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**Internet X.509 Public Key Infrastructure: Additional Algorithm  
Identifiers for RSASSA-PSS and ECDSA using SHAKES  
draft-ietf-lamps-pkix-shake-05**

**Abstract**

Digital signatures are used to sign messages, X.509 certificates and CRLs (Certificate Revocation Lists). This document describes the conventions for using the SHAKE function family in Internet X.509 certificates and CRLs as one-way hash functions with the RSA Probabilistic signature and ECDSA signature algorithms. The conventions for the associated subject public keys are also described.

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## [1.](#) Change Log

[ EDNOTE: Remove this section before publication. ]

### o [draft-ietf-lamps-pkix-shake-05](#):

- \* Added [RFC8174](#) reference and text.
- \* Explicitly explained why RSASSA-PSS-params are omitted in [section 5.1.1](#).
- \* Simplified Public Keys section by removing redundand info from RFCs.

### o [draft-ietf-lamps-pkix-shake-04](#):

- \* Removed paragraph suggesting KMAC to be used in generating k in Deterministic ECDSA. That should be [RFC6979](#)-bis.
- \* Removed paragraph from Security Considerations that talks about randomness of k because we are using deterministic ECDSA.
- \* Various ASN.1 fixes.



- \* Text fixes.
- o [draft-ietf-lamps-pkix-shake-03](#):
  - \* Updates based on suggestions and clarifications by Jim.
  - \* Added ASN.1.
- o [draft-ietf-lamps-pkix-shake-02](#):
  - \* Significant reorganization of the sections to simplify the introduction, the new OIDs and their use in PKIX.
  - \* Added new OIDs for RSASSA-PSS that hardcode hash, salt and MGF, according the WG consensus.
  - \* Updated Public Key section to use the new RSASSA-PSS OIDs and clarify the algorithm identifier usage.
  - \* Removed the no longer used SHAKE OIDs from [section 3.1](#).
  - \* Consolidated subsection for message digest algorithms.
  - \* Text fixes.
- o [draft-ietf-lamps-pkix-shake-01](#):
  - \* Changed titles and section names.
  - \* Removed DSA after WG discussions.
  - \* Updated shake OID names and parameters, added MGF1 section.
  - \* Updated RSASSA-PSS section.
  - \* Added Public key algorithm OIDs.
  - \* Populated Introduction and IANA sections.
- o [draft-ietf-lamps-pkix-shake-00](#):
  - \* Initial version

## **[2.](#) Introduction**

This document describes cryptographic algorithm identifiers for several cryptographic algorithms which use variable length output



SHAKE functions introduced in [[SHA3](#)] which can be used with the Internet X.509 Certificate and CRL profile [[RFC5280](#)].

In the SHA-3 family, two extendable-output functions (SHAKEs), SHAKE128 and SHAKE256, are defined. Four other hash function instances, SHA3-224, SHA3-256, SHA3-384, and SHA3-512 are also defined but are out of scope for this document. A SHAKE is a variable length hash function. The output length, in bits, of a SHAKE is defined by the *d* parameter. The corresponding collision and second preimage resistance strengths for SHAKE128 are  $\min(d/2, 128)$  and  $\min(d, 128)$  bits respectively. And, the corresponding collision and second preimage resistance strengths for SHAKE256 are  $\min(d/2, 256)$  and  $\min(d, 256)$  bits respectively.

A SHAKE can be used as the message digest function (to hash the message to be signed) in RSASSA-PSS and ECDSA and as the hash in the mask generating function in RSASSA-PSS. This specification describes the identifiers for SHAKEs to be used in X.509 and their meaning.

### 3. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [BCP 14](#) [[RFC2119](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

### 4. Identifiers

This section defines four new OIDs for RSASSA-PSS and ECDSA when SHAKE128 and SHAKE256 are used. The same algorithm identifiers are used for identifying a public key in RSASSA-PSS.

The new identifiers for RSASSA-PSS signatures using SHAKEs are below.

id-RSASSA-PSS-SHAKE128 OBJECT IDENTIFIER ::= { TBD }

id-RSASSA-PSS-SHAKE256 OBJECT IDENTIFIER ::= { TBD }

[ EDNOTE: "TBD" will be specified by NIST later. ]

The new algorithm identifiers of ECDSA signatures using SHAKEs are below.



```
id-ecdsa-with-shake128 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
    country(16) us(840) organization(1) gov(101)
    csor(3) algorithms(4) id-ecdsa-with-shake(3)
    TBD }
```

```
id-ecdsa-with-shake256 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2)
    country(16) us(840) organization(1) gov(101)
    csor(3) algorithms(4) id-ecdsa-with-shake(3)
    TBD }
```

[ EDNOTE: "TBD" will be specified by NIST later. ]

The parameters for the four identifiers above MUST be absent. That is, the identifier SHALL be a SEQUENCE of one component, the OID.

[Section 5.1.1](#) and [Section 5.1.2](#) specify the required output length for each use of SHAKE128 or SHAKE256 in RSASSA-PSS and ECDSA. In summary, when hashing messages to be signed, output lengths of SHAKE128 and SHAKE256 are 256 and 512 bits respectively. When the SHAKEs are used as mask generation functions RSASSA-PSS, their output length is  $(n - 264)$  or  $(n - 520)$  bits respectively, where  $n$  is a RSA modulus size in bits.

## 5. Use in PKIX

### 5.1. Signatures

Signatures can be placed in a number of different ASN.1 structures. The top level structure for an X.509 certificate, to illustrate how signatures are frequently encoded with an algorithm identifier and a location for the signature, is

```
Certificate ::= SEQUENCE {
    tbsCertificate      TBSCertificate,
    signatureAlgorithm   AlgorithmIdentifier,
    signatureValue       BIT STRING }
```

The identifiers defined in [Section 4](#) can be used as the AlgorithmIdentifier in the signatureAlgorithm field in the sequence Certificate and the signature field in the sequence tbsCertificate in X.509 [[RFC5280](#)].

Conforming CA implementations MUST specify the algorithms explicitly by using the OIDs specified in [Section 4](#) when encoding RSASSA-PSS or ECDSA with SHAKE signatures in certificates and CRLs. Conforming client implementations that process RSASSA-PSS or ECDSA with SHAKE





signatures when processing certificates and CRLs MUST recognize the corresponding OIDs. Encoding rules for RSASSA-PSS and ECDSA signature values are specified in [RFC4055] and [RFC5480] respectively.

#### **5.1.1. RSASSA-PSS Signatures**

The RSASSA-PSS algorithm is defined in [RFC8017]. When id-RSASSA-PSS-SHAKE128 or id-RSASSA-PSS-SHAKE256 specified in [Section 4](#) is used, the encoding MUST omit the parameters field. That is, the AlgorithmIdentifier SHALL be a SEQUENCE of one component, id-RSASSA-PSS-SHAKE128 or id-RSASSA-PSS-SHAKE256. [RFC4055] defines RSASSA-PSS-params that are used to define the algorithms and inputs to the algorithm. This specification does not use parameters because the hash and mask generating algorithm and trailer and salt are embedded in the OID definition.

The hash algorithm to hash a message being signed and the hash algorithm as the mask generation function used in RSASSA-PSS MUST be the same, SHAKE128 or SHAKE256 respectively. The output-length of the hash algorithm which hashes the message SHALL be 32 or 64 bytes respectively.

The mask generation function takes an octet string of variable length and a desired output length as input, and outputs an octet string of the desired length. In RSASSA-PSS with SHAKES, the SHAKES MUST be used natively as the MGF function, instead of the MGF1 algorithm that uses the hash function in multiple iterations as specified in Section B.2.1 of [RFC8017]. In other words, the MGF is defined as the SHAKE128 or SHAKE256 output of the mgfSeed for id-RSASSA-PSS-SHAKE128 and id-RSASSA-PSS-SHAKE256 respectively. The mgfSeed is the seed from which mask is generated, an octet string [RFC8017]. The output length is  $(n - 264)/8$  or  $(n - 520)/8$  bytes respectively, where  $n$  is the RSA modulus in bits. For example, when RSA modulus  $n$  is 2048, the output length of SHAKE128 or SHAKE256 as the MGF will be 223 or 191-bits when id-RSASSA-PSS-SHAKE128 or id-RSASSA-PSS-SHAKE256 is used respectively.

The RSASSA-PSS saltLength MUST be 32 or 64 bytes respectively. Finally, the trailerField MUST be 1, which represents the trailer field with hexadecimal value 0xBC [RFC8017].

#### **5.1.2. Deterministic ECDSA Signatures**

The Elliptic Curve Digital Signature Algorithm (ECDSA) is defined in [X9.62]. When the id-ecdsa-with-SHAKE128 or id-ecdsa-with-SHAKE256 (specified in [Section 4](#)) algorithm identifier appears, the respective SHAKE function (SHAKE128 or SHAKE256) is used as the hash. The



encoding MUST omit the parameters field. That is, the AlgorithmIdentifier SHALL be a SEQUENCE of one component, the OID id-ecdsa-with-SHAKE128 or id-ecdsa-with-SHAKE256.

For simplicity and compliance with the ECDSA standard specification, the output length of the hash function must be explicitly determined. The output length, *d*, for SHAKE128 or SHAKE256 used in ECDSA MUST be 256 or 512 bits respectively.

Conforming CA implementations that generate ECDSA with SHAKE signatures in certificates or CRLs MUST generate such signatures with a deterministically generated, non-random *k* in accordance with all the requirements specified in [RFC6979]. They MAY also generate such signatures in accordance with all other recommendations in [X9.62] or [SEC1] if they have a stated policy that requires conformance to these standards. These standards may have not specified SHAKE128 and SHAKE256 as hash algorithm options. However, SHAKE128 and SHAKE256 with output length being 32 and 64 octets respectively are substitutions for 256 and 512-bit output hash algorithms such as SHA256 and SHA512 used in the standards.

## 5.2. Public Keys

Certificates conforming to [RFC5280] can convey a public key for any public key algorithm. The certificate indicates the public key algorithm through an algorithm identifier. This algorithm identifier is an OID and optionally associated parameters.

Conforming CA implementations MUST specify the X.509 public key algorithm explicitly by using the OIDs specified in [Section 4](#) when encoding RSASSA-PSS or ECDSA with SHAKE public keys in certificates and CRLs. Conforming client implementations that process RSASSA-PSS or ECDSA with SHAKE public key when processing certificates and CRLs MUST recognize the corresponding OIDs. The conventions and encoding for RSASSA-PSS and ECDSA public keys algorithm identifiers are as specified in [Section 2.3 of \[RFC3279\]](#), [Section 3.1 of \[RFC4055\]](#) and [Section 2.1 of \[RFC5480\]](#).

When the RSA private key owner wishes to limit the use of the public key exclusively to RSASSA-PSS, the AlgorithmIdentifiers for RSASSA-PSS defined in [Section 4](#) can be used as the algorithm field in the SubjectPublicKeyInfo sequence [RFC5280]. The identifier parameters, as explained in [Section 4](#), MUST be absent. The RSASSA-PSS algorithm functions and output lengths are the same as defined in [Section 5.1.1](#).



## **6. IANA Considerations**

[ EDNOTE: Update here only if there are OID allocations by IANA. ]

This document has no IANA actions.

## **7. Security Considerations**

The SHAKEs are deterministic functions. Like any other deterministic function, executing multiple times with the same input will produce the same output. Therefore, users should not expect unrelated outputs (with the same or different output lengths) from running a SHAKE function with the same input multiple times. The shorter of any two outputs produced from a SHAKE with the same input is a prefix of the longer one. It is a similar situation as truncating a 512-bit output of SHA-512 by taking its 256 left-most bits. These 256 left-most bits are a prefix of the 512-bit output.

Implementations must protect the signer's private key. Compromise of the signer's private key permits masquerade attacks.

Implementers should be aware that cryptographic algorithms may become weaker with time. As new cryptanalysis techniques are developed and computing power increases, the work factor or time required to break a particular cryptographic algorithm may decrease. Therefore, cryptographic algorithm implementations should be modular allowing new algorithms to be readily inserted. That is, implementers should be prepared to regularly update the set of algorithms in their implementations.

## **8. Acknowledgements**

We would like to thank Sean Turner and Jim Schaad for their valuable contributions to this document.

## **9. References**

### **9.1. Normative References**

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", [BCP 14](#), [RFC 2119](#), DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.



- [RFC4055] Schaad, J., Kaliski, B., and R. Housley, "Additional Algorithms and Identifiers for RSA Cryptography for use in the Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", [RFC 4055](#), DOI 10.17487/RFC4055, June 2005, <<https://www.rfc-editor.org/info/rfc4055>>.
- [RFC5280] Cooper, D., Santesson, S., Farrell, S., Boeyen, S., Housley, R., and W. Polk, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", [RFC 5280](#), DOI 10.17487/RFC5280, May 2008, <<https://www.rfc-editor.org/info/rfc5280>>.
- [RFC5480] Turner, S., Brown, D., Yiu, K., Housley, R., and T. Polk, "Elliptic Curve Cryptography Subject Public Key Information", [RFC 5480](#), DOI 10.17487/RFC5480, March 2009, <<https://www.rfc-editor.org/info/rfc5480>>.
- [RFC6979] Pornin, T., "Deterministic Usage of the Digital Signature Algorithm (DSA) and Elliptic Curve Digital Signature Algorithm (ECDSA)", [RFC 6979](#), DOI 10.17487/RFC6979, August 2013, <<https://www.rfc-editor.org/info/rfc6979>>.
- [RFC8017] Moriarty, K., Ed., Kaliski, B., Jonsson, J., and A. Rusch, "PKCS #1: RSA Cryptography Specifications Version 2.2", [RFC 8017](#), DOI 10.17487/RFC8017, November 2016, <<https://www.rfc-editor.org/info/rfc8017>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in [RFC 2119](#) Key Words", [BCP 14](#), [RFC 8174](#), DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/info/rfc8174>>.
- [SHA3] National Institute of Standards and Technology, "SHA-3 Standard - Permutation-Based Hash and Extendable-Output Functions FIPS PUB 202", August 2015, <<https://www.nist.gov/publications/sha-3-standard-permutation-based-hash-and-extendable-output-functions>>.

## **9.2. Informative References**

- [RFC3279] Bassham, L., Polk, W., and R. Housley, "Algorithms and Identifiers for the Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", [RFC 3279](#), DOI 10.17487/RFC3279, April 2002, <<https://www.rfc-editor.org/info/rfc3279>>.





- [SEC1] Standards for Efficient Cryptography Group, "SEC 1: Elliptic Curve Cryptography", May 2009, <<http://www.secg.org/sec1-v2.pdf>>.
- [X9.62] American National Standard for Financial Services (ANSI), "X9.62-2005 Public Key Cryptography for the Financial Services Industry: The Elliptic Curve Digital Signature Standard (ECDSA)", November 2005.

## **Appendix A. ASN.1 module**

This appendix includes the ASN.1 module for SHAKEs in X.509. This module does not come from any existing RFC.

```
PKIXAlgsForSHAKE-2018 { iso(1) identified-organization(3) dod(6)
  internet(1) security(5) mechanisms(5) pkix(7) id-mod(0)
  id-mod-pkix1-shake-2018(TBD) }

DEFINITIONS EXPLICIT TAGS ::=

BEGIN

-- EXPORTS ALL;

IMPORTS

-- FROM [RFC5912]

PUBLIC-KEY, SIGNATURE-ALGORITHM, DIGEST-ALGORITHM, SMIME-CAPS
FROM AlgorithmInformation-2009
  { iso(1) identified-organization(3) dod(6) internet(1) security(5)
    mechanisms(5) pkix(7) id-mod(0)
    id-mod-algorithmInformation-02(58) }

-- FROM [RFC5912]

RSAPublicKey, rsaEncryption, id-ecPublicKey,
  ECPoint, ECDSA-Sig-Value
FROM PKIXAlgs-2009 { iso(1) identified-organization(3) dod(6)
  internet(1) security(5) mechanisms(5) pkix(7) id-mod(0)
  id-mod-pkix1-algorithms2008-02(56) }

--
-- Message Digest Algorithms (mda-)
--
HashAlgs DIGEST-ALGORITHM ::= {
  ...
```



```
-- This expands MessageAuthAlgs from [RFC5912]
mda-shake128    |
mda-shake256,
...
}

--
-- One-Way Hash Functions
-- SHAKE128
mda-shake128 DIGEST-ALGORITHM ::= {
    IDENTIFIER id-shake128 -- with output length 32 bytes.
}
id-shake128 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2) country(16)
                                     us(840) organization(1) gov(101)
                                     csor(3) nistAlgorithm(4)
                                     hashAlgs(2) 11 }

-- SHAKE-256
mda-shake256 DIGEST-ALGORITHM ::= {
    IDENTIFIER id-shake256 -- with output length 64 bytes.
}
id-shake256 OBJECT IDENTIFIER ::= { joint-iso-itu-t(2) country(16)
                                     us(840) organization(1) gov(101)
                                     csor(3) nistAlgorithm(4)
                                     hashAlgs(2) 12 }

--
-- Public Key (pk-) Algorithms
--
PublicKeys PUBLIC-KEY ::= {
    ...
    pk-rsaSSA-PSS-SHAKE128 |
    pk-rsaSSA-PSS-SHAKE256,
    ...
}

-- From [RFC5912] - Here so it compiles.
pk-rsa PUBLIC-KEY ::= {
    IDENTIFIER rsaEncryption
    KEY RSAPublicKey
    PARAMS TYPE NULL ARE absent
    -- Private key format not in this module --
    CERT-KEY-USAGE {digitalSignature, nonRepudiation,
    keyEncipherment, dataEncipherment, keyCertSign, cRLSign}
}

-- The hashAlgorithm is mda-shake128
-- The maskGenAlgorithm is id-shake128
```



```
-- Mask Gen Algorithm is SHAKE128 with output length
-- (n - 264)/8, where n is the RSA modulus in bits.
-- the saltLength is 32
-- the trailerField is 1
pk-rsaSSA-PSS-SHAKE128 PUBLIC-KEY ::= {
    IDENTIFIER id-RSASSA-PSS-SHAKE128
    KEY RSAPublicKey
    PARAMS TYPE NULL ARE absent
    -- Private key format not in this module --
    CERT-KEY-USAGE { nonRepudiation, digitalSignature,
                    keyCertSign, cRLSign }
}

-- The hashAlgorithm is mda-shake256
-- The maskGenAlgorithm is id-shake256
-- Mask Gen Algorithm is SHAKE256 with output length
-- (n - 520)/8, where n is the RSA modulus in bits.
-- the saltLength is 64
-- the trailerField is 1
pk-rsaSSA-PSS-SHAKE256 PUBLIC-KEY ::= {
    IDENTIFIER id-RSASSA-PSS-SHAKE256
    KEY RSAPublicKey
    PARAMS TYPE NULL ARE absent
    -- Private key format not in this module --
    CERT-KEY-USAGE { nonRepudiation, digitalSignature,
                    keyCertSign, cRLSign }
}

pk-ec PUBLIC-KEY ::= {
    IDENTIFIER id-ecPublicKey
    KEY ECPoint
    PARAMS TYPE ECPParameters ARE required
    -- Private key format not in this module --
    CERT-KEY-USAGE { digitalSignature, nonRepudiation, keyAgreement,
                    keyCertSign, cRLSign }
}

ECPParameters ::= CHOICE {
    namedCurve      CURVE.&id({NamedCurve})
    -- implicitCurve  NULL
    -- implicitCurve MUST NOT be used in PKIX
    -- specifiedCurve SpecifiedCurve
    -- specifiedCurve MUST NOT be used in PKIX
    -- Details for specifiedCurve can be found in [X9.62]
    -- Any future additions to this CHOICE should be coordinated
    -- with ANSI X.9.
}

--
```



```
-- Signature Algorithms (sa-)
--
SignatureAlgs SIGNATURE-ALGORITHM ::= {
    ...
    -- This expands SignatureAlgorithms from [RFC5912]
    sa-rsaspssWithSHAKE128 |
    sa-rsaspssWithSHAKE256,
    ...
    sa-ecdsaWithSHAKE128 |
    sa-ecdsaWithSHAKE256,
    ...
}

--
-- SMIME Capabilities (sa-)
--
SMimeCaps SMIME-CAPS ::= {
    ...
    -- The expands SMimeCaps from [RFC5912]
    sa-rsaspssWithSHAKE128.&smimeCaps |
    sa-rsaspssWithSHAKE256.&smimeCaps,
    sa-ecdsaWithSHAKE128.&smimeCaps |
    sa-ecdsaWithSHAKE256.&smimeCaps,
    ...
}

-- RSASSA-PSS with SHAKE128
sa-rsaspssWithSHAKE128 SIGNATURE-ALGORITHM ::= {
    IDENTIFIER id-RSASSA-PSS-SHAKE128
    PARAMS TYPE NULL ARE absent
        -- The hashAlgorithm is mda-shake128
        -- The maskGenAlgorithm is id-shake128
        -- Mask Gen Algorithm is SHAKE128 with output length
        -- (n - 264)/8, where n is the RSA modulus in bits.
        -- the saltLength is 32
        -- the trailerField is 1
        HASHES mda-shake128
    PUBLIC-KEYS { pk-rsa | pk-rsaSSA-PSS-SHAKE128 }
    SMIME-CAPS { IDENTIFIED BY id-RSASSA-PSS-SHAKE128 }
}
id-RSASSA-PSS-SHAKE128 OBJECT IDENTIFIER ::= { TBD }

-- RSASSA-PSS with SHAKE256
sa-rsaspssWithSHAKE256 SIGNATURE-ALGORITHM ::= {
    IDENTIFIER id-RSASSA-PSS-SHAKE256
    PARAMS TYPE NULL ARE absent
        -- The hashAlgorithm is mda-shake256
        -- The maskGenAlgorithm is id-shake256
```





```
-- Mask Gen Algorithm is SHAKE256 with output length
-- (n - 520)/8, where n is the RSA modulus in bits.
-- the saltLength is 64
-- the trailerField is 1
    HASHES mda-shake256
    PUBLIC-KEYS { pk-rsa | pk-rsaSSA-PSS-SHAKE256 }
    SMIME-CAPS { IDENTIFIED BY id-RSASSA-PSS-SHAKE256 }
}
id-RSASSA-PSS-SHAKE256  OBJECT IDENTIFIER ::= { TBD }

-- Deterministic ECDSA with SHAKE128
sa-ecdsaWithSHAKE128 SIGNATURE-ALGORITHM ::= {
    IDENTIFIER id-ecdsa-with-shake128
    VALUE ECDSA-Sig-Value
    PARAMS TYPE NULL ARE absent
    HASHES { mda-shake128 }
    PUBLIC-KEYS { pk-ec }
    SMIME-CAPS { IDENTIFIED BY id-ecdsa-with-shake128 }
}
id-ecdsa-with-shake128 ::= { joint-iso-itu-t(2) country(16)
                             us(840) organization(1) gov(101)
                             csor(3) nistAlgorithm(4)
                             sigAlgs(3) TBD }
```

```
-- Deterministic ECDSA with SHAKE256
sa-ecdsaWithSHAKE256 SIGNATURE-ALGORITHM ::= {
    IDENTIFIER id-ecdsa-with-shake256
    VALUE ECDSA-Sig-Value
    PARAMS TYPE NULL ARE absent
    HASHES { mda-shake256 }
    PUBLIC-KEYS { pk-ec }
    SMIME-CAPS { IDENTIFIED BY id-ecdsa-with-shake256 }
}
id-ecdsa-with-shake256 ::= { joint-iso-itu-t(2) country(16)
                             us(840) organization(1) gov(101)
                             csor(3) nistAlgorithm(4)
                             sigAlgs(3) TBD }
```

END

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