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COMPUTER SECURITY

National Institute of Standards and Technology
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Abstract

The National Institute of Standards and Technology (NIST) provides cryptographic key management guidance for defining and implementing appropriate key management procedures, using algorithms that adequately protect sensitive information, and planning ahead for possible changes in the use of cryptography because of algorithm breaks or the availability of more powerful computing techniques. NIST Special Publication (SP) 800-57, Part 1 includes a general approach for transitioning from one algorithm or key length to another. This Recommendation (SP 800-131A) provides more specific guidance for transitions to the use of stronger cryptographic keys and more robust algorithms.

Keywords

cryptographic algorithm; digital signatures; encryption; hash function; key agreement; key derivation functions; key management; key transport; key wrapping; message authentication codes; post-quantum algorithms; random number generation; security strength; transition.

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Notes to Reviewers

1. One of the primary revisions to this document is providing a plan for retiring TDEA. Two-key TDEA is now disallowed for applying cryptographic protection (e,g, encryption, but allowed for processing already-protected information. In accordance with NIST's announcement regarding the continued use of TDEA (see the TDEA Announcement), this document is proposing a schedule for sunsetting the use of TDEA for applying cryptographic protection (e.g., encryption, MAC generation, etc.). However, there may be applications for which the continued use of TDEA might be appropriate; NIST will provide guidance on this at a later time. The use of TDEA for processing already-protected information will continue to be allowed for legacy use, with the caveat that some risk is associated with doing so.

   NIST requests comments on this schedule and an identification of any applications for which the continued use of TDEA would be appropriate, along with rationale for considering this use to be secure.

2. A revision of SP 800-57, Part 1 is planned that will be consistent with the changes in SP 800-131A.

3. The elliptic curves currently defined in FIPS 186-4, Digital Signature Standard (DSS), will be moved to a new publication, SP 800-186, that will soon be available for public comment. Additional elliptic curves will also be included in that SP 800-186. SP 800-131A refers to this new document.

4. A revision of FIPS 186 (FIPS 186-5) will soon be available for public comment. This revision will include EdDSA. SP 800-131A takes this into account.

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1 Introduction

1.1 Background and Purpose

At the beginning of the 21st century, the National Institute of Standards and Technology (NIST) began the task of providing cryptographic key management guidance. This guidance was based on the lessons learned over many years of dealing with key management issues and is intended to 1) encourage the specification and implementation of appropriate key management procedures, 2) use algorithms that adequately protect sensitive information, and 3) plan for possible changes in the use of cryptographic algorithms, including any migration to different algorithms. The third item addresses not only the possibility of new cryptanalysis, but also the increasing power of classical computing technology and the potential emergence of quantum computers.

General key-management guidance, including the general approach for transitioning from one algorithm or key length to another, is addressed in Part 1 of Special Publication (SP) 800-57[1].

This document (SP 800-131A) is intended to provide more detail about the transitions associated with the use of cryptography by federal government agencies for the protection of sensitive, but unclassified information. The document addresses the use of algorithms and key lengths specified in Federal Information Processing Standards (FIPS) and NIST Special Publications (SPs).

NIST recognizes that large-scale quantum computers, when available, will threaten the security of NIST-approved public key algorithms. In particular, NIST-approved digital signature schemes, key agreement using Diffie-Hellman and MQV, and key agreement and key transport using RSA may need to be replaced with secure quantum-resistant (or "post-quantum") counterparts. At the time that this SP 800-131A revision was published, NIST was undergoing a process to select post-quantum cryptographic algorithms for standardization. This process is a multi-year project; when these new standards are available, this Recommendation will be updated with the guidance for the transition to post-quantum cryptographic standards. NIST encourages implementers to plan for cryptographic agility to facilitate transitions to quantum-resistant algorithms where needed in the future. Information on the post-quantum project is available at https://csrc.nist.gov/projects/post-quantum-cryptography.

SP 800-131A was originally published in January 2011 and revised in 2015. This revision updates the transition guidance provided in the 2015 version; these changes are listed in Appendix B. The most significant difference is the schedule for retiring the Triple Data Encryption Algorithm (TDEA), the inclusion of safe-prime groups for finite field Diffie-Hellman and MQV, and the inclusion of KMAC for MAC generation.

[1] SP 800-57, Part 1: *Recommendation for Key Management: General*.

1.2 Useful Terms for Understanding this Recommendation

1.2.1 Security Strengths

Some of the guidance provided in SP 800-57 includes the definition of an estimated maximum security strength (hereafter shortened to just "security strength"), the association of the algorithms and key lengths with these security strengths, and a projection of the time frames during which the algorithms and key lengths could be expected to provide adequate security. Note that the length of the cryptographic keys is an integral part of these determinations.

In SP 800-57, the security strength provided by an algorithm with a particular key length[2] is measured in bits and is a measure of the difficulty of subverting the cryptographic protection that is provided by the algorithm and key. An estimated security strength for each algorithm is provided in SP 800-57. This is the security strength that an algorithm with a particular key length can provide, given that the key used with that algorithm has sufficient entropy[3].

> Note: The term "security strength" refers to the classical security strength – a measure of the difficulty of subverting the cryptographic protection (e.g., discovering the key) using classical computers. When post-quantum cryptography is introduced in NIST standards, quantum security strength, i.e. the difficulty of subverting the protection using quantum computers, will be defined.

The appropriate (classical) security strength to be used to protect data depends on the sensitivity of the data being protected and needs to be determined by the owner of that data (e.g., a person or an organization). For the federal government, a security strength of at least 112 bits is required at this time for applying cryptographic protection (e.g., for encrypting or signing data). Note that prior to 2014, a security strength of at least 80 bits was required for applying these protections, and the transitions in this document reflect this change to a required security strength of at least 112 bits. However, a large quantity of data was protected at the 80-bit security strength and may need to be processed (e.g., decrypted). The processing of this already-protected data at the lower security strength is allowed, but a certain amount of risk must be accepted[4].

Specific key lengths are provided in FIPS 186[5] for digital signatures, in SP 800-56A[6] for finite field Diffie-Hellman (DH) and MQV key agreement, and in SP 800-56B[7] for RSA

[2] The term "key size" is commonly used in other documents.

[3] Entropy is a measure of the amount of disorder, randomness or variability in a closed system.

[4] For example, if the data was encrypted and transmitted over public networks when the algorithm was still considered secure, it may have been captured (by an adversary) at that time and later decrypted by that adversary when the algorithm was no longer considered secure; thus, the confidentiality of the data would no longer be assured.

[5] FIPS 186, *Digital Signature Standard (DSS)*.

[6] SP 800-56A, *Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Logarithm Cryptography*.

[7] SP 800-56B, *Recommendation for Pair-Wise Key Establishment Using Integer Factorization*.

key agreement and key transport. SP 800-186[8] provides elliptic curves for elliptic curve digital signatures and elliptic curve DH and MQV key agreement; the elliptic curve specifications provide the key lengths associated with each curve. These key lengths are strongly recommended for interoperability, and their estimated security strengths are provided in SP 800-57. However, other key lengths are commonly used. The security strengths associated with these key lengths may be determined using the formula provided in Section 7.5 of the FIPS 140 Implementation Guideline.[9]

1.2.2 General Definitions

Apply cryptographic protection	Depending on the algorithm, to encrypt or sign data, generate a hash function or Message Authentication Code (MAC), or establish keys (including wrapping and deriving keys).
Approval status	Used to designate usage by the U.S. Federal Government.
Approved	FIPS-**approved** or NIST-Recommended. An algorithm or technique that is either 1) specified in a FIPS or NIST Recommendation, or 2) adopted in a FIPS or NIST Recommendation and specified either (a) in an appendix to the FIPS or NIST Recommendation, or (b) in a document referenced by the FIPS or NIST Recommendation.
len(x)	The bit length of x.
Shall	A requirement for federal government use. Note that **shall** may be coupled with **not** to become **shall not**.

1.2.3 Definition of Status Approval Terms

The terms "**acceptable**", "**deprecated**", "**legacy use**" and "**disallowed**" are used throughout this Recommendation to indicate the approval status of an algorithm. The approval status for an algorithm often will also depend on the length of its key, any domain parameters and the mode or manner in which it is used.

- **Acceptable** is used to mean that the algorithm and key length in a FIPS or SP is safe to use; no security risk is currently known when used in accordance with any associated guidance. The FIPS 140 Implementation Guideline may indicate additional algorithms that are acceptable for use, but not specified in a FIPS or NIST Recommendation.

- **Deprecated** means that the algorithm and key length may be used, but the user must accept some security risk. The term is used when discussing the key lengths or algorithms that may be used to apply cryptographic protection.

[8] SP 800-186, *Recommendation for Discrete Logarithm-based Cryptography: Elliptic Curve Domain Parameters*. Until SP 800-186 is published, approved elliptic curves are specified in FIPS 186-4.

[9] FIPS 140 Implementation Guide: *Implementation Guidance for FIPS 140-2 and the Cryptographic Module Validation Program*.

- **Disallowed** means that the algorithm or key length is no longer allowed for applying cryptographic protection.
- **Legacy use** means that the algorithm or key length may be used only to process already protected information (e.g., to decrypt ciphertext data or to verify a digital signature).

The use of algorithms and key lengths for which the terms **deprecated** and **legacy use** are listed require that the user must accept some risk[10] that increases over time. If a user determines that the risk is unacceptable, then the algorithm or key length is considered disallowed from the perspective of that user. It is the responsibility of the user or the user's organization to determine the level of risk that can be tolerated for an application and its associated data and to define any methods for mitigating those risks.

Other cryptographic terms used in this document are defined in the documents listed in Appendix A.

2 Encryption and Decryption Using Block Cipher Algorithms

Encryption is a cryptographic operation that is used to provide confidentiality for sensitive information, and decryption is the inverse operation. Over time, several block cipher algorithms have been specified for use by the federal government:

- The Triple Data Encryption Algorithm (TDEA) (often referred to as Triple DES) is specified in SP 800-67[11], and has two variations, known as two-key TDEA and three-key TDEA. Three-key TDEA is the stronger of the two variations. The latest revision of SP 800-67 disallows the use of two-key TDEA for applying cryptographic protection and restricts the use of three-key TDEA for applying cryptographic protection to no more than 2^{20} data blocks using a single key bundle[12].
- SKIPJACK was approved in FIPS 185[13]. However, approval for the use of SKIPJACK is now disallowed for applying cryptographic protection, since its security strength of 80 bits is now considered inadequate; it may still be used for processing information previously protected using SKIPJACK (e.g., for decryption).
- AES is specified in FIPS 197[14] and has three key lengths: 128, 192 and 256 bits.

Note that encryption and decryption using these algorithms require the use of modes of operation (see the SP 800-38 series of publications). Some of these modes also provide

[10] For example, if the data was encrypted and transmitted over public networks when the algorithm was still considered secure, it may have been captured (by an adversary) at that time and later decrypted by that adversary when the algorithm was no longer considered secure; thus, the confidentiality of the data would no longer be assured. Also see Appendix A.

[11] SP 800-67, *Recommendation for the Triple Data Encryption Algorithm (TDEA) Block Cipher*.

[12] A TDEA key bundle consists of three keys.

[13] FIPS 185, *Escrowed Encryption Standard*.

[14] FIPS 197, *Advanced Encryption Standard*.

authentication when performing encryption and provide verification when performing decryption on the encrypted and authenticated information (see SP 800-38C[15] and SP 800-38D[16]). Another authenticated encryption mode is specified for key wrapping, which is discussed in Section 7.

The approval status of the block cipher encryption/decryption modes of operation are provided in Table 1.

Table 1: Approval Status of Symmetric Algorithms Used for Encryption and Decryption

Algorithm	Status
Two-key TDEA Encryption	Disallowed
Two-key TDEA Decryption	Legacy use
Three-key TDEA Encryption	Deprecated through 2023 Disallowed after 2023
Three-key TDEA Decryption	Legacy use
SKIPJACK Encryption	Disallowed
SKIPJACK Decryption	Legacy use
AES-128 Encryption and Decryption	Acceptable
AES-192 Encryption and Decryption	Acceptable
AES-256 Encryption and Decryption	Acceptable

Two-key TDEA encryption and decryption:

Encryption using two-key TDEA is **disallowed**.

Decryption using two-key TDEA is allowed for **legacy use** using the encryption modes of operation specified in SP 800-38A.

Three-key TDEA encryption and decryption:

Effective as of the final publication of this revision of SP 800-131A, encryption using three-key TDEA is **deprecated** through December 31, 2023 using the **approved** encryption modes. Note that SP 800-67 specifies a restriction on the protection of no more than 2^{20} data blocks using the same single key bundle. Three-key TDEA may continue to be used for encryption in existing applications but **shall not** be used for encryption in new applications.

After December 31, 2023, three-key TDEA is **disallowed** for encryption unless specifically allowed by other NIST guidance.

Decryption using three-key TDEA is allowed for **legacy use**.

[15] SP 800-38D, *Recommendation for Block Cipher Modes of Operation: the CCM Mode for Authentication and Confidentiality*.

[16] SP 800-38D, *Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC*.

SKIPJACK encryption and decryption:

The use of SKIPJACK for encryption is **disallowed**.

The use of SKIPJACK for decryption is allowed for **legacy use**.

AES encryption and decryption:

The use of AES-128, AES-192, AES-256 is **acceptable** for encryption and decryption using the **approved** modes in the SP 800-38 series of publications.

3 Digital Signatures

Digital signatures are used to provide assurance of origin authentication and data integrity. These assurances are sometimes extended to provide assurance that a party in a dispute (the signatory) cannot repudiate (i.e., refute) the validity of the signed document; this is commonly known as non-repudiation. The digital signature algorithms are specified in FIPS 186.

The security strength estimated for a digital signature algorithm depends on the hash function used, the key length and method for key generation and any other parameters used during the digital signature process.

- DSA: DSA keys are generated and used with domain parameters p, q and g. The security strength that can be provided by the algorithm depends on the length of p (L), the length of q (N), and the proper generation of the domain parameters used.
- Elliptic Curve-based Digital Signatures (ECDSA and EdDSA[17]): Keys are generated and used with respect to domain parameters that define elliptic curves. The length of n (the domain parameter that specifies the order of the base point G) is used to determine the security strength that can be provided by a properly generated curve. Elliptic curves used for the generation of digital signatures are provided in SP 800-186.[18]
- RSA: RSA keys are generated with respect to a modulus n, which is used to determine the security strength that can be provided by a digital signature.

Note that the security strength provided by a digital signature generation process is no greater than the minimum of 1) the security strength that the digital signature algorithm can support with a given key length and 2) the security strength (with respect to collision resistance) supported by the cryptographic hash function that is used to hash the data to be signed. The estimated security strength that can be provided by a given algorithm and key length is provided in SP 800-57.

Discussions of the hash functions used during the generation of digital signatures are provided in Section 9.

Table 2 provides the approval status of the algorithms and key lengths used for the generation and verification of digital signatures in accordance with FIPS 186. Note that

[17] EdDSA will be specified in FIPS 186-5 for public comment.

[18] Until SP 800-186 is completed, recommended elliptic curves are specified in FIPS 186-4.

digital signature generation methods not in conformance with FIPS 186 are disallowed for Federal government applications.

Table 2: Approval Status of Algorithms Used for Digital Signature Generation and Verification

Digital Signature Process	Domain Parameters	Status
Digital Signature Generation	< 112 bits of security strength: DSA: $(L, N) \neq$ (2048, 224), (2048, 256) or (3072, 256) ECDSA: $\mathbf{len}(n) < 224$ RSA: $\mathbf{len}(n) < 2048$	Disallowed
	≥ 112 bits of security strength: DSA: $(L, N) =$ (2048, 224), (2048, 256) or (3072, 256) ECDSA or EdDSA: $\mathbf{len}(n) \geq 224$ RSA: $\mathbf{len}(n) \geq 2048$	Acceptable
Digital Signature Verification	< 112 bits of security strength: DSA[19]: $((512 \leq L < 2048)$ or $(160 \leq N < 224))$ ECDSA: $160 \leq \mathbf{len}(n) < 224$ RSA: $1024 \leq \mathbf{len}(n) < 2048$	Legacy use
	≥ 112 bits of security strength: DSA: $(L, N) =$ (2048, 224), (2048, 256) or (3072, 256) ECDSA and EdDSA: $\mathbf{len}(n) \geq 224$ RSA: $\mathbf{len}(n) \geq 2048$	Acceptable

Digital signature generation:

Private-key lengths providing less than 112 bits of security **shall not** be used to generate digital signatures.

Private-key lengths providing at least 112 bits of security are **acceptable** for the generation of digital signatures.

- DSA: The DSA domain parameter lengths **shall** be (2048, 224) or (2048, 256), which provide a security strength of 112 bits; or (3072, 256), which provides a security strength of 128 bits.

[19] The lower bounds for **len**(p) and **len**(q) are those that were specified in FIPS 186-2.

- ECDSA and EdDSA: The security strength provided by an elliptic curve signature is 1/2 of the length of the domain parameter *n*. Therefore, the length of *n* **shall** be at least 224 bits to meet the minimum security-strength requirement of 112 bits for federal government use. Elliptic curves for digital signature generation are provided in SP 800-186[20]. Elliptic curves that meet the security strength requirements are also allowed when they satisfy the requirements of IG A.2.

- RSA: The length of the modulus *n* **shall** be 2048 bits or more to meet the minimum security-strength requirement of 112 bits for federal government use. The security strength associated with a particular modulus length may be estimated using the formula in IG 7.5.

Digital signature verification:

Key lengths providing less than 112 bits of security that were previously specified in FIPS 186 are allowed for **legacy use** when verifying digital signatures. Note that the lower bounds are provided in Table 2 above to indicate the lowest acceptable key length that was ever approved by NIST (but is no longer acceptable); the verification of signatures that used key lengths less than these lower bounds **shall** be regarded as having unacceptable risks.

- DSA: See FIPS 186-2[21] and FIPS 186-4, [22] which include key lengths of 512 and 1024 bits that may continue to be used for signature verification but not signature generation.

- ECDSA: See FIPS 186-2[23] and FIPS 186-4, which include specifications of elliptic curves that may continue to be used for signature verification but not signature generation: B-163, K-163 and P-192.

- RSA: See FIPS 186-2[24] and FIPS 186-4,[25] which include modulus lengths of 1024, 1280, 1536 and 1792 bits that may continue to be used for signature verification but not signature generation.

Key lengths providing at least 112 bits of security are **acceptable** for the verification of digital signatures.

- DSA: (L, N) = (2048, 224), (2048, 256) or (3072, 256).

[20] Until SP 800-186 is completed, the recommended elliptic curves are provided in FIPS 186-4.

[21] FIPS 186-2 includes the 512 and 1024-bit key lengths.

[22] FIPS 186-4 includes the 1024-bit key length.

[23] FIPS 186-2 approved the use of ANS X9.62, *The Elliptic Curve Digital Signature Algorithm (ECDSA)*, which specified the ECDSA algorithm.

[24] FIPS 186-2 approved the use of ANS X9.31-1998, *Digital Signatures Using Reversible Public Key Cryptography for the Financial Services Industry (rDSA).* ANS X9.31 included approval for modulus lengths of 1024, 1280, 1536 and 1732 bits.

[25] FIPS 186-4 includes approval for the 1024-bit modulus length.

- ECDSA and EdDSA: The elliptic curves specified in SP 800-186 and additional elliptic curves that provide a security strength of at least 112 bits and satisfy the requirements of IG A.2.
- RSA: The modulus $n \geq 2048$ bits.[26]

4 Random Bit Generation

Random numbers are used for various purposes such as the generation of keys, nonces and authentication challenges. Several deterministic random bit generator (DRBG) algorithms have been specified for use by the federal government. SP 800-90A includes three DRBG algorithms: Hash_DRBG, HMAC_DRBG and CTR_DRBG.

A previous version of SP 800-90A included a fourth algorithm, the DUAL_EC_DRBG, whose use is now **disallowed** for federal government applications. In addition, several other algorithms that were previously approved for random number generation are now **disallowed**.

The approval status for DRBGs is provided in Table 3.

Table 3: Approval Status of Algorithms Used for Random Bit Generation

Algorithm	Status
Hash_DRBG and HMAC_DRBG	Acceptable
CTR_DRBG with three-key TDEA	Deprecated through 2023 Disallowed after 2023
CTR_DRBG with AES-128, AES-192 and AES-256	Acceptable
DUAL_EC_DRBG	Disallowed
RNGs in FIPS 186-2[27], ANS X9.31 and ANS X9.62-1998	Disallowed

Hash_DRBG and HMAC_DRBG:

The use of Hash_DRBG and HMAC_DRBG is **acceptable** with any hash function specified in FIPS 180 or FIPS 202.

CTR_DRBG:

Effective as of the final publication of this revision of SP 800-131A, the use of CTR_DRBG using three-key TDEA is **deprecated** through December 31, 2023.

After December 31, 2023, the use of the CTR_DRBG using three-key TDEA is **disallowed**.

The use of CTR_DRBG using AES-128, AES-192 or AES-256 is **acceptable**.

[26] Additional key lengths beyond those approved in FIPS 186-4 will be allowed in FIPS 186-5.

[27] FIPS 186-2, *Digital Signature Standard (DSS).*

Dual_EC_DRBG:

The use of Dual_EC_DRBG is **disallowed**.

RNGs in other documents:

The use of the RNGs specified in FIPS 186-2, American National Standard (ANS) X.31 and the 1998 version of ANS X9.62 are **disallowed**.

5 Key Agreement Using Diffie-Hellman and MQV

Key agreement is a technique that is used to establish keying material between two entities that intend to communicate, whereby both parties contribute information to the key-agreement process. Two families of key agreement schemes are specified in SP 800-56A: Diffie-Hellman (DH) and Menezes-Qu-Vanstone (MQV). Each has been defined over two different mathematical structures: finite fields and elliptic curves.

Key agreement includes two steps: the use of an appropriate DH or MQV "primitive" to generate a shared secret, and the use of a key derivation method (KDM) to generate one or more keys from the shared secret. SP 800-56A contains the DH and MQV primitives and refers to SP 800-56C[28] for KDMs.

The security strength of a key-agreement scheme specified in SP 800-56A depends on the key-agreement algorithm, the parameters used with that algorithm (e.g., the keys) and its form (finite field or elliptic curve).

- Finite field DH and MQV: The keys for these algorithms are generated and used with domain parameters *p*, *q* and *g*. The security strength that can be provided by the algorithm depends on the length of *p*, the length of *q* and the proper generation of the domain parameters and the key.
- Elliptic Curve DH and MQV: The keys for these algorithms are generated and used with respect to domain parameters that define elliptic curves. The length of *n* (the order of the base point *G*), is used to determine the security strength that can be provided by a properly generated curve.

Table 4 contains the federal government approval status for the DH and MQV key agreement schemes.

[28] SP 800-56C, *Recommendation for Key-Derivation Methods in Key-Establishment Schemes.*

Table 4: Approval Status for SP 800-56A Key Agreement (DH and MQV) Schemes

Scheme	Domain Parameters	Status
SP 800-56A DH and MQV schemes using finite fields	< 112 bits of security strength: (**len**(p), **len**(q)) = (1024, 160)	Disallowed
	≥ 112 bits of security strength: Using listed safe-prime groups OR FIPS 186-type domain parameters (112-bit security strength only): (**len**(p), **len**(q)) = (2048, 224) or (2048, 256)	Acceptable
Non-compliant DH and MQV schemes using finite fields	< 112 bits of security strength: **len**(p) < 2048 OR **len**(q) < 224	Disallowed
	Non-conformance to SP 800-56A	Disallowed after 2020
SP 800-56A DH and MQV schemes using elliptic curves	< 112 bits of security strength: **len**(n) < 224	Disallowed
	≥ 112 bits of security strength: (Using specified curves)	Acceptable
Non-compliant DH and MQV schemes using elliptic curves	< 112 bits of security strength: **len**(n) < 224	Disallowed
	≥ 112 bits of security strength: Non-conformance to SP 800-56A or IG A.2	Disallowed after 2020

SP 800-56A DH and MQV schemes using finite fields:

The use of finite field schemes in SP 800-56A is **disallowed** when the supported security strength is less than 112 bits, i.e., when using the FA domain parameter set specified in previous versions of SP 800-56A: ((**len**(p), **len**(q)) = (1024, 160).

The use of the finite field schemes is **acceptable** when:

1. Using the safe-prime domain-parameter groups listed in Appendix D of SP 800-56A.

2. Using the FB and FC domain parameter sets specified in SP 800-56A, i.e., $(\textbf{len}(p), \textbf{len}(q)) = (2048, 224)$ or $(2048, 256)$.

Non-compliant DH and MQV schemes using finite fields:

The use of these schemes is **disallowed** when a security strength less than 112 bits is supported, i.e., using FIPS 186-type domain parameters where $\textbf{len}(p) < 2048$ or $\textbf{len}(q) < 224$.

After December 31, 2020, the use of these schemes is **disallowed** (i.e., all finite field DH and MQV schemes must conform to SP 800-56A).

SP 800-56A DH and MQV schemes using elliptic curves:

The use of elliptic curve schemes is **disallowed** when using elliptic curves that only support a security strength less than 112 bits, i.e., $\textbf{len}(n) < 224$.

The use of the elliptic curve schemes for key agreement that provide at least 112 bits of security strength is **acceptable** when using the elliptic curves listed in SP 800-56A or when using curves that satisfy the requirements of IG A.2.

Non-compliant DH and MQV schemes using elliptic curves:

The use of these schemes is **disallowed** when the only supported security strength is less than 112 bits, i.e., when $\textbf{len}(n) < 224$.

After December 31, 2020, all of these schemes are **disallowed** if they do not conform to the requirements of this section of SP 800-131A.

6 Key Agreement and Key Transport Using RSA

SP 800-56B specifies the use of RSA for both key agreement and key transport. Additional key-transport schemes may be allowed in other NIST guidance. Key agreement is a technique in which both parties contribute information to the generation of keying material. Key transport is a key-establishment technique in which only one party determines the key and sends it to the other party.

RSA keys are generated with respect to a modulus n. The length of n is used to determine the security strength of a key-establishment scheme that uses n, assuming that n and the RSA keys are generated as specified in SP 800-56B. Note that SP 800-56B refers to FIPS 186 for generation guidance.

Guidance on key lengths for RSA is provided in SP 800-56B. SP 800-56B explicitly specifies several key lengths, along with their supported security strengths, beginning with $n = 2048$, which is estimated to support a security strength of 112 bits. Additional key lengths greater than 2048 and not explicitly listed in SP 800-56B may be used; the approximate security strength that is supported by a given key length may be estimated using a formula in SP 800-56B.

In the case of key-transport keys (i.e., the keys used to encrypt other keys for transport), this document (SP 800-131A) applies to both the encryption and decryption of the transported keys.

Table 5 (below) provides the approval status the choice of n.

Table 5: Approval Status for the RSA-based Key Agreement and Key Transport Schemes

Scheme	Modulus Length	Status
SP 800-56B Key Agreement schemes	**len**(*n*) < 2048	Disallowed
	len(*n*) ≥ 2048	Acceptable
SP 800-56B Key Transport schemes	**len**(*n*) < 2048	Disallowed
	len(*n*) ≥ 2048	Acceptable
Non-56B-compliant Key Transport schemes	**len**(*n*) < 2048	Disallowed
	PKCS 1 v1.5	Deprecated through 2023 Disallowed after 2023
	Other non-compliance with SP 800-56B	Deprecated through 2020 Disallowed after 2020

SP 800-56B RSA key-agreement schemes:

The use of these schemes is **disallowed** if **len**(*n*) < 2048.

The use of these schemes is **acceptable** if **len**(*n*) ≥ 2048.

SP 800-56B RSA key-transport schemes:

The use of these schemes is **disallowed** if **len**(*n*) < 2048.

The use of these schemes is **acceptable** if **len**(*n*) ≥ 2048

Non-56B-compliant RSA key-transport schemes:

The use of these schemes is **disallowed** if **len**(*n*) < 2048.

Effective as of the final publication of this revision of SP 800-131A, the use of PKCS 1, version 1.5 and other RSA key-transport schemes that are not compliant with SP 800-56B are **deprecated**.

After December 31, 2023, the use of PKCS 1, version 1.5 is **disallowed**.

After December 31, 2020, the use of other RSA key-transport schemes that are not compliant with SP 800-56B are **disallowed**.

7 Key Wrapping

Key wrapping is the encryption and integrity protection of keying material using a key-wrapping algorithm and a symmetric key. **Approved** methods for key wrapping are provided in SP 800-38F.[29]

SP 800-38F specifies three algorithms for key wrapping that use block ciphers: KW and KWP, which use AES; and TKW, which uses TDEA. SP 800-38F also approves the CCM and GCM authenticated-encryption modes specified in SP 800-38C and SP 800-38D for key wrapping, as well as combinations of an **approved** encryption mode with an **approved** authentication method.

Table 6 provides the approval status of the block cipher algorithms used for key wrapping.

Table 6: Approval Status of Block Cipher Algorithms Used for Key Wrapping

Algorithm	Status
Key wrapping using two-key TDEA	Disallowed
Key unwrapping using two-key TDEA	Legacy use
Key wrapping using three-key TDEA and any **approved** key-wrapping method	Deprecated through 2023 Disallowed after 2023
Key unwrapping using three-key TDEA and any **approved** key-unwrapping method	Legacy use
Key wrapping and unwrapping using AES-128, AES-192 or AES-256 and any method for key wrapping that is specified or otherwise **approved** in SP 800-38F	Acceptable

Two-key TDEA:

The use of two-key TDEA for key wrapping is **disallowed**.

The use of two-key TDEA for unwrapping keying material is allowed for **legacy use**.

Three-key TDEA:

Effective as of the final publication of this revision of SP 800-131A, key wrapping using three-key TDEA is **deprecated** through December 31, 2023.

After December 31, 2023, the use of three-key TDEA is **disallowed** for key wrapping unless specifically allowed by other NIST guidance.

Key unwrapping using three-key TDEA is allowed for **legacy use**.

AES:

The use of AES-128, AES-192 and AES-256 for both the wrapping and unwrapping of keying material is **acceptable**.

[29] SP 800-38F, *Recommendation for Block Cipher Modes of Operation: Methods for Key Wrapping*.

8 Deriving Additional Keys from a Cryptographic Key

SP 800-108 specifies key derivation functions (KDFs) that use pseudorandom functions (PRFs) and a pre-shared cryptographic key (called a key-derivation key) to generate additional keys. The length of the key-derivation key **shall** be at least 112 bits. Two PRFs are used in the KDFs specified in SP 800-108:

- HMAC (as specified in FIPS 198[30]) requires the use of a hash function (see Section 9).
- CMAC (as specified in SP 800-38B) requires the use of a block cipher algorithm (e.g., AES-128, which is specified in FIPS 197).

HMAC and CMAC are also known as Message Authentication Code (MAC) algorithms that require the use of keys; these algorithms and the keys used with them are discussed in Section 10.

Table 7 provides the approval status of the PRFs for key derivation.

Table 7: Approval Status of the Algorithms Used for a Key Derivation Function (KDF)

KDF Type	Algorithm	Status
HMAC-based KDF	HMAC using any **approved** hash function	Acceptable
CMAC-based KDF	CMAC using two-key TDEA	Disallowed
	CMAC using three-key TDEA	Deprecated through 2023 Disallowed after 2023
	CMAC using AES	Acceptable

HMAC-based KDF:

The use of HMAC-based KDFs is **acceptable** using a hash function specified in FIPS 180 or FIPS 202 with a key whose length is at least 112 bits.

CMAC-based KDF:

The use of two-key TDEA as the block cipher algorithm in a CMAC-based KDF is **disallowed**.

Effective as of the final publication of this revision of SP 800-131A, the use of three-key TDEA is **deprecated** through December 31, 2023. Note that SP 800-67 specifies a restriction on the use of three-key TDEA to no more than 2^{20} data blocks using the same single key bundle.

After December 31, 2023, the use of three-key TDEA is **disallowed** unless specifically allowed by other NIST guidance.

The use of AES-128, AES-192, AES-256 is **acceptable**.

[30] FIPS 198, *Keyed-Hash Message Authentication Code (HMAC)*.

9 Hash Functions

A hash function is used to produce a condensed representation of its input, taking an input of arbitrary length and outputting a value with a predetermined length. Hash functions are used in the generation and verification of digital signatures, for key derivation, for random number generation, in the computation of message authentication codes and for hash-only applications.

Several hash functions have been specified:

- FIPS 180[31] specifies SHA-1 and the SHA-2 family of hash functions (i.e., SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224 and SHA-512/256). Discussions about the different uses of SHA-1 and the SHA-2 hash functions are provided in SP 800-107.[32] Information about the security strengths that can be provided by these hash functions is given in SP 800-57.
- FIPS 202[33] specifies the SHA-3 family of hash functions (i.e., SHA3-224, SHA3-256, SHA3-384 and SHA3-512). Discussions about the SHA-3 hash functions specified in FIPS 202 are provided in that FIPS, and the security strengths that can be provided by these functions are given in SP 800-57. Note that FIPS 202 also specifies extendable output functions (XOFs); however, these are not considered to be hash functions, and their use is not included in this document[34].
- SP 800-185[35] specifies two SHA-3-derived hash functions (i.e., TupleHash and ParallelHash) and discusses their use and the security strengths that they can support.

Table 8 provides the approval status of the hash functions.

Table 8: Approval Status of Hash Functions

Hash Function	Use	Status
SHA-1	Digital signature generation	Disallowed, except where specifically allowed by NIST protocol-specific guidance.
	Digital signature verification	Legacy use
	Non-digital-signature applications	Acceptable
SHA-2 family (SHA-224, SHA-256, SHA-384, SHA-512, SHA-	Acceptable for all hash function applications	

[31] FIPS 180, *Secure Hash Standard (SHS).*

[32] SP 800-107, *Recommendation for Applications Using Approved Hash Algorithms.*

[33] FIPS 202, *Permutation-Based Hash and Extendable-Output Functions*.

[34] The approved uses of XOFs may be addressed in future publications.

[35] SP 800-185, *SHA-3 Derived Functions: cSHAKE, KMAC, TupleHash and ParallelHash.*

512/224 and SHA-512/256)	
SHA-3 family (SHA3-224, SHA3-256, SHA3-384, and SHA3-512)	Acceptable for all hash function applications
TupleHash and ParallelHash	Acceptable

SHA-1 for digital signature generation:

SHA-1 may only be used for digital signature generation where specifically allowed by NIST protocol-specific guidance. For all other applications, SHA-1 is **disallowed** for digital signature generation.

SHA-1 for digital signature verification:

When used for digital signature verification, SHA-1 is allowed for **legacy use**.

SHA-1 for non-digital signature applications:

For non-digital-signature applications, the use of SHA-1 is **acceptable** for applications that do not require collision resistance.

SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, and SHA-512/256:

The use of these hash functions is **acceptable** for all hash function applications.

SHA3-224, SHA3-256, SHA3-384, and SHA3-512:

The use of these hash functions is **acceptable** for all hash function applications.

TupleHash and ParallelHash:

The use of TupleHash and ParallelHash is **acceptable** for the purposes specified in SP 800-185.

10 Message Authentication Codes (MACs)

A Message Authentication Code (MAC) is used to provide assurance of data integrity and source authentication; it is generated using a MAC algorithm and a cryptographic key. A MAC is a cryptographic checksum on the data over which it is computed; it can provide assurance that the data has not been modified since the MAC was generated and that the MAC was computed by the party or parties sharing the key.

Three types of message authentication code mechanisms are specified for use:

- FIPS 198 specifies a keyed-hash message authentication code (HMAC) that uses a hash function; SP 800-107 provides additional guidance on the uses of HMAC, whether using SHA-1 or the SHA-2 or SHA-3 families of hash functions (see Section 9).

- SP 800-38B and SP 800-38D [36] specify the CMAC and GMAC modes (respectively) for block ciphers. The CMAC mode defined in SP 800-38B is specified for either AES or TDEA; the GMAC mode defined in SP 800-38D is specified only for AES.
- SP 800-185 defines the KMAC algorithm that is based on the SHA-3 functions specified in FIPS 202.

The security strength that can be supported by a given MAC algorithm depends on the primitive algorithm used (e.g., the hash function or block cipher used) and on the length of the cryptographic key.

Table 9 provides the approval status and required key lengths for the MAC algorithms in order to provide a security strength of 112 bits or more.

Table 9: Approval Status of MAC Algorithms

MAC Algorithm	Key Lengths	Status
HMAC Generation	Key lengths < 112 bits	Disallowed
	Key lengths ≥ 112 bits	Acceptable
HMAC Verification	Key lengths < 112 bits	Legacy use
	Key lengths ≥ 112 bits	Acceptable
CMAC Generation	Two-key TDEA	Disallowed
	Three-key TDEA	Deprecated through 2023 Disallowed after 2023
	AES	Acceptable
CMAC Verification	Two-key TDEA	Legacy use
	Three-key TDEA	Legacy use
	AES	Acceptable
GMAC Generation and Verification	AES	Acceptable
KMAC Generation and Verification	Key lengths < 112 bits	Disallowed
	Key lengths ≥ 112 bits	Acceptable

HMAC Generation:

Any **approved** hash function may be used.

Keys less than 112 bits in length are **disallowed** for HMAC generation.

[36] Note that the CCM authenticated encryption mode specified in SP 800-38C also generates a MAC. However, the CCM mode cannot be used to only generate a MAC without also performing encryption. The modes listed in this section are used only to generate a MAC.

The use of key lengths ≥ 112 bits is **acceptable** for HMAC generation.

HMAC Verification:

The use of key lengths < 112 bits for HMAC verification is allowed for **legacy use**.

The use of key lengths ≥ 112 bits for HMAC verification is **acceptable.**

CMAC Generation:

The use of two-key TDEA for CMAC generation is **disallowed**.

Effective as of the final publication of this revision of SP 800-131A, the use of three-key TDEA for CMAC generation is **deprecated** through December 31, 2023. Three-key TDEA may be used for CMAC generation in existing applications but **shall not** be used in new applications.

After December 31, 2023, three-key TDEA is **disallowed** for CMAC generation unless specifically allowed by other NIST guidance.

The use of AES-128, AES-192 and AES-256 for CMAC generation is **acceptable**.

CMAC Verification:

The use of two-key TDEA and three-key TDEA for CMAC verification is allowed for **legacy use**.

The use of AES for CMAC verification is **acceptable**.

GMAC Generation and Verification:

The use of GMAC for MAC generation and verification is **acceptable** when using AES-128, AES-192 or AES-256.

KMAC Generation and Verification:

Keys less than 112 bits in length are **disallowed** for KMAC generation.

The use of key lengths ≥ 112 bits is **acceptable** for KMAC generation.

Appendix A: References

[FIPS 140] Federal Information Processing Standard (FIPS) 140-2, Security Requirements for Cryptographic Modules, with Change Notices, December 2002.

[FIPS 140 IG] Implementation Guidance for FIPS 140-2 and the Cryptographic Module Validation Program, available here.

[FIPS 180-4] Federal Information Processing Standard (FIPS) 180-4, Secure Hash Standard (SHS), March 2012.

[FIPS 185] Federal Information Processing Standard (FIPS) 185, Escrowed Encryption Standard, Feb 1994, Withdrawn.

[FIPS 186] Federal Information Processing Standard (FIPS) 186-4, Digital Signature Standard, July 2013.

[FIPS 186-2] Federal Information Processing Standard (FIPS) 186-2, Digital Signature Standard, January 2000.

[FIPS 186-4] Federal Information Processing Standard (FIPS) 186-4, Digital Signature Standard, July 2013.

[FIPS 197] Federal Information Processing Standard (FIPS) 197, Advanced Encryption Standard, November 2001.

[FIPS 198] Federal Information Processing Standard (FIPS) 198-1, Keyed-Hash Message Authentication Code (HMAC), July 2008.

[FIPS 202] Federal Information Processing Standard (FIPS) 202, SHA-3 Standard: Permutation-Based Hash and Extendable-Output Functions, August 2015.

[IG X.Y] Implementation Guidance for FIPS 140-2 and the Cryptographic Module Validation Program, where X.Y is the section number.

[SP 800-38A] Special Publication (SP) 800-38A, Recommendation for Block Cipher Modes of Operation: Methods and Techniques, December 2001.

[SP 800-38B] Special Publication (SP) 800-38B, Recommendation for Block Cipher Modes of Operation: The CMAC Mode for Authentication, May 2005.

[SP 800-38C] Special Publication (SP) 800-38C, Recommendation for Block Cipher Modes of Operation: the CCM Mode for Authentication and Confidentiality, May 2004.

[SP 800-38D] Special Publication (SP) 800-38D, Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC, November 2007.

[SP 800-38F] Special Publication (SP) 800-38F, Recommendation for Block Cipher Modes of Operation: Methods for Key Wrapping, December 2012.

[SP 800-56A] Special Publication (SP) 800-56A, Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Logarithm Cryptography, April 2018.

[SP 800-56B] Special Publication (SP) 800-56B Revision 2, Recommendation for Pair-Wise Key Establishment Using Integer Factorization, DRAFT, July 2018.

[SP 800-56C] Special Publication (SP) 800-56C Revision 1, *Recommendation for Key-Derivation Methods in Key-Establishment Schemes*, April 2018.

[SP 800-57] Special Publication (SP) 800-57, Part 1, Recommendation for Key Management: General, January 2016.

[SP 800-67] Special Publication (SP) 800-67, Recommendation for the Triple Data Encryption Algorithm (TDEA) Block Cipher, November 2017.

[SP 800-90A] Special Publication (SP) 800-90A, Recommendation for Random Number Generation Using Deterministic Random Bit Generators, Rev. 1, June 2015.

[SP 800-107] Special Publication (SP) 800-107, Recommendation for Applications Using Approved Hash Algorithms, August 2012.

[SP 800-108] Special Publication (SP) 800-108, Recommendation for Key Derivation Using Pseudorandom Functions, November 2008.

[SP 800-185] Special Publication (S) 800-185, SHA-3 Derived Functions: cSHAKE, KMAC, TupleHash and ParallelHash, December 2016.

[SP 800-186] Special Publication (SP) 800-186, Recommendation for Discrete Logarithm-based Cryptography: Elliptic Curve Domain Parameters, [NOT YET AVAILABLE].

Non-NIST References:

[X9.31] American National Standard (ANS) X9.31-1998, Digital Signatures Using Reversible Public Key Cryptography for the Financial Services Industry (rDSA). Withdrawn.

[X9.62] American National Standard (ANS) X9.62-1998, Public Key Cryptography for the Financial Services Industry: The Elliptic Curve Digital Signature Algorithm (ECDSA). Now renumbered to ASC X9.142.

Appendix B: Change History

The following is a list of non-editorial changes from the 2011 version of this document.

1. The use of two-key TDEA for applying cryptographic protection (e.g., encryption, key wrapping or CMAC generation in KDFs) is restricted through December 31, 2015. Its use for processing already-protected information (e.g., decryption, key unwrapping and MAC verification) is allowed for **legacy use**.
2. The use of SKIPJACK is **disallowed** for encryption, but allowed for **legacy use** (e.g., decryption of already encrypted information).
3. Section 1.2.3 was added to define the single symbol used in this Recommendation: **len**(x); this has been used to replace $|p|$, $|q|$, $|n|$ and $|h|$, rather than defining them in footnotes.
4. The use of keys that provide less than 112 bits of security strength for digital signature generation are no longer allowed; however, their use for digital signature verification is allowed for **legacy use** (i.e., the verification of already-generated digital signatures). For digital signature verification using DSA, the **legacy-use** row has been specified to reflect the lower bound that was specified in FIPS 186-2 (i.e., 512 bits).
5. The use of the DUAL_EC_DRBG, formerly specified in [SP 800-90A], is no longer allowed.
6. The use of the RNGs specified in [FIPS 186-2], [X9.31] and [X9.62] is **deprecated** until December 31, 2015 and **disallowed** thereafter.
7. The use of keys that provide less than 112 bits of security strength for key agreement is now **disallowed**.
8. The use of non-approved key-agreement schemes is **deprecated** through December 31, 2017 and **disallowed** thereafter.
9. The use of non-approved key-transport schemes is **deprecated** through December 31, 2017 and is **disallowed** thereafter.
10. Non-approved key-wrapping methods are disallowed after December 31, 2017.
11. The use of SHA-1 for digital signature generation is **disallowed** (except where specifically allowed in NIST protocol-specific guidance); however, its use for digital signature verification is allowed for **legacy use** (i.e., the verification of already-generated digital signatures).
12. The SHA-3 family of hash functions specified in [FIPS 202] has been included in Section 9 as **acceptable**.
13. The use of HMAC keys less than 112 bits in length is no longer allowed for the generation of a MAC; however, they may be used for **legacy use** (i.e., the verification of already-generated MACs).

The following changes have been made to the 2018 version:

1. Section 1: Revised to discuss coming availability of quantum computers and to identify the most significant differences between this version of SP 800-131A and the previous version.
2. Section 1.2.2: New section added to define terms.
3. Section 1.2.3 (old Section 1.2.2): The **restricted** approval status term was removed.
4. Section 2: Disallowed the use of two-key TDEA for encryption and provided a sunset schedule for three-key TDEA.
5. Section 3: Clarified the DSA disallowed and acceptable domain parameters, added EdDSA as an additional elliptic curve algorithm.
6. Section 4: Provided a sunset schedule for using the CTR_DRBG with three-key TDEA.
7. Section 5: Clarified the DH parameters and elliptic curves that are now disallowed or acceptable, added the DH groups listed in SP 800-56A as acceptable, and provided a termination date for non-SP 800-56A-compliant key-agreement schemes.
8. Section 6: Added PKCS 1 v1.5 and included a sunset schedule.
9. Section 7: Provided a sunset schedule for the use of TDEA for key wrapping.
10. Section 8: Provided a sunset schedule for the use of CMAC-based KDF using TDEA.
11. Section 9: Added TupleHash and ParallelHash.
12. Section 10: Provided a sunset schedule for the use of CMAC using TDEA and added KMAC.
13. (Old) Appendix A (Mitigating Risk When Using Algorithms and Keys for legacy Use): Removed.
14. (New) Appendix A (old Appendix B): Updated the references.