

3.1 CNG Primitive Functions

The following security-relevant functions are exported by Kernel Mode Cryptographic Primitives Library:

- BCryptCloseAlgorithmProvider
- BCryptCreateHash
- BCryptCreateMultiHash
- BCryptDecrypt
- BCryptDeriveKey

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- BCryptDeriveKeyPBKDF2
- BCryptDestroyHash
- BCryptDestroyKey
- BCryptDestroySecret
- BCryptDuplicateHash
- BCryptDuplicateKey
- BCryptEncrypt
- BCryptExportKey
- BCryptFinalizeKeyPair
- BCryptFinishHash
- BCryptFreeBuffer
- BCryptGenerateKeyPair
- BCryptGenerateSymmetricKey
- BCryptGenRandom
- BCryptGetProperty
- BCryptHash
- BCryptHashData
- BCryptImportKey
- BCryptImportKeyPair
- BCryptKeyDerivation
- BCryptOpenAlgorithmProvider
- BCryptProcessMultiOperations
- BCryptSecretAgreement
- BCryptSetProperty
- BCryptSignHash
- BCryptVerifySignature
- SystemPrng
- EntropyPoolTriggerReseedForIum
- EntropyProvideData
- EntropyRegisterSource
- EntropyUnregisterSource

All of these functions are used in the approved mode. Furthermore, these are the only approved functions that this module can perform.

Kernel Mode Cryptographic Primitives Library has additional export functions described in Non-Security Relevant Configuration Interfaces.

3.1.1 Algorithm Providers and Properties

3.1.1.1 BCryptOpenAlgorithmProvider

```
NTSTATUS WINAPI BCryptOpenAlgorithmProvider(
        BCRYPT_ALG_HANDLE   *phAlgorithm,
        LPCWSTR pszAlgId,
        LPCWSTR pszImplementation,
        ULONG   dwFlags);
```

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The BCryptOpenAlgorithmProvider() function has four parameters: algorithm handle output to the opened algorithm provider, desired algorithm ID input, an optional specific provider name input, and optional flags. This function loads and initializes a CNG provider for a given algorithm, and returns a handle to the opened algorithm provider on success.

Unless the calling function specifies the name of the provider, the default provider is used.

The calling function must pass the BCRYPT_ALG_HANDLE_HMAC_FLAG flag in order to use an HMAC function with a hash algorithm.

3.1.1.2 BCryptCloseAlgorithmProvider

```
NTSTATUS WINAPI BCryptCloseAlgorithmProvider(
        BCRYPT_ALG_HANDLE   hAlgorithm,
        ULONG   dwFlags);
```

This function closes an algorithm provider handle opened by a call to BCryptOpenAlgorithmProvider() function.

3.1.1.3 BCryptSetProperty

```
NTSTATUS WINAPI BCryptSetProperty(
        BCRYPT_HANDLE   hObject,
        LPCWSTR pszProperty,
        PUCHAR   pbInput,
        ULONG   cbInput,
        ULONG   dwFlags);
```

The BCryptSetProperty() function sets the value of a named property for a CNG object. The CNG object is a handle, the property name is a NULL terminated string, and the value of the property is a length-specified byte string.

3.1.1.4 BCryptGetProperty

```
NTSTATUS WINAPI BCryptGetProperty(
        BCRYPT_HANDLE   hObject,
        LPCWSTR pszProperty,
        PUCHAR   pbOutput,
        ULONG   cbOutput,
        ULONG   *pcbResult,
        ULONG   dwFlags);
```

The BCryptGetProperty() function retrieves the value of a named property for a CNG object. The CNG object is a handle, the property name is a NULL terminated string, and the value of the property is a length-specified byte string.

3.1.1.5 BCryptFreeBuffer

```
VOID WINAPI BCryptFreeBuffer(
        PVOID   pvBuffer);
```

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Some of the CNG functions allocate memory on caller's behalf. The BCryptFreeBuffer() function frees memory that was allocated by such a CNG function.

3.1.2 Random Number Generation

3.1.2.1 BCryptGenRandom

```
NTSTATUS WINAPI BCryptGenRandom(
        BCRYPT_ALG_HANDLE   hAlgorithm,
        PUCHAR  pbBuffer,
        ULONG   cbBuffer,
        ULONG   dwFlags);
```

The BCryptGenRandom() function fills a buffer with random bytes. The random number generation algorithm is:

- BCRYPT_RNG_ALGORITHM. This is the AES-256 counter mode based random generator as defined in SP 800-90A.

This function is a wrapper for SystemPrng.

3.1.2.2 SystemPrng

```
BOOL SystemPrng(
        unsigned char   *pbRandomData,
        size_t          cbRandomData );
```

The SystemPrng() function fills a buffer with random bytes generated from output of NIST SP 800-90A AES-256 counter mode based DRBG seeded from the Windows entropy pool. The Windows entropy pool is populated from the following sources:

- An initial entropy value provided by the Windows OS Loader at boot time.
- The values of the high-resolution CPU cycle counter at times when hardware interrupts are received.
- Random values gathered from the Trusted Platform Module (TPM), if one is available on the system.
- Random values gathered by calling the RDRAND CPU instruction, if supported by the CPU.

The Windows DRBG infrastructure located in cng.sys continues to gather entropy from these sources during normal operation, and the DRBG cascade is periodically reseeded with new entropy.

3.1.2.3 EntropyRegisterSource

```
NTSTATUS EntropyRegisterSource(
        ENTROPY_SOURCE_HANDLE * phEntropySource,
        ENTROPY_SOURCE_TYPE     entropySourceType,
PCWSTR              entropySourceName );
```

This function is used to obtain a handle that can be used to contribute randomness to the Windows entropy pool. The handle is returned in the phEntropySource parameter. For this function,

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entropySource must be set to ENTROPY_SOURCE_TYPE_HIGH_PUSH, and entropySourceName must be a Unicode string describing the entropy source.

3.1.2.4 EntropyUnregisterSource

```
NTSTATUS EntropyRegisterSource(
ENTROPY_SOURCE_HANDLE hEntropySource);
```

This function is used to destroy a handle created with EntropyRegisterSource().

3.1.2.5 EntropyProvideData

```
NTSTATUS EntropyProvideData(
        ENTROPY_SOURCE_HANDLE   hEntropySource,
        PCBYTE                  pbData,
        SIZE_T                  cbData,
        ULONG                   entropyEstimateInMilliBits );
```

This function is used to contribute entropy to the Windows entropy pool. hEntropySource must be a handle returned by an earlier call to EntropyRegisterSource. The caller provides cbData bytes in the buffer pointed to by pbData, as well as an estimate (in the entropyEstimateInMilliBits parameter) of how many millibits of entropy are contained in these bytes.

3.1.2.6 EntropyPoolTriggerReseedForIum

```
VOID EntropyPoolTriggerReseedForIum(BOOLEAN fPerformCallbacks);
```

This function will trigger a kernel DRBG reseed for the cng.sys inside the IUM (Isolated User Mode) environment. If called inside the IUM environment, it triggers a reseed from one or more of the entropy pools of the system. If called inside the normal world (non-IUM) environment, this function does nothing.

3.1.3 Key and Key-Pair Generation

3.1.3.1 BCryptGenerateSymmetricKey

```
NTSTATUS WINAPI BCryptGenerateSymmetricKey(
        BCRYPT_ALG_HANDLE   hAlgorithm,
        BCRYPT_KEY_HANDLE   *phKey,
        PUCHAR   pbKeyObject,
        ULONG   cbKeyObject,
        PUCHAR   pbSecret,
        ULONG   cbSecret,
        ULONG   dwFlags);
```

The BCryptGenerateSymmetricKey() function generates a symmetric key object directly from a DRBG for use with a symmetric encryption algorithm or key derivation algorithm from a supplied key value. The calling application must specify a handle to the algorithm provider created with the BCryptOpenAlgorithmProvider() function. The algorithm specified when the provider was created must support symmetric key encryption or key derivation.

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3.1.3.2 BCryptGenerateKeyPair

```
NTSTATUS WINAPI BCryptGenerateKeyPair(
    BCRYPT_ALG_HANDLE   hAlgorithm,
    BCRYPT_KEY_HANDLE   *phKey,
    ULONG   dwLength,
    ULONG   dwFlags);
```

The BCryptGenerateKeyPair() function creates an empty public/private key pair. After creating a key using this function, call the BCryptSetProperty() function to set its properties. The key pair can be used only after BCryptFinalizeKeyPair() function is called.

3.1.3.3 BCryptFinalizeKeyPair

```
NTSTATUS WINAPI BCryptFinalizeKeyPair(
    BCRYPT_KEY_HANDLE   hKey,
    ULONG   dwFlags);
```

The BCryptFinalizeKeyPair() function completes a public/private key pair import or generation directly from the output of a DRBG. The key pair cannot be used until this function has been called. After this function has been called, the BCryptSetProperty() function can no longer be used for this key.

3.1.3.4 BCryptDuplicateKey

```
NTSTATUS WINAPI BCryptDuplicateKey(
    BCRYPT_KEY_HANDLE   hKey,
    BCRYPT_KEY_HANDLE   *phNewKey,
    PUCHAR   pbKeyObject,
    ULONG   cbKeyObject,
    ULONG   dwFlags);
```

The BCryptDuplicateKey() function creates a duplicate of a symmetric key.

3.1.3.5 BCryptDestroyKey

```
NTSTATUS WINAPI BCryptDestroyKey(
    BCRYPT_KEY_HANDLE   hKey);
```

The BCryptDestroyKey() function destroys the specified key.

3.1.4 Key Entry and Output

3.1.4.1 BCryptImportKey

```
NTSTATUS WINAPI BCryptImportKey(
    BCRYPT_ALG_HANDLE hAlgorithm,
    BCRYPT_KEY_HANDLE hImportKey,
    LPCWSTR pszBlobType,
    BCRYPT_KEY_HANDLE *phKey,
    PUCHAR   pbKeyObject,
    ULONG   cbKeyObject,
    PUCHAR   pbInput,
```

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```
        ULONG   cbInput,
        ULONG   dwFlags);
```

The BCryptImportKey() function imports a symmetric key from a key blob.

3.1.4.2 BCryptImportKeyPair

```
    NTSTATUS WINAPI BCryptImportKeyPair(
        BCRYPT_ALG_HANDLE hAlgorithm,
        BCRYPT_KEY_HANDLE hImportKey,
        LPCWSTR pszBlobType,
        BCRYPT_KEY_HANDLE *phKey,
        PUCHAR   pbInput,
        ULONG   cbInput,
        ULONG   dwFlags);
```

The BCryptImportKeyPair() function is used to import a public/private key pair from a key blob.

3.1.4.3 BCryptExportKey

```
    NTSTATUS WINAPI BCryptExportKey(
        BCRYPT_KEY_HANDLE   hKey,
        BCRYPT_KEY_HANDLE   hExportKey,
        LPCWSTR pszBlobType,
        PUCHAR   pbOutput,
        ULONG   cbOutput,
        ULONG   *pcbResult,
        ULONG   dwFlags);
```

The BCryptExportKey() function exports a key to a memory blob that can be persisted for later use.

3.1.5 Encryption and Decryption

3.1.5.1 BCryptEncrypt

```
    NTSTATUS WINAPI BCryptEncrypt(
        BCRYPT_KEY_HANDLE hKey,
        PUCHAR   pbInput,
        ULONG   cbInput,
        VOID    *pPaddingInfo,
        PUCHAR   pbIV,
        ULONG   cbIV,
        PUCHAR   pbOutput,
        ULONG   cbOutput,
        ULONG   *pcbResult,
        ULONG   dwFlags);
```

The BCryptEncrypt() function encrypts a block of data of given length.

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3.1.5.2 BCryptDecrypt

```
NTSTATUS WINAPI BCryptDecrypt(
        BCRYPT_KEY_HANDLE   hKey,
        PUCHAR   pbInput,
        ULONG   cbInput,
        VOID    *pPaddingInfo,
        PUCHAR   pbIV,
        ULONG   cbIV,
        PUCHAR   pbOutput,
        ULONG   cbOutput,
        ULONG   *pcbResult,
        ULONG   dwFlags);
```

The BCryptDecrypt() function decrypts a block of data of given length.

3.1.6 Hashing and Message Authentication

3.1.6.1 BCryptCreateHash

```
NTSTATUS WINAPI BCryptCreateHash(
        BCRYPT_ALG_HANDLE   hAlgorithm,
        BCRYPT_HASH_HANDLE  *phHash,
        PUCHAR   pbHashObject,
        ULONG   cbHashObject,
        PUCHAR   pbSecret,
        ULONG   cbSecret,
        ULONG   dwFlags);
```

The BCryptCreateHash() function creates a hash object with an optional key. The optional key is used for HMAC, AES GMAC and AES CMAC.

3.1.6.2 BCryptHashData

```
NTSTATUS WINAPI BCryptHashData(
        BCRYPT_HASH_HANDLE  hHash,
        PUCHAR   pbInput,
        ULONG   cbInput,
        ULONG   dwFlags);
```

The BCryptHashData() function performs a one way hash on a data buffer. Call the BCryptFinishHash() function to finalize the hashing operation to get the hash result.

3.1.6.3 BCryptDuplicateHash

```
NTSTATUS WINAPI BCryptDuplicateHash(
        BCRYPT_HASH_HANDLE  hHash,
        BCRYPT_HASH_HANDLE  *phNewHash,
        PUCHAR   pbHashObject,
```

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```
        ULONG   cbHashObject,
        ULONG   dwFlags);
```

The BCryptDuplicateHash()function duplicates an existing hash object. The duplicate hash object contains all state and data that was hashed to the point of duplication.

3.1.6.4 BCryptFinishHash

```
NTSTATUS WINAPI BCryptFinishHash(
        BCRYPT_HASH_HANDLE hHash,
        PUCHAR   pbOutput,
        ULONG   cbOutput,
        ULONG   dwFlags);
```

The BCryptFinishHash() function retrieves the hash value for the data accumulated from prior calls to BCryptHashData() function.

3.1.6.5 BCryptDestroyHash

```
NTSTATUS WINAPI BCryptDestroyHash(
        BCRYPT_HASH_HANDLE  hHash);
```

The BCryptDestroyHash() function destroys a hash object.

3.1.6.6 BCryptHash

```
NTSTATUS WINAPI BCryptHash(
        BCRYPT_ALG_HANDLE hAlgorithm,
        PUCHAR pbSecret,
        ULONG cbSecret,
        PUCHAR pbInput,
        ULONG cbInput,
        PUCHAR pbOutput,
        ULONG  cbOutput);
```

The function BCryptHash() performs a single hash computation. This is a convenience function that wraps calls to the BCryptCreateHash(), BCryptHashData(), BCryptFinishHash(), and BCryptDestroyHash() functions.

3.1.6.7 BCryptCreateMultiHash

```
NTSTATUS WINAPI BCryptCreateMultiHash(
        BCRYPT_ALG_HANDLE hAlgorithm,
        BCRYPT_HASH_HANDLE *phHash,
        ULONG nHashes,
        PUCHAR pbHashObject,
        ULONG cbHashObject,
        PUCHAR pbSecret,
        ULONG cbSecret,
        ULONG dwFlags);
```

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BCryptCreateMultiHash() is a function that creates a new MultiHash object that is used in parallel hashing to improve performance. The MultiHash object is equivalent to an array of normal (reusable) hash objects.

3.1.6.8 BCryptProcessMultiOperations

```
NTSTATUS WINAPI BCryptProcessMultiOperations(
        BCRYPT_HANDLE  hObject,
        BCRYPT_MULTI_OPERATION_TYPE operationType,
        PVOID pOperations,
        ULONG cbOperations,
        ULONG dwFlags );
```

The BCryptProcessMultiOperations() function is used to perform multiple operations on a single multi-object handle such as a MultiHash object handle. If any of the operations fail, then the function will return an error.

Each element of the operations array specifies an operation to be performed on/with the hObject.

For hash operations, there are two operation types:

- Hash data
- Finalize hash

These correspond directly to BCryptHashData() and BCryptFinishHash(). Each operation specifies an index of the hash object inside the hObject MultiHash object that this operation applies to. Operations are executed in any order or even in parallel, with the sole restriction that the set of operations that specify the same index are all executed in-order.

3.1.7 Signing and Verification

3.1.7.1 BCryptSignHash

```
NTSTATUS WINAPI BCryptSignHash(
        BCRYPT_KEY_HANDLE   hKey,
        VOID    *pPaddingInfo,
        PUCHAR   pbInput,
        ULONG   cbInput,
        PUCHAR   pbOutput,
        ULONG   cbOutput,
        ULONG   *pcbResult,
        ULONG   dwFlags);
```

The BCryptSignHash() function creates a signature of a hash value.
Note: this function accepts SHA-1 hashes, which according to NIST SP 800-131A is *disallowed* for digital signature generation. SHA-1 is currently *legacy-use* for digital signature verification.

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3.1.7.2 BCryptVerifySignature

```
NTSTATUS WINAPI BCryptVerifySignature(
    BCRYPT_KEY_HANDLE   hKey,
    VOID    *pPaddingInfo,
    PUCHAR   pbHash,
    ULONG   cbHash,
    PUCHAR   pbSignature,
    ULONG   cbSignature,
    ULONG   dwFlags);
```

The BCryptVerifySignature() function verifies that the specified signature matches the specified hash. Note: this function accepts SHA-1 hashes, which according to NIST SP 800-131A is *disallowed* for digital signature generation. SHA-1 is currently *legacy-use* for digital signature verification.

3.1.8 Secret Agreement and Key Derivation

3.1.8.1 BCryptSecretAgreement

```
NTSTATUS WINAPI BCryptSecretAgreement(
    BCRYPT_KEY_HANDLE      hPrivKey,
    BCRYPT_KEY_HANDLE      hPubKey,
    BCRYPT_SECRET_HANDLE    *phAgreedSecret,
    ULONG                dwFlags);
```

The BCryptSecretAgreement() function creates a secret agreement value from a private and a public key. This function is used with Diffie-Hellman (DH) and Elliptic Curve Diffie-Hellman (ECDH) algorithms.

3.1.8.2 BCryptDeriveKey

```
NTSTATUS WINAPI BCryptDeriveKey(
    BCRYPT_SECRET_HANDLE hSharedSecret,
    LPCWSTR           pwszKDF,
    BCryptBufferDesc     *pParameterList,
    PUCHAR pbDerivedKey,
    ULONG            cbDerivedKey,
    ULONG            *pcbResult,
    ULONG            dwFlags);
```

The BCryptDeriveKey() function derives a key from a secret agreement value.
Note: When supporting a key agreement scheme that requires a nonce, BCryptDeriveKey uses whichever nonce is supplied by the caller in the BCryptBufferDesc. Examples of the nonce types are found in Section 5.4 of http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-56Ar2.pdf

When using a nonce, a random nonce should be used. And then if the random nonce is used, the entropy (amount of randomness) of the nonce and the security strength of the DRBG has to be at least one half of the minimum required bit length of the subgroup order.

For example:

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for KAS FFC, entropy of nonce must be 112 bits for FB, 128 bits for FC.

for KAS ECC, entropy of the nonce must be 128 bits for EC, 192 for ED, 256 for EE.

3.1.8.3 BCryptDestroySecret

```
NTSTATUS WINAPI BCryptDestroySecret(
        BCRYPT_SECRET_HANDLE   hSecret);
```

The BCryptDestroySecret() function destroys a secret agreement handle that was created by using the BCryptSecretAgreement() function.

3.1.8.4 BCryptKeyDerivation

```
NTSTATUS WINAPI BCryptKeyDerivation(
        _In_       BCRYPT_KEY_HANDLE hKey,
        _In_opt_   BCryptBufferDesc     *pParameterList,
        _Out_writes_bytes_to_(cbDerivedKey, *pcbResult) PUCHAR pbDerivedKey,
        _In_       ULONG            cbDerivedKey,
        _Out_      ULONG            *pcbResult,
        _In_       ULONG            dwFlags);
```

The BCryptKeyDerivation() function executes a Key Derivation Function (KDF) on a key generated with BCryptGenerateSymmetricKey() function. It differs from the BCryptDeriveKey() function in that it does not require a secret agreement step to create a shared secret.

3.1.8.5 BCryptDeriveKeyPBKDF2

```
NTSTATUS WINAPI BCryptDeriveKeyPBKDF2(
        BCRYPT_ALG_HANDLE hPrf,
        PUCHAR pbPassword,
        ULONG cbPassword,
        PUCHAR pbSalt,
        ULONG cbSalt,
        ULONGLONG cIterations,
        PUCHAR pbDerivedKey,
        ULONG cbDerivedKey,
        ULONG dwFlags);
```

The BCryptDeriveKeyPBKDF2() function derives a key from a hash value by using the password based key derivation function as defined by SP 800-132 PBKDF and IETF RFC 2898 (specified as PBKDF2).

3.1.9 Cryptographic Transitions

3.1.9.1 DH and ECDH

Through the year 2010, implementations of DH and ECDH were allowed to have an acceptable bit strength of at least 80 bits of security (for DH at least 1024 bits and for ECDH at least 160 bits). From 2011 through 2013, 80 bits of security strength was considered deprecated, and was disallowed starting

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January 1, 2014. As of that date, only security strength of at least 112 bits is acceptable. ECDH uses curve sizes of at least 256 bits (that means it has at least 128 bits of security strength), so that is acceptable. However, DH has a range of 1024 to 4096 and that changed to 2048 to 4096 after 2013.

3.1.9.2 SHA-1

From 2011 through 2013, SHA-1 could be used in a deprecated mode for use in digital signature generation. As of Jan. 1, 2014, SHA-1 is no longer allowed for digital signature generation, and it is allowed for legacy use only for digital signature verification.

3.2 Control Input Interface

The Control Input Interface are the functions in Algorithm Providers and Properties. Options for control operations are passed as input parameters to these functions.

3.3 Status Output Interface

The Status Output Interface for Kernel Mode Cryptographic Primitives Library is the return value from each export function in the Kernel Mode Cryptographic Primitives Library.

3.4 Data Output Interface

The Data Output Interface for Kernel Mode Cryptographic Primitives Library consists of the Kernel Mode Cryptographic Primitives Library export functions except for the Control Input Interfaces. Data is returned to the function's caller via output parameters.

3.5 Data Input Interface

The Data Input Interface for Kernel Mode Cryptographic Primitives Library consists of the Kernel Mode Cryptographic Primitives Library export functions except for the Control Input Interfaces. Data and options are passed to the interface as input parameters to the export functions. Data Input is kept separate from Control Input by passing Data Input in separate parameters from Control Input.

3.6 Non-Security Relevant Configuration Interfaces

The following interfaces are not cryptographic functions and are used to configure cryptographic providers on the system. Please see https://msdn.microsoft.com for details.

Table 4

Function Name	Description
BCryptEnumAlgorithms	Enumerates the algorithms for a given set of operations.
BCryptEnumProviders	Returns a list of CNG providers for a given algorithm.
BCryptRegisterConfigChangeNotify	This is deprecated beginning with Windows Server.
BCryptResolveProviders	Resolves queries against the set of providers currently registered on the local system and the configuration information specified in the machine and domain configuration tables, returning an ordered list of references to one or more providers matching the specified criteria.

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BCryptAddContextFunctionProvider	Adds a cryptographic function provider to the list of providers that are supported by an existing CNG context.
BCryptRegisterProvider	Registers a CNG provider.
BCryptUnregisterProvider	Unregisters a CNG provider.
BCryptUnregisterConfigChangeNotify	Removes a CNG configuration change event handler. This API differs slightly between User-Mode and Kernel-Mode.
BCryptGetFipsAlgorithmMode **CngGetFipsAlgorithmMode**	Determines whether Kernel Mode Cryptographic Primitives Library is operating in FIPS mode. Some applications use the value returned by this API to alter their own behavior, such as blocking the use of some SSL versions.
EntropyRegisterCallback	Registers the callback function that will be called in a worker thread after every reseed that the system performs. The callback is merely informational.
BCryptQueryProviderRegistration	Retrieves information about a CNG provider.
BCryptEnumRegisteredProviders	Retrieves information about the registered providers.
BCryptCreateContext	Creates a new CNG configuration context.
BCryptDeleteContext	Deletes an existing CNG configuration context.
BCryptEnumContexts	Obtains the identifiers of the contexts in the specified configuration table.
BCryptConfigureContext	Sets the configuration information for an existing CNG context.
BCryptQueryContextConfiguration	Retrieves the current configuration for the specified CNG context.
BCryptAddContextFunction	Adds a cryptographic function to the list of functions that are supported by an existing CNG context.
BCryptRemoveContextFunction	Removes a cryptographic function from the list of functions that are supported by an existing CNG context.
BCryptEnumContextFunctions	Obtains the cryptographic functions for a context in the specified configuration table.
BCryptConfigureContextFunction	Sets the configuration information for the cryptographic function of an existing CNG context.
BCryptQueryContextFunctionConfiguration	Obtains the cryptographic function configuration information for an existing CNG context.
BCryptEnumContextFunctionProviders	Obtains the providers for the cryptographic functions for a context in the specified configuration table.
BCryptSetContextFunctionProperty	Sets the value of a named property or a cryptographic function in an existing CNG context.
BCryptQueryContextFunctionProperty	Obtains the value of a named property for a cryptographic function in an existing CNG context.
BCryptSetAuditingInterface	Sets the auditing interface.

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4 Roles, Services and Authentication

4.1 Roles

Kernel Mode Cryptographic Primitives Library is a kernel-mode driver that does not interact with the user through any service therefore the module's functions are fully automatic and not configurable. FIPS 140 validations define formal "User" and "Cryptographic Officer" roles. Both roles can use any of this module's services.

4.2 Services

Kernel Mode Cryptographic Primitives Library services are:

1. **Algorithm Providers and Properties** – This module provides interfaces to register algorithm providers
2. **Random Number Generation**
3. **Key and Key-Pair Generation**
4. **Key Entry and Output**
5. **Encryption and Decryption**
6. **Hashing and Message Authentication**
7. **Signing and Verification**
8. **Secret Agreement and Key Derivation**
9. **Show Status**
10. **Self-Tests** - The module provides a power-up self-tests service that is automatically executed when the module is loaded into memory. See Self-Tests.
11. **Zeroizing Cryptographic Material -** See Cryptographic Key Management

4.2.1 Mapping of Services, Algorithms, and Critical Security Parameters

The following table maps the services to their corresponding algorithms and critical security parameters (CSPs).

Table 5 Services

Service	Algorithms	CSPs
Algorithm Providers and Properties	None	None
Random Number Generation	AES-256 CTR DRBG NDRNG (allowed, used to provide entropy to DRBG)	AES-CTR DRBG Seed AES-CTR DRBG Entropy Input AES-CTR DRBG V AES-CTR DRBG Key
Key and Key-Pair Generation	RSA, DH, ECDH, ECDSA, RC2, RC4, DES, Triple-DES, AES, and HMAC (RC2, RC4, and DES cannot be used in FIPS mode.)	Symmetric Keys Asymmetric Public Keys Asymmetric Private Keys
Key Entry and Output	SP 800-38F AES Key Wrapping (128, 192, and 256)	Symmetric Keys Asymmetric Public Keys Asymmetric Private Keys

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Encryption and Decryption	• Triple-DES with 3 key in ECB, CBC, CFB8 and CFB64 modes • AES-128, AES-192, and AES-256 in ECB, CBC, CFB8, CFB128, and CTR modes; • AES-128, AES-192, and AES-256 in CCM, CMAC, and GMAC modes; • AES-128, AES-192, and AES-256 GCM decryption; • NIST SP XTS-AES XTS-128 and XTS-256; • SP 800-56B RSADP mod 2048 • (AES GCM encryption, RC2, RC4, RSA, and DES, which cannot be used in FIPS mode)	Symmetric Keys Asymmetric Public Keys Asymmetric Private Keys
Hashing and Message Authentication	• FIPS 180-4 SHS SHA-1, SHA-256, SHA-384, and SHA-512; • FIPS 180-4 SHA-1, SHA-256, SHA-384, SHA-512 HMAC; • AES-128, AES-192, and AES-256 in CCM, CMAC, and GMAC; • MD5 and HMAC-MD5 (allowed in TLS and EAP-TLS); • MD2 and MD4 (disallowed in FIPS mode)	Symmetric Keys (for HMAC, AES CCM, AES CMAC, and AES GMAC)
Signing and Verification	• FIPS 186-4 RSA (RSASSA-PKCS1-v1_5 and RSASSA-PSS) digital signature generation and verification with 2048 and 3072 modulus; supporting SHA-1[8], SHA-256, SHA-384, and SHA-512 • FIPS 186-4 ECDSA with the following NIST curves: P-256, P-384, P-521	Asymmetric Public Keys Asymmetric RSA Private Keys Asymmetric ECDSA Public Keys Asymmetric ECDSA Private keys
Secret Agreement and Key Derivation	• KAS – SP 800-56A Diffie-Hellman Key Agreement; Finite Field Cryptography (FFC) • KAS – SP 800-56A EC Diffie-Hellman Key Agreement with the following NIST curves: P-256, P-384, P-521 and the	DH Private and Public Values ECDH Private and Public Values IKEv1 and IKEv2 DH shared secrets TLS Pre-Master Secret

[8] SHA-1 is only acceptable for legacy signature verification.

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	FIPS non-Approved curves listed in Non-Approved Algorithms • SP 800-108 Key Derivation Function (KDF) CMAC-AES (128, 192, 256), HMAC (SHA1, SHA-256, SHA-384, SHA-512) • SP 800-132 PBKDF • SP 800-135 IKEv1, IKEv2, and TLS KDF primitives • Legacy CAPI KDF (cannot be used in FIPS mode) • HKDF (cannot be used in FIPS mode)	
Show Status	None	None
Self-Tests	See Section 8 Self-Tests for the list of algorithms	None
Zeroizing Cryptographic Material	All	All

4.2.2 Mapping of Services, Export Functions, and Invocations

The following table maps the services to their corresponding export functions and invocations.

Table 6 Map of Services to Functions

Service	Export Functions	Invocations
Algorithm Providers and Properties	BCryptOpenAlgorithmProvider BCryptCloseAlgorithmProvider BCryptSetProperty BCryptGetProperty BCryptFreeBuffer	This service is executed whenever one of these exported functions is called.
Random Number Generation	BcryptGenRandom SystemPrng EntropyRegisterSource EntropyUnregisterSource EntropyProvideData EntropyPoolTriggerReseedForIum	This service is executed whenever one of these exported functions is called.
Key and Key-Pair Generation	BCryptGenerateSymmetricKey BCryptGenerateKeyPair BCryptFinalizeKeyPair BCryptDuplicateKey BCryptDestroyKey	This service is executed whenever one of these exported functions is called.
Key Entry and Output	BCryptImportKey BCryptImportKeyPair BCryptExportKey	This service is executed whenever one of these exported functions is called.

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Encryption and Decryption	BCryptEncrypt BCryptDecrypt	This service is executed whenever one of these exported functions is called.
Hashing and Message Authentication	BCryptCreateHash BCryptHashData BCryptDuplicateHash BCryptFinishHash BCryptDestroyHash BCryptHash BCryptCreateMultiHash BCryptProcessMultiOperations	This service is executed whenever one of these exported functions is called.
Signing and Verification	BCryptSignHash BCryptVerifySignature	This service is executed whenever one of these exported functions is called.
Secret Agreement and Key Derivation	BCryptSecretAgreement BCryptDeriveKey BCryptDestroySecret BCryptKeyDerivation BCryptDeriveKeyPBKDF2	This service is executed whenever one of these exported functions is called.
Show Status	All Exported Functions	This service is executed upon completion of an exported function.
Self-Tests	DriverEntry	This service is executed upon startup of this module.
Zeroizing Cryptographic Material	BCryptDestroyKey BCryptDestroySecret	This service is executed whenever one of these exported functions is called.

4.2.3 Non-Approved Services

The following table lists non-Approved services and non-security relevant or non-approved APIs exported from the crypto module.

Table 7 Non-Approved Services and Export Functions

Function Name or Service Name	Description
BCryptDeriveKeyCapi	Derives a key from a hash value. This function is provided as a helper function to assist in migrating from legacy Cryptography API (CAPI) to CNG.
BCRYPT_KDF_HKDF	Derives a key from a hash value. This function is provided to support potential enhancements to Windows.
SslDecryptPacket **SslEncryptPacket** **SslExportKey** **SslFreeObject** **SslImportKey** **SslLookupCipherLengths**	Supports Secure Sockets Layer (SSL) protocol functionality. These functions are non-approved.

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SslLookupCipherSuiteInfo **SslOpenProvider** **SslIncrementProviderReferenceCount** **SslDecrementProviderReferenceCount**	

4.3 Authentication

The module does not provide authentication. Roles are implicitly assumed based on the services that are executed.

5 Finite State Model

5.1 Specification

The following diagram shows the finite state model for Kernel Mode Cryptographic Primitives Library:

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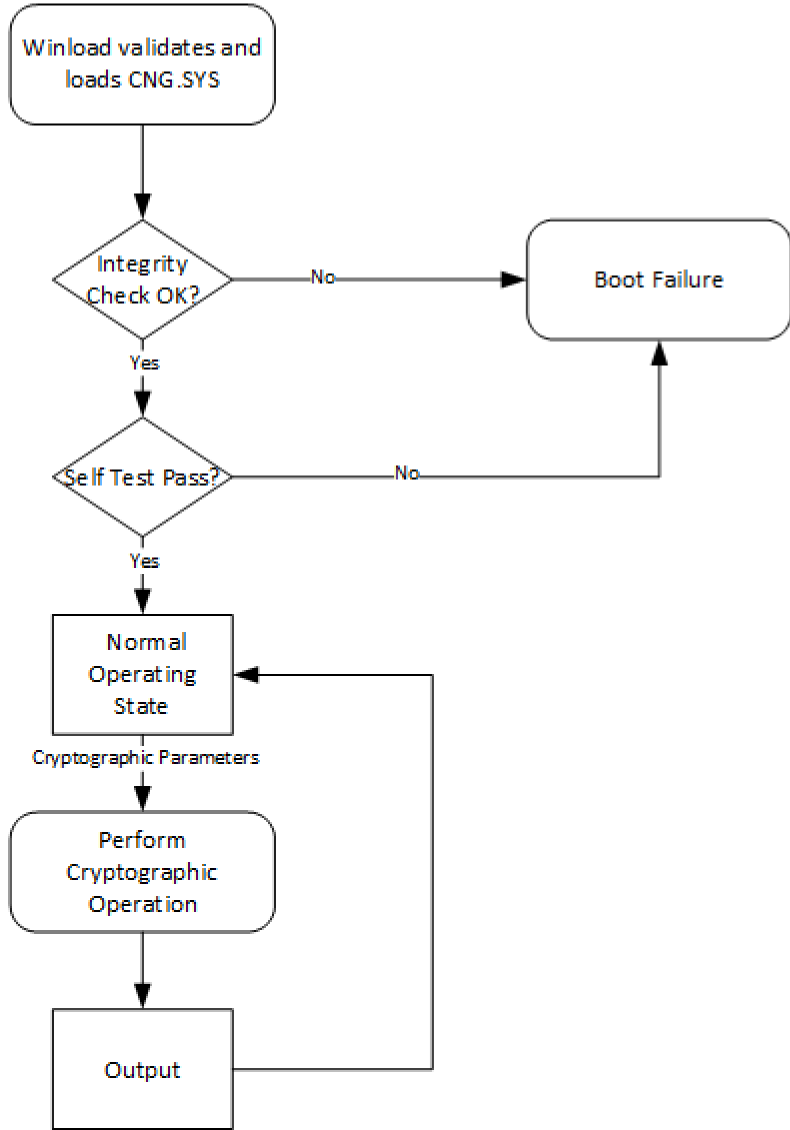

6 Operational Environment

The operational environment for Kernel Mode Cryptographic Primitives Library is the Windows Server operating system running on a supported hardware platform listed in section 1.2.

6.1 Single Operator

The for Kernel Mode Cryptographic Primitives Library is loaded into kernel memory as part of the boot process and before the logon component is initialized. The "single operator" for the module is the Windows Kernel.

6.2 Cryptographic Isolation

In the Windows operating system, all kernel-mode modules, including CNG.SYS, are loaded into the Windows Kernel (ntoskrnl.exe) which executes as a single process. The Windows operating system

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environment enforces process isolation from user-mode processes including memory and CPU scheduling between the kernel and user-mode processes.

6.3 Integrity Chain of Trust

Modules running in the Windows OS environment provide integrity verification through different mechanisms depending on when the module loads in the OS load sequence and also on the hardware and OS configuration. The following diagrams describe the Integrity Chain of trust for each supported configuration that impacts integrity checks:

- Windows Server 2019 build 10.0.17763.10021 and 10.0.17763.10127

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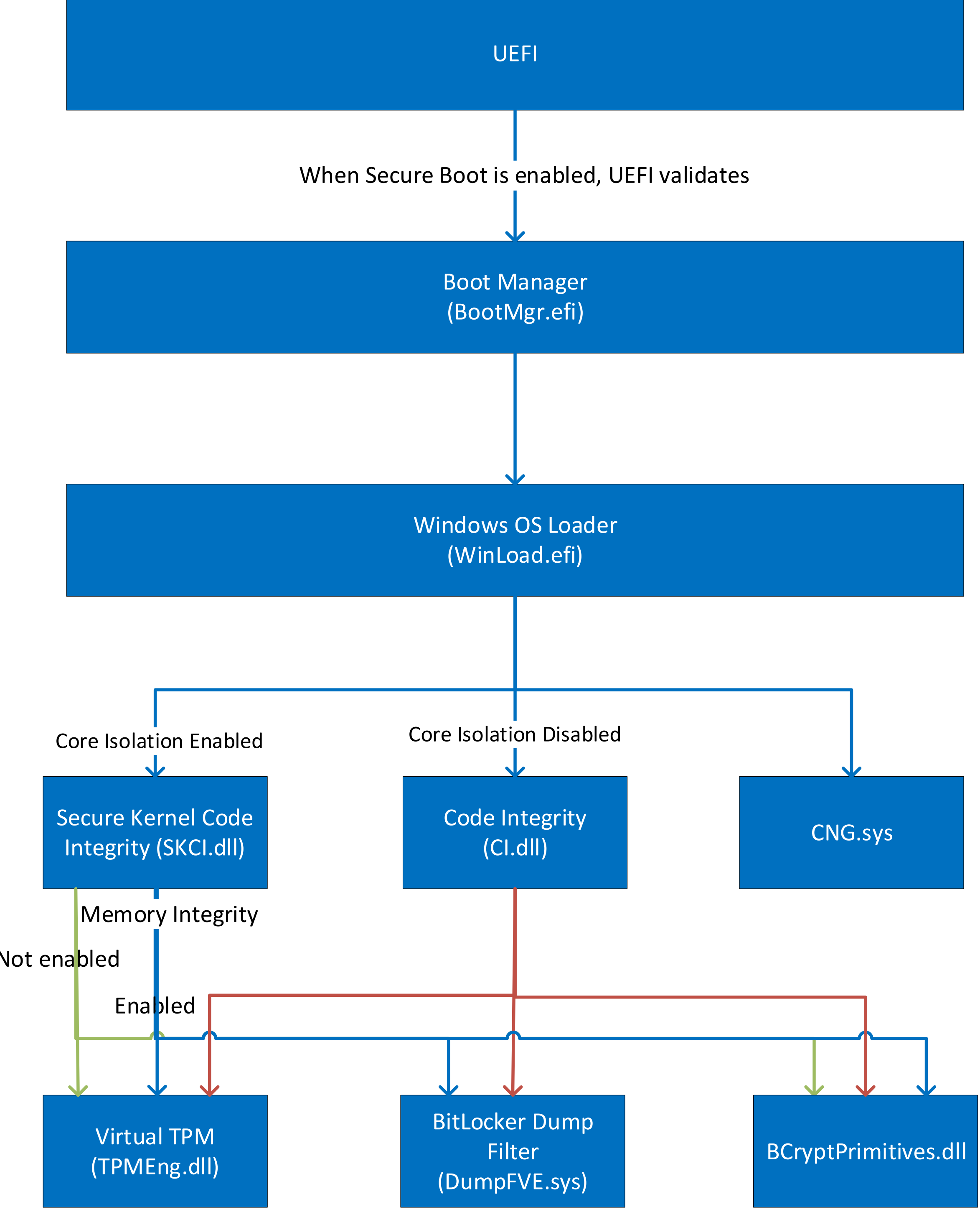

The Windows OS Loader checks the integrity of Kernel Mode Cryptographic Primitives Library before it is loaded into ntoskrnl.exe.

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Windows binaries include a SHA-256 hash of the binary signed with the 2048 bit Microsoft RSA code-signing key (i.e., the key associated with the Microsoft code-signing certificate). The integrity check uses the public key component of the Microsoft code signing certificate to verify the signed hash of the binary.

7 Cryptographic Key Management

The Kernel Mode Cryptographic Primitives Library crypto module uses the following critical security parameters (CSPs) for FIPS Approved security functions:

Table 8 CSPs

Security Relevant Data Item	Description
Symmetric encryption/decryption keys	Keys used for AES encryption/decryption and Triple-DES encryption/decryption. Key sizes for AES are 128, 192, and 256 bits, and key size for Triple-DES is 192 bits.
HMAC keys	Keys used for HMAC-SHA1, HMAC-SHA256, HMAC-SHA384, and HMAC-SHA512
Asymmetric ECDSA Public Keys	Keys used for the verification of ECDSA digital signatures. Curve sizes are P-256, P-384, and P-521.
Asymmetric ECDSA Private Keys	Keys used for the calculation of ECDSA digital signatures. Curve sizes are P-256, P-384, and P-521. May be generated using ECDSA Key Generation.
Asymmetric RSA Public Keys	Keys used for the verification of RSA digital signatures. Key sizes are 2048 and 3072 bits. These keys can be produced using RSA Key Generation.
Asymmetric RSA Private Keys	Keys used for the calculation of RSA digital signatures. Key sizes are 2048 and 3072 bits. These keys can be produced using RSA Key Generation.
AES-CTR DRBG Entropy Input	A secret value that is at least 256 bits and maintained internal to the module that provides the entropy material for AES-CTR DRBG output[9]. The module generates at least 256-bits of entropy before generating keys.
AES-CTR DRBG Seed	A 384 bit secret value maintained internal to the module that provides the seed material for AES-CTR DRBG output[10]

[9] Microsoft Common Criteria Windows Security Target, Page 29.
[10] Recommendation for Random Number Generation Using Deterministic Random Bit Generators, NIST SP 800-90A Revision 1, page 49.

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AES-CTR DRBG V	A 128 bit secret value maintained internal to the module that provides the entropy material for AES-CTR DRBG output[11]
AES-CTR DRBG Key	A 256 bit secret value maintained internal to the module that provides the entropy material for AES-CTR DRBG output[12]
DH Private and Public values	Private and public values used for Diffie-Hellman key establishment. Key sizes are 2048 to 4096 bits.
ECDH Private and Public values	Private and public values used for EC Diffie-Hellman key establishment. Curve sizes are P-256, P-384, and P-521 and the ones listed in section 2.3.
IKEv1 and IKEv2 DH shared secrets	Diffie-Hellman shared secret lengths are 2048 (SHA 256), 256 (SHA 256), and 384 (SHA 384).
TLS Pre-Master Secret	Shared secret input into TLS KDF. Key size can be 256, 384, or 2048 bits.

7.1 Access Control Policy

The Kernel Mode Cryptographic Primitives Library crypto module allows controlled access to the security relevant data items contained within it. The following table defines the access that a service has to each. The permissions are categorized as a set of four separate permissions: read (r), write (w), execute (x), delete (d). If no permission is listed, the service has no access to the item.

Table 9 Access Control Policy

Kernel Mode Cryptographic Primitives Library crypto module **Service Access Policy**	Symmetric encryption/decryption keys	HMAC keys	Asymmetric ECDSA Public keys	Asymmetric ECDSA Private keys	Asymmetric RSA Public Keys	Asymmetric RSA Private Keys	DH Public and Private values	ECDH Public and Private values	AES-CTR DRBG Seed, AES-CTR DRBG Entropy Input, AES-CTR DRBG V, & AES-CTR DRBG key	IKEv1 & IKEv2 DH Shared Secrets	TLS Pre-Master Secret
Algorithm Providers and Properties											
Random Number Generation									x		
Key and Key-Pair Generation	wd	wd	wd	wd	wd	wd	wd	wd	x		
Key Entry and Output	rw	rw	rw	rw	rw	rw	rw	rw			
Encryption and Decryption	x										

[11] Ibid.

[12] Ibid.

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Hashing and Message Authentication		wx									
Signing and Verification			x	x	x	x			x		
Secret Agreement and Key Derivation							x	x	x	x	x
Show Status											
Self-Tests											
Zeroizing Cryptographic Material	wd	wd	wd	wd	wd	wd	wd	wd	wd	w d	w d

7.2 Key Material

When Kernel Mode Cryptographic Primitives Library is loaded in the Windows Server operating system kernel, no keys exist within it. A kernel module is responsible for importing keys into Kernel Mode Cryptographic Primitives Library or using Kernel Mode Cryptographic Primitives Library’s functions to generate keys.

7.3 Key Generation

Kernel Mode Cryptographic Primitives Library can create and use keys for the following algorithms: RSA, DH, ECDH, ECDSA, RC2, RC4, DES, Triple-DES, AES, and HMAC. However, RC2, RC4, and DES cannot be used in FIPS mode.

Random keys can be generated by calling the BCryptGenerateSymmetricKey() and BCryptGenerateKeyPair() functions. Random data generated by the BCryptGenRandom() function is provided to BCryptGenerateSymmetricKey() function to generate symmetric keys. DES, Triple-DES, AES, RSA, ECDSA, DH, and ECDH keys and key-pairs are generated following the techniques given in SP 800-133r2 (Section 4).

Keys generated while not operating in the FIPS mode of operation cannot be used in FIPS mode, and vice versa.

7.4 Key Establishment

In its Approved mode of operation, the Kernel Mode Cryptographic Primitives Library supports approved Diffie-Hellman key agreement (DH), Elliptic Curve Diffie-Hellman key agreement (ECDH), manual methods to establish keys, and the following Approved key derivation functions (KDFs) to derive key material from a specified secret value or password.

- BCRYPT_KDF_SP80056A_CONCAT. This KDF supports the Concatenation KDF as specified in SP 800-56A (Section 5.8.1).
- BCRYPT_SP80056A_CONCAT_ALGORITHM. This KDF supports the Concatenation KDF as specified in SP 800-56Ar2 (Section 5.8.1).
- BCRYPT_KDF_HASH. This KDF supports FIPS approved SP800-56A (Section 5.8) key derivation.

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- BCRYPT_KDF_HMAC. This KDF supports the IPsec IKEv1 key derivation that is non-Approved but is an allowed legacy implementation in FIPS mode when used to establish keys for IKEv1 as per scenario 4 of IG D.8.
- BCRYPT_SP800108_CTR_HMAC_ALGORITHM. This KDF supports the counter-mode variant of the KDF specified in SP 800-108 (Section 5.1) with HMAC as the underlying PRF.
- BCRYPT_PBKDF2_ALGORITHM. This KDF supports the Password Based Key Derivation Function specified in SP 800-132 (Section 5.3).

The following non-Approved key establishment methods are supported by the module, but disallowed in FIPS mode.

- RSA key transport

The following non-Approved KDFs are supported by the module, but disallowed in FIPS mode.

- BCRYPT_KDF_HASH. This KDF implements X9.63 and X9.42 key derivation.
- Industry standard KDF, HKDF (CNG flag BCRYPT_KDF_HKDF), and the legacy proprietary CryptDerive Key KDF, (BCRYPT_CAPI_KDF_ALGORITHM, described at https://learn.microsoft.com/en-us/windows/win32/api/wincrypt/nf-wincrypt-cryptderivekey.

7.4.1 NIST SP 800-132 Password Based Key Derivation Function (PBKDF)

There are two options presented in NIST SP 800-132, pages 8 – 10, that are used to derive the Data Protection Key (DPK) from the Master Key. With the Kernel Mode Cryptographic Primitives Library, it is up to the caller to select the option to generate/protect the DPK. For example, DPAPI uses option 2a. Kernel Mode Cryptographic Primitives Library provides all the building blocks for the caller to select the desired option.

The Kernel Mode Cryptographic Primitives Library supports the following HMAC hash functions as parameters for PBKDF:

- SHA-1 HMAC
- SHA-256 HMAC
- SHA-384 HMAC
- SHA-512 HMAC

Keys derived from passwords, as described in SP 800-132, may only be used for storage applications. In order to run in a FIPS Approved manner, strong passwords must be used and they may only be used for storage applications. The password/passphrase length is enforced by the caller of the PBKDF interfaces when the password/passphrase is created and not by this cryptographic module.[13]

[13] The probability of guessing a password is determined by its length and complexity, an organization should define a policy for these based based their threat model, suh as the example guidance in NIST SP800-63b, Appendix A.

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7.4.2 NIST SP 800-38F AES Key Wrapping

As outlined in FIPS 140-2 IG, D.2 and D.9, AES key wrapping serves as a form of key transport, which in turn is a form of key establishment. This implementation of AES key wrapping is in accordance with NIST SP 800-38F Recommendation for Block Cipher Modes of Operation: Methods for Key Wrapping.

7.5 Key Entry and Output

Keys can be both exported and imported out of and into Kernel Mode Cryptographic Primitives Library via BCryptExportKey(), BCryptImportKey(), and BCryptImportKeyPair() functions.

Symmetric key entry and output can also be done by exchanging keys using the recipient's asymmetric public key via BCryptSecretAgreement() and BCryptDeriveKey() functions.

Exporting the RSA private key by supplying a blob type of BCRYPT_PRIVATE_KEY_BLOB, BCRYPT_RSAFULLPRIVATE_BLOB, or BCRYPT_RSAPRIVATE_BLOB to BCryptExportKey() is not allowed in FIPS mode.

7.6 Key Storage

Kernel Mode Cryptographic Primitives Library does not provide persistent storage of keys.

7.7 Key Archival

Kernel Mode Cryptographic Primitives Library does not directly archive cryptographic keys. A user may choose to export a cryptographic key (cf. "Key Entry and Output" above), but management of the secure archival of that key is the responsibility of the user. All key copies inside Kernel Mode Cryptographic Primitives Library are destroyed and their memory location zeroized after used. It is the caller's responsibility to maintain the security of keys when the keys are outside Kernel Mode Cryptographic Primitives Library.

7.8 Key Zeroization

All keys are destroyed and their memory location zeroized when the operator calls BCryptDestroyKey() or BCryptDestroySecret() on that key handle.

8 Self-Tests

8.1 Power-On Self-Tests

The Kernel Mode Cryptographic Primitives Library module implements Known Answer Test (KAT) functions when the module is loaded into ntoskrnl.exe at boot time and the default driver entry point, DriverEntry, is called.

Kernel Mode Cryptographic Primitives Library performs the following power-on (startup) self-tests:

- HMAC (SHA-1, SHA-256, and SHA-512) Known Answer Tests
- Triple-DES encrypt/decrypt ECB Known Answer Tests
- AES-128 encrypt/decrypt ECB Known Answer Tests

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- AES-128 encrypt/decrypt CCM Known Answer Tests
- AES-128 encrypt/decrypt CBC Known Answer Tests
- AES-128 CMAC Known Answer Test
- AES-128 encrypt/decrypt GCM Known Answer Tests
- XTS-AES encrypt/decrypt Known Answer Tests
- RSA sign/verify Known Answer Tests using RSA_SHA256_PKCS1 signature generation and verification
- ECDSA sign/verify Known Answer Tests on P256 curve
- DH secret agreement Known Answer Test with 2048-bit key
- ECDH secret agreement Known Answer Test on P256 curve
- SP 800-90A AES-256 counter mode DRBG Known Answer Tests (instantiate, generate and reseed)
- SP 800-108 KDF Known Answer Test
- SP 800-132 PBKDF Known Answer Test
- SHA-256 Known Answer Test
- SHA-512 Known Answer Test
- SP800-135 TLS 1.0/1.1 KDF Known Answer Test
- SP800-135 TLS 1.2 KDF Known Answer Test
- IKE SP800_135 KDF Known Answer Test

In any self-test fails, the Kernel Mode Cryptographic Primitives Library module does not load, an error code is returned to ntoskrnl.exe, and the computer will fail to boot.

8.2 Conditional Self-Tests

Kernel Mode Cryptographic Primitives Library performs pair-wise consistency checks upon each invocation of RSA, DH, ECDH, and ECDSA key-pair generation and import as defined in FIPS 140-2.

DH and ECDH key usage assurances are performed according to NIST SP 800-56A sections 5.5.2, 5.6.2, and 5.6.3.

A Continuous Random Number Generator Test (CRNGT) and the DRBG health tests are performed for SP 800-90A AES-256 CTR DRBG.

A CRNGT is performed for the non-approved NDRNG per FIPS 140-2 IG 9.8.

When BCRYPT_ENABLE_INCOMPATIBLE_FIPS_CHECKS flag (required by policy) is used with BCryptGenerateSymmetricKey, then the XTS-AES Key_1 ≠ Key_2 check is performed in compliance with FIPS 140-2 IG A.9.

If the conditional self-test fails the function returns the status code STATUS_INTERNAL_ERROR.

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9 Design Assurance

The secure installation, generation, and startup procedures of this cryptographic module are part of the overall operating system secure installation, configuration, and startup procedures for the Windows Server operating system.

The Windows Server operating system must be pre-installed on a computer by an OEM, installed by the end-user, by an organization's IT administrator, or updated from a previous Windows Server version downloaded from Windows Update.

An inspection of authenticity of the physical medium can be made by following the guidance at this Microsoft web site: https://www.microsoft.com/en-us/howtotell/default.aspx

The installed version of Windows Server must be verified to match the version that was validated. See Appendix A – How to Verify Windows Versions and Digital Signatures for details on how to do this.

For Windows Updates, the client only accepts binaries signed by Microsoft certificates. The Windows Update client only accepts content whose SHA-2 hash matches the SHA-2 hash specified in the metadata. All metadata communication is done over a Secure Sockets Layer (SSL) port. Using SSL ensures that the client is communicating with the real server and so prevents a spoof server from sending the client harmful requests. The version and digital signature of new cryptographic module releases must be verified to match the version that was validated. See Appendix A – How to Verify Windows Versions and Digital Signatures for details on how to do this.

10 Mitigation of Other Attacks

The following table lists the mitigations of other attacks for this cryptographic module:

Table 10 Mitigation of Other Attacks

Algorithm	Protected Against	Mitigation
SHA1	Timing Analysis Attack	Constant time implementation
	Cache Attack	Memory access pattern is independent of any confidential data
SHA2	Timing Analysis Attack	Constant time implementation
	Cache Attack	Memory access pattern is independent of any confidential data
Triple-DES	Timing Analysis Attack	Constant time implementation
AES	Timing Analysis Attack	Constant time implementation
	Cache Attack	Memory access pattern is independent of any confidential data
		Protected against cache attacks only when used with AES NI

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11 Security Levels

The security level for each FIPS 140-2 security requirement is given in the following table.

Table 11 Security Levels

Security Requirement	Security Level
Cryptographic Module Specification	1
Cryptographic Module Ports and Interfaces	1
Roles, Services, and Authentication	1
Finite State Model	1
Physical Security	1
Operational Environment	1
Cryptographic Key Management	1
EMI/EMC	1
Self-Tests	1
Design Assurance	2
Mitigation of Other Attacks	1

Kernel Mode Cryptographic Primitives Library is a multi-chip standalone software-hybrid module whose host platforms meet the level 1 physical security requirements. The module consists of production-grade components that include standard passivation techniques and is entirely contained within a metal or hard plastic production-grade enclosure that may include doors or removable covers.

12 Additional Details

For the latest information on Microsoft Windows, check out the Microsoft web site at:

https://www.microsoft.com/en-us/windows

For more information about FIPS 140 validations of Microsoft products, please see:

https://docs.microsoft.com/en-us/windows/security/threat-protection/fips-140-validation

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13 Appendix A – How to Verify Windows Versions and Digital Signatures

13.1 How to Verify Windows Versions

The installed version of Windows Server OEs must be verified to match the version that was validated using the following method:

1. In the Search box type "cmd" and open the Command Prompt desktop app.
2. The command window will open.
3. At the prompt, enter "ver”.
4. The version information will be displayed in a format like this:
   `Microsoft Windows [Version 10.0.xxxxx]`

If the version number reported by the utility matches the expected output, then the installed version has been validated to be correct.

13.2 How to Verify Windows Digital Signatures

After performing a Windows Update that includes changes to a cryptographic module, the digital signature and file version of the binary executable file must be verified. This is done like so:

1. Open a new window in Windows Explorer.
2. Type “C:\Windows\” in the file path field at the top of the window.
3. Type the cryptographic module binary executable file name (for example, “CNG.SYS”) in the search field at the top right of the window, then press the Enter key.
4. The file will appear in the window.
5. Right click on the file’s icon.
6. Select Properties from the menu and the Properties window opens.
7. Select the Details tab.
8. Note the File version Property and its value, which has a number in this format: xx.x.xxxxx.xxxx.
9. If the file version number matches one of the version numbers that appear at the start of this security policy document, then the version number has been verified.
10. Select the Digital Signatures tab.
11. In the Signature list, select the Microsoft Windows signer.
12. Click the Details button.
13. Under the Digital Signature Information, you should see: “This digital signature is OK.” If that condition is true, then the digital signature has been verified.

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14 Appendix B – References

This table lists the specifications for each elliptic curve in section 2.3

Table 12 References

Curve	Specification
Curve25519	https://cr.yp.to/ecdh/curve25519-20060209.pdf
brainpoolP160r1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP192r1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP192t1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP224r1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP224t1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP256r1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP256t1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP320r1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP320t1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP384r1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP384t1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP512r1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
brainpoolP512t1	http://www.ecc-brainpool.org/download/Domain-parameters.pdf
ec192wapi	http://www.gbstandards.org/GB_standards/GB_standard.asp?id=900 (The GB standard is available here for purchase)
nistP192	http://csrc.nist.gov/groups/ST/toolkit/documents/dss/NISTReCur.pdf
nistP224	http://csrc.nist.gov/groups/ST/toolkit/documents/dss/NISTReCur.pdf
numsP256t1	https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/curvegen.pdf
numsP384t1	https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/curvegen.pdf
numsP512t1	https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/curvegen.pdf
secP160k1	http://www.secg.org/sec2-v2.pdf
secP160r1	http://www.secg.org/sec2-v2.pdf
secP160r2	http://www.secg.org/sec2-v2.pdf
secP192k1	http://www.secg.org/sec2-v2.pdf
secP192r1	http://www.secg.org/sec2-v2.pdf
secP224k1	http://www.secg.org/sec2-v2.pdf
secP224r1	http://www.secg.org/sec2-v2.pdf
secP256k1	http://www.secg.org/sec2-v2.pdf
secP256r1	http://www.secg.org/sec2-v2.pdf
secP384r1	http://www.secg.org/sec2-v2.pdf
secP521r1	http://www.secg.org/sec2-v2.pdf
wtls12	http://www.openmobilealliance.org/tech/affiliates/wap/wap-261-wtls-20010406-a.pdf
wtls7	http://www.openmobilealliance.org/tech/affiliates/wap/wap-261-wtls-20010406-a.pdf

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Curve	Specification
wtls9	http://www.openmobilealliance.org/tech/affiliates/wap/wap-261-wtls-20010406-a.pdf
x962P192v1	https://global.ihs.com/doc_detail.cfm?&item_s_key=00325725&item_key_date=941231&input_doc_number=ANSI%20X9%2E62&input_doc_title= (The ANSI X9.62 standard is available here for purchase)
x962P192v2	https://global.ihs.com/doc_detail.cfm?&item_s_key=00325725&item_key_date=941231&input_doc_number=ANSI%20X9%2E62&input_doc_title= (The ANSI X9.62 standard is available here for purchase)
x962P192v3	https://global.ihs.com/doc_detail.cfm?&item_s_key=00325725&item_key_date=941231&input_doc_number=ANSI%20X9%2E62&input_doc_title= (The ANSI X9.62 standard is available here for purchase)
x962P239v1	https://global.ihs.com/doc_detail.cfm?&item_s_key=00325725&item_key_date=941231&input_doc_number=ANSI%20X9%2E62&input_doc_title= (The ANSI X9.62 standard is available here for purchase)
x962P239v2	https://global.ihs.com/doc_detail.cfm?&item_s_key=00325725&item_key_date=941231&input_doc_number=ANSI%20X9%2E62&input_doc_title= (The ANSI X9.62 standard is available here for purchase)
x962P239v3	https://global.ihs.com/doc_detail.cfm?&item_s_key=00325725&item_key_date=941231&input_doc_number=ANSI%20X9%2E62&input_doc_title= (The ANSI X9.62 standard is available here for purchase)
x962P256v1	https://global.ihs.com/doc_detail.cfm?&item_s_key=00325725&item_key_date=941231&input_doc_number=ANSI%20X9%2E62&input_doc_title= (The ANSI X9.62 standard is available here for purchase)

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