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JSON Web Encryption (JWE)
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Abstract

JSON Web Encryption (JWE) is a means of representing encrypted content using JavaScript Object Notation (JSON) data structures. Cryptographic algorithms and identifiers for use with this specification are described in the separate JSON Web Algorithms (JWA) specification. Related digital signature and MAC capabilities are described in the separate JSON Web Signature (JWS) specification.

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1. Introduction

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JSON Web Encryption (JWE) is a compact encryption format intended for space constrained environments such as HTTP Authorization headers and URI query parameters. It represents this content using JavaScript Object Notation (JSON) **[RFC4627]** based data structures. The JWE cryptographic mechanisms encrypt and provide integrity protection for arbitrary sequences of bytes.

Cryptographic algorithms and identifiers for use with this specification are described in the separate JSON Web Algorithms (JWA) **[JWA]** specification. Related digital signature and MAC capabilities are described in the separate JSON Web Signature (JWS) **[JWS]** specification.

1.1. Notational Conventions

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The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in Key words for use in RFCs to Indicate Requirement Levels **[RFC2119]**.

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2. Terminology

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JSON Web Encryption (JWE)
: A data structure representing an encrypted message. The structure consists of five parts: the JWE Header, the JWE Encrypted Key, the JWE Initialization Vector, the JWE Ciphertext, and the JWE Integrity Value.

Plaintext
: The bytes to be encrypted -- a.k.a., the message. The plaintext can contain an arbitrary sequence of bytes.

Ciphertext
: An encrypted representation of the Plaintext.

Content Encryption Key (CEK)
: A symmetric key used to encrypt the Plaintext for the recipient to produce the Ciphertext.

Content Integrity Key (CIK)
: A key used with a MAC function to ensure the integrity of the Ciphertext and the parameters used to create it.

Content Master Key (CMK)
: A key from which the CEK and CIK are derived. When key wrapping or key encryption are employed, the CMK is randomly generated and encrypted to the recipient as the JWE Encrypted Key. When direct encryption with a shared symmetric key is employed, the CMK is the shared key. When key agreement without key wrapping is employed, the CMK is the result of the key agreement algorithm.

JWE Header
: A string representing a JSON object that describes the encryption operations applied to create the JWE Encrypted Key, the JWE Ciphertext, and the JWE Integrity Value.

JWE Encrypted Key
: When key wrapping or key encryption are employed, the Content Master Key (CMK) is encrypted with the intended recipient's key and the resulting encrypted content is recorded as a byte array, which is referred to as the JWE Encrypted Key. Otherwise, when direct encryption with a shared or agreed upon symmetric key is employed, the JWE Encrypted Key is the empty byte array.

JWE Initialization Vector
: A byte array containing the Initialization Vector used when encrypting the Plaintext.

JWE Ciphertext
: A byte array containing the Ciphertext.

JWE Integrity Value
: A byte array containing a MAC value that ensures the integrity of the Ciphertext and the parameters used to create it.

Base64url Encoding
: The URL- and filename-safe Base64 encoding described in **RFC 4648** [RFC4648], Section 5, with the (non URL-safe) '=' padding characters omitted, as permitted by Section 3.2. (See Appendix C of **[JWS]** for notes on implementing base64url encoding without padding.)

Encoded JWE Header
: Base64url encoding of the bytes of the UTF-8 **[RFC3629]** representation of the JWE Header.

Encoded JWE Encrypted Key
: Base64url encoding of the JWE Encrypted Key.

Encoded JWE Initialization Vector
: Base64url encoding of the JWE Initialization Vector.

Encoded JWE Ciphertext
: Base64url encoding of the JWE Ciphertext.

Encoded JWE Integrity Value
: Base64url encoding of the JWE Integrity Value.

Header Parameter Name
: The name of a member of the JSON object representing a JWE Header.

Header Parameter Value
: The value of a member of the JSON object representing a JWE Header.

JWE Compact Serialization
: A representation of the JWE as the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Integrity Value in that order, with the five strings being separated by four period ('.') characters.

AEAD Algorithm
: An Authenticated Encryption with Associated Data (AEAD) **[RFC5116]** encryption algorithm is one that provides an integrated content integrity check. AEAD encryption algorithms accept two inputs, the plaintext and the "additional authenticated data" value, and produce two outputs, the ciphertext and the "authentication tag" value. AES Galois/Counter Mode (GCM) is one such algorithm.

Collision Resistant Namespace
: A namespace that allows names to be allocated in a manner such that they are highly unlikely to collide with other names. For instance, collision resistance can be achieved through administrative delegation of portions of the namespace or through use of collision-resistant name allocation functions. Examples of Collision Resistant Namespaces include: Domain Names, Object Identifiers (OIDs) as defined in the ITU-T X.660 and X.670 Recommendation series, and Universally Unique IDentifiers (UUIDs) **[RFC4122]**. When using an administratively delegated namespace, the definer of a name needs to take reasonable precautions to ensure they are in control of the portion of the namespace they use to define the name.

StringOrURI
: A JSON string value, with the additional requirement that while arbitrary string values MAY be used, any value containing a ":" character MUST be a URI **[RFC3986]**. StringOrURI values are compared as case-sensitive strings with no transformations or canonicalizations applied.

3. JSON Web Encryption (JWE) Overview

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JWE represents encrypted content using JSON data structures and base64url encoding. The representation consists of five parts: the JWE Header, the JWE Encrypted Key, the JWE Initialization Vector, the JWE Ciphertext, and the JWE Integrity Value. In the Compact Serialization, the five parts are base64url-encoded for transmission, and represented as the concatenation of the encoded strings in that order, with the five strings being separated by four period ('.') characters. (A JSON Serialization for this information is defined in the separate JSON Web Encryption JSON Serialization (JWE-JS) **[JWE-JS]** specification.)

JWE utilizes encryption to ensure the confidentiality of the Plaintext. JWE adds a content integrity check if not provided by the underlying encryption algorithm.

3.1. Example JWE using RSAES OAEP and AES GCM

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This example encrypts the plaintext "Live long and prosper." to the recipient using RSAES OAEP and AES GCM. The AES GCM algorithm has an integrated integrity check.

The following example JWE Header declares that:

- the Content Master Key is encrypted to the recipient using the RSAES OAEP algorithm to produce the JWE Encrypted Key and
- the Plaintext is encrypted using the AES GCM algorithm with a 256 bit key to produce the Ciphertext.

```
{"alg":"RSA-OAEP","enc":"A256GCM"}
```

Base64url encoding the bytes of the UTF-8 representation of the JWE Header yields this Encoded JWE Header value:

```
eyJhbGciOiJSU0EtT0FFUCIsImVuYyI6IkEyNTZHQ00ifQ
```

The remaining steps to finish creating this JWE are:

- Generate a random Content Master Key (CMK)
- Encrypt the CMK with the recipient's public key using the RSAES OAEP algorithm to produce the JWE Encrypted Key
- Base64url encode the JWE Encrypted Key to produce the Encoded JWE Encrypted Key
- Generate a random JWE Initialization Vector
- Base64url encode the JWE Initialization Vector to produce the Encoded JWE Initialization Vector
- Concatenate the Encoded JWE Header value, a period character ('.'), the Encoded JWE Encrypted Key, a second period character ('.'), and the Encoded JWE Initialization Vector to create the "additional authenticated data" parameter for the AES GCM algorithm
- Encrypt the Plaintext with AES GCM, using the CMK as the encryption key, the JWE Initialization Vector, and the "additional authenticated data" value above, requesting a 128 bit "authentication tag" output
- Base64url encode the resulting Ciphertext to create the Encoded JWE Ciphertext
- Base64url encode the resulting "authentication tag" to create the Encoded JWE Integrity Value
- Assemble the final representation: The Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Integrity Value in that order, with the five strings being separated by four period ('.') characters.

The final result in this example (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0EtT0FFUCIsImVuYyI6IkEyNTZHQ00ifQ.
M2XxpbORKezKSzzQL_95-GjiudRBTqn_omS8z9xgoRb7L0Jw5UsEbxmtyHn2T71m
rZLkjg4Mp8gbhYoltPkEOHvAopz25-vZ8C2e1cOaAo5WPcbSIuFcB4DjBOM3t0UA
O6JHkWLuAEYoe58lcxIQneyKdaYSLbV9cKqoUoFQpvKWYRHZbfszIyfsa18rmgTj
zrtLDTPnc09DSJE24aQ8w3i8RXEDthW9T1J6LsTH_vwHdwUgkI-tC2PNeGrnM-dN
SfzF3Y7-lwcGy0FsdXkPXytvDV7y4pZeeUiQ-0VdibIN2AjjfW60nfrPuOjepMFG
6BBBbR37pHcyzext9epOAQ.
48V1_ALb6US04U3b.
_e21tGGhac_peEFkLXr2dMPUZiUkrw.
7V5ZDko0v_mf2PAc4JMiUg
```

See **Appendix A.1** for the complete details of computing this JWE.

3.2. Example JWE using RSAES-PKCS1-V1_5 and AES CBC

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This example encrypts the plaintext "No matter where you go, there you are." to the recipient using RSAES-PKCS1-V1_5 and AES CBC. AES CBC does not have an integrated integrity check, so a separate integrity check calculation is performed using HMAC SHA-256, with separate encryption and integrity keys being derived from a master key using the Concat KDF with the SHA-256 digest function.

The following example JWE Header (with line breaks for display purposes only) declares that:

- the Content Master Key is encrypted to the recipient using the RSAES-PKCS1-V1_5 algorithm to produce the JWE Encrypted Key and
- the Plaintext is encrypted using the AES CBC algorithm with a 128 bit key to produce the Ciphertext, with the integrity of the Ciphertext and the parameters used to create it being secured using the HMAC SHA-256 algorithm.

```
{"alg":"RSA1_5","enc":"A128CBC+HS256"}
```

Base64url encoding the bytes of the UTF-8 representation of the JWE Header yields this Encoded JWE Header value:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDK0hTMjU2In0
```

The remaining steps to finish creating this JWE are like the previous example, but with an additional step to compute the separate integrity value:

- Generate a random Content Master Key (CMK)
- Encrypt the CMK with the recipient's public key using the RSAES-PKCS1-V1_5 algorithm to produce the JWE Encrypted Key
- Base64url encode the JWE Encrypted Key to produce the Encoded JWE Encrypted Key
- Generate a random JWE Initialization Vector
- Base64url encode the JWE Initialization Vector to produce the Encoded JWE Initialization Vector
- Use the Concat key derivation function to derive Content Encryption Key (CEK) and Content Integrity Key (CIK) values from the CMK
- Encrypt the Plaintext with AES CBC using the CEK and JWE Initialization Vector to produce the Ciphertext
- Base64url encode the resulting Ciphertext to create the Encoded JWE Ciphertext
- Concatenate the Encoded JWE Header value, a period character ('.'), the Encoded JWE Encrypted Key, a second period character ('.'), the Encoded JWE Initialization Vector, a third period ('.') character, and the Encoded JWE Ciphertext to create the value to integrity protect
- Compute the HMAC SHA-256 of this value using the CIK to create the JWE Integrity Value
- Base64url encode the resulting JWE Integrity Value to create the Encoded JWE Integrity Value

- Assemble the final representation: The Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Integrity Value in that order, with the five strings being separated by four period ('.') characters.

The final result in this example (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDK0hTMjU2In0.
O6AqXqgVlJJ4c4lp5sXZd7bpGHAw6ARkHUeXQxD1cAW4-X1x0qtj_AN0mukqEOl4
Y6UOwJXIJY9-G1ELK-RQWrKH_StR-AM9H7GpKmSEji8QYOcMOjr-u9H1Lt_pBEie
G802SxWz0rbFTXRcj4BWLxcpCtjUZ31AP-sc-L_eCZ5UNl0aSRNqFskuPkzRsFZR
DJqSSJeVOyJ7pZCQ83fli19Vgi_3R7XMUqluQuuc7ZHOWixi47jXlBTlWRZ5iFxa
S8G6J8wUrd4BKggAw3qX5XoIfXQVlQZE0Vmkq_zQSIo5LnFKyowooRcdsEuNh9B9
Mkyt0ZQElG-jGdtHWjZSOA.
AxY8DCtDaGlsbGljb3RoZQ.
1eBWFgcrz40wC88cgv8rPgu3EfmC1p4zT0kIxxfSF2zDJcQ-iEHk1jQM95xAdr5Z.
RBGhYzE8_cZLHjJqqHuLhzbgWgL_wV3LDSUrcbkOiIA
```

See **Appendix A.2** for the complete details of computing this JWE.

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4. JWE Header

The members of the JSON object represented by the JWE Header describe the encryption applied to the Plaintext and optionally additional properties of the JWE. The Header Parameter Names within this object MUST be unique; JWEs with duplicate Header Parameter Names MUST be rejected. Implementations MUST understand the entire contents of the header; otherwise, the JWE MUST be rejected.

There are two ways of distinguishing whether a header is a JWS Header or a JWE Header. The first is by examining the `alg` (algorithm) header value. If the value represents a digital signature or MAC algorithm, or is the value `none`, it is for a JWS; if it represents an encryption or key agreement algorithm, it is for a JWE. A second method is determining whether an `enc` (encryption method) member exists. If the `enc` member exists, it is a JWE; otherwise, it is a JWS. Both methods will yield the same result for all legal input values.

There are three classes of Header Parameter Names: Reserved Header Parameter Names, Public Header Parameter Names, and Private Header Parameter Names.

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4.1. Reserved Header Parameter Names

The following header parameter names are reserved with meanings as defined below. All the names are short because a core goal of JWE is for the representations to be compact.

Additional reserved header parameter names MAY be defined via the IANA JSON Web Signature and Encryption Header Parameters registry **[JWS]**. As indicated by the common registry, JWSs and JWEs share a common header parameter space; when a parameter is used by both specifications, its usage must be compatible between the specifications.

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4.1.1. "alg" (Algorithm) Header Parameter

The `alg` (algorithm) header parameter identifies the cryptographic algorithm used to encrypt or determine the value of the Content Master Key (CMK). The algorithm specified by the `alg` value MUST be supported by the implementation and there MUST be a key for use with that algorithm associated with the intended recipient or the JWE MUST be rejected. `alg` values SHOULD either be registered in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]** or be a URI that contains a Collision Resistant Namespace. The `alg` value is a case sensitive string containing a StringOrURI value. This header parameter is REQUIRED.

A list of defined `alg` values can be found in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]**; the initial contents of this registry are the values defined in Section 4.1 of the JSON Web Algorithms (JWA) **[JWA]** specification.

4.1.2. "enc" (Encryption Method) Header Parameter

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The `enc` (encryption method) header parameter identifies the block encryption algorithm used to encrypt the Plaintext to produce the Ciphertext. This algorithm MUST be an AEAD algorithm with a specified key length. The algorithm specified by the `enc` value MUST be supported by the implementation or the JWE MUST be rejected. `enc` values SHOULD either be registered in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]** or be a URI that contains a Collision Resistant Namespace. The `enc` value is a case sensitive string containing a StringOrURI value. This header parameter is REQUIRED.

A list of defined `enc` values can be found in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]**; the initial contents of this registry are the values defined in Section 4.2 of the JSON Web Algorithms (JWA) **[JWA]** specification.

4.1.3. "epk" (Ephemeral Public Key) Header Parameter

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The `epk` (ephemeral public key) value created by the originator for the use in key agreement algorithms. This key is represented as a JSON Web Key **[JWK]** value. This header parameter is OPTIONAL, although its use is REQUIRED with some `alg` algorithms.

4.1.4. "zip" (Compression Algorithm) Header Parameter

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The `zip` (compression algorithm) applied to the Plaintext before encryption, if any. If present, the value of the `zip` header parameter MUST be the case sensitive string "DEF". Compression is performed with the DEFLATE **[RFC1951]** algorithm. If no `zip` parameter is present, no compression is applied to the Plaintext before encryption. This header parameter is OPTIONAL.

4.1.5. "jku" (JWK Set URL) Header Parameter

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The `jku` (JWK Set URL) header parameter is a URI **[RFC3986]** that refers to a resource for a set of JSON-encoded public keys, one of which corresponds to the key used to encrypt the JWE; this can be used to determine the private key needed to decrypt the JWE. The keys MUST be encoded as a JSON Web Key Set (JWK Set) **[JWK]**. The protocol used to acquire the resource MUST provide integrity protection; an HTTP GET request to retrieve the certificate MUST use TLS **[RFC2818]** **[RFC5246]**; the identity of the server MUST be validated, as per Section 3.1 of HTTP Over TLS **[RFC2818]**. This header parameter is OPTIONAL.

4.1.6. "jwk" (JSON Web Key) Header Parameter

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The `jwk` (JSON Web Key) header parameter is a public key that corresponds to the key used to encrypt the JWE; this can be used to determine the private key needed to decrypt the JWE. This key is represented as a JSON Web Key **[JWK]**. This header parameter is OPTIONAL.

4.1.7. "x5u" (X.509 URL) Header Parameter

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The x5u (X.509 URL) header parameter is a URI **[RFC3986]** that refers to a resource for the X.509 public key certificate or certificate chain **[RFC5280]** corresponding to the key used to encrypt the JWE; this can be used to determine the private key needed to decrypt the JWE. The identified resource MUST provide a representation of the certificate or certificate chain that conforms to **RFC 5280** [RFC5280] in PEM encoded form **[RFC1421]**. The certificate containing the public key of the entity that encrypted the JWE MUST be the first certificate. This MAY be followed by additional certificates, with each subsequent certificate being the one used to certify the previous one. The protocol used to acquire the resource MUST provide integrity protection; an HTTP GET request to retrieve the certificate MUST use TLS **[RFC2818]** **[RFC5246]**; the identity of the server MUST be validated, as per Section 3.1 of HTTP Over TLS **[RFC2818]**. This header parameter is OPTIONAL.

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4.1.8. "x5t" (X.509 Certificate Thumbprint) Header Parameter

The x5t (X.509 Certificate Thumbprint) header parameter provides a base64url encoded SHA-1 thumbprint (a.k.a. digest) of the DER encoding of the X.509 certificate **[RFC5280]** corresponding to the key used to encrypt the JWE; this can be used to determine the private key needed to decrypt the JWE. This header parameter is OPTIONAL.

If, in the future, certificate thumbprints need to be computed using hash functions other than SHA-1, it is suggested that additional related header parameters be defined for that purpose. For example, it is suggested that a new x5t#S256 (X.509 Certificate Thumbprint using SHA-256) header parameter could be defined by registering it in the IANA JSON Web Signature and Encryption Header Parameters registry **[JWS]**.

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4.1.9. "x5c" (X.509 Certificate Chain) Header Parameter

The x5c (X.509 Certificate Chain) header parameter contains the X.509 public key certificate or certificate chain **[RFC5280]** corresponding to the key used to encrypt the JWE; this can be used to determine the private key needed to decrypt the JWE. The certificate or certificate chain is represented as an array of certificate value strings. Each string is a base64 encoded (**[RFC4648]** Section 4 -- not base64url encoded) DER **[ITU.X690.1994]** PKIX certificate value. The certificate containing the public key of the entity that encrypted the JWE MUST be the first certificate. This MAY be followed by additional certificates, with each subsequent certificate being the one used to certify the previous one. The recipient MUST verify the certificate chain according to **[RFC5280]** and reject the JWE if any validation failure occurs. This header parameter is OPTIONAL.

See Appendix B of **[JWS]** for an example x5c value.

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4.1.10. "kid" (Key ID) Header Parameter

The kid (key ID) header parameter is a hint indicating which key was used to encrypt the JWE; this can be used to determine the private key needed to decrypt the JWE. This parameter allows originators to explicitly signal a change of key to recipients. Should the recipient be unable to locate a key corresponding to the kid value, they SHOULD treat that condition as an error. The interpretation of the kid value is unspecified. Its value MUST be a string. This header parameter is OPTIONAL.

When used with a JWK, the kid value MAY be used to match a JWK kid parameter value.

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4.1.11. "typ" (Type) Header Parameter

The typ (type) header parameter is used to declare the type of this object. The type value JWE MAY be used to indicate that this object is a JWE. The typ value is a case sensitive string. This header parameter is OPTIONAL.

MIME Media Type **[RFC2046]** values MAY be used as `typ` values.

`typ` values SHOULD either be registered in the IANA JSON Web Signature and Encryption Type Values registry **[JWS]** or be a URI that contains a Collision Resistant Namespace.

4.1.12. "cty" (Content Type) Header Parameter

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The `cty` (content type) header parameter is used to declare the type of the encrypted content (the Plaintext). The `cty` value is a case sensitive string. This header parameter is OPTIONAL.

The values used for the `cty` header parameter come from the same value space as the `typ` header parameter, with the same rules applying.

4.1.13. "apu" (Agreement PartyUInfo) Header Parameter

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The `apu` (agreement PartyUInfo) value for key agreement algorithms using it (such as `ECDH-ES`), represented as a base64url encoded string. This header parameter is OPTIONAL.

4.1.14. "apv" (Agreement PartyVInfo) Header Parameter

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The `apv` (agreement PartyVInfo) value for key agreement algorithms using it (such as `ECDH-ES`), represented as a base64url encoded string. This header parameter is OPTIONAL.

4.1.15. "epu" (Encryption PartyUInfo) Header Parameter

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The `epu` (encryption PartyUInfo) value for plaintext encryption algorithms using it (such as `A128CBC+HS256`), represented as a base64url encoded string. This header parameter is OPTIONAL.

4.1.16. "epv" (Encryption PartyVInfo) Header Parameter

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The `epv` (encryption PartyVInfo) value for plaintext encryption algorithms using it (such as `A128CBC+HS256`), represented as a base64url encoded string. This header parameter is OPTIONAL.

4.2. Public Header Parameter Names

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Additional header parameter names can be defined by those using JWEs. However, in order to prevent collisions, any new header parameter name SHOULD either be registered in the IANA JSON Web Signature and Encryption Header Parameters registry **[JWS]** or be a URI that contains a Collision Resistant Namespace. In each case, the definer of the name or value needs to take reasonable precautions to make sure they are in control of the part of the namespace they use to define the header parameter name.

New header parameters should be introduced sparingly, as they can result in non-interoperable JWEs.

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4.3. Private Header Parameter Names

A producer and consumer of a JWE may agree to any header parameter name that is not a Reserved Name **Section 4.1** or a Public Name **Section 4.2**. Unlike Public Names, these private names are subject to collision and should be used with caution.

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5. Message Encryption

The message encryption process is as follows. The order of the steps is not significant in cases where there are no dependencies between the inputs and outputs of the steps.

1. When key wrapping, key encryption, or key agreement with key wrapping are employed, generate a random Content Master Key (CMK). See **RFC 4086** [RFC4086] for considerations on generating random values. The CMK MUST have a length equal to that required for the block encryption algorithm.
2. When key agreement is employed, use the key agreement algorithm to compute the value of the agreed upon key. When key agreement without key wrapping is employed, let the Content Master Key (CMK) be the agreed upon key. When key agreement with key wrapping is employed, the agreed upon key will be used to wrap the CMK.
3. When key wrapping, key encryption, or key agreement with key wrapping are employed, encrypt the CMK for the recipient (see **Section 7**) and let the result be the JWE Encrypted Key. Otherwise, when direct encryption with a shared or agreed upon symmetric key is employed, let the JWE Encrypted Key be the empty byte array.
4. When direct encryption with a shared symmetric key is employed, let the Content Master Key (CMK) be the shared key.
5. Base64url encode the JWE Encrypted Key to create the Encoded JWE Encrypted Key.
6. Generate a random JWE Initialization Vector of the correct size for the block encryption algorithm (if required for the algorithm); otherwise, let the JWE Initialization Vector be the empty byte string.
7. Base64url encode the JWE Initialization Vector to create the Encoded JWE Initialization Vector.
8. Compress the Plaintext if a `zip` parameter was included.
9. Serialize the (compressed) Plaintext into a byte sequence M.
10. Create a JWE Header containing the encryption parameters used. Note that white space is explicitly allowed in the representation and no canonicalization need be performed before encoding.
11. Base64url encode the bytes of the UTF-8 representation of the JWE Header to create the Encoded JWE Header.
12. Let the "additional authenticated data" value be the bytes of the ASCII representation of the concatenation of the Encoded JWE Header, a period ('.') character, the Encoded JWE Encrypted Key, a second period character ('.'), and the Encoded JWE Initialization Vector.
13. Encrypt M using the CMK, the JWE Initialization Vector, and the "additional authenticated data" value using the specified block encryption algorithm to create the JWE Ciphertext value and the JWE Integrity Value (which is the "authentication tag" output from the calculation).
14. Base64url encode the JWE Ciphertext to create the Encoded JWE Ciphertext.
15. Base64url encode the JWE Integrity Value to create the Encoded JWE Integrity Value.
16. The five encoded parts, taken together, are the result.
17. The Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Integrity Value in that order, with the five strings being separated by four period ('.') characters.

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6. Message Decryption

The message decryption process is the reverse of the encryption process. The order of the steps is not significant in cases where there are no dependencies between the inputs and

outputs of the steps. If any of these steps fails, the JWE MUST be rejected.

1. Determine the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Integrity Value values contained in the JWE. When using the Compact Serialization, these five values are represented in that order, separated by four period ('.') characters.
2. The Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Integrity Value MUST be successfully base64url decoded following the restriction that no padding characters have been used.
3. The resulting JWE Header MUST be completely valid JSON syntax conforming to **RFC 4627** [RFC4627].
4. The resulting JWE Header MUST be validated to only include parameters and values whose syntax and semantics are both understood and supported.
5. Verify that the JWE uses a key known to the recipient.
6. When key agreement is employed, use the key agreement algorithm to compute the value of the agreed upon key. When key agreement without key wrapping is employed, let the Content Master Key (CMK) be the agreed upon key. When key agreement with key wrapping is employed, the agreed upon key will be used to decrypt the JWE Encrypted Key.
7. When key wrapping, key encryption, or key agreement with key wrapping are employed, decrypt the JWE Encrypted Key to produce the Content Master Key (CMK). The CMK MUST have a length equal to that required for the block encryption algorithm.
8. When direct encryption with a shared symmetric key is employed, let the Content Master Key (CMK) be the shared key.
9. Let the "additional authenticated data" value be the bytes of the ASCII representation of the concatenation of the Encoded JWE Header, a period ('.') character, the Encoded JWE Encrypted Key, a second period character ('.'), and the Encoded JWE Initialization Vector.
10. Decrypt the JWE Ciphertext using the CMK, the JWE Initialization Vector, the "additional authenticated data" value, and the JWE Integrity Value (which is the "authentication tag" input to the calculation) using the specified block encryption algorithm, returning the decrypted plaintext and verifying the JWE Integrity Value in the manner specified for the algorithm, rejecting the input without emitting any decrypted output if the JWE Integrity Value is incorrect.
11. Uncompress the decrypted plaintext if a `zip` parameter was included.
12. Output the resulting Plaintext.

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7. CMK Encryption

JWE supports three forms of Content Master Key (CMK) encryption:

- Asymmetric encryption under the recipient's public key.
- Symmetric encryption under a key shared between the sender and receiver.
- Symmetric encryption under a key agreed upon between the sender and receiver.

See the algorithms registered for `enc` usage in the IANA JSON Web Signature and Encryption Algorithms registry **[JWA]** and Section 4.1 of the JSON Web Algorithms (JWA) **[JWA]** specification for lists of encryption algorithms that can be used for CMK encryption.

TOC

8. Encrypting JWEs with Cryptographic Algorithms

JWE uses cryptographic algorithms to encrypt the Plaintext and the Content Encryption Key (CMK) and to provide integrity protection for the JWE Header, JWE Encrypted Key, and JWE Ciphertext. The JSON Web Algorithms (JWA) **[JWA]** specification specifies a set of cryptographic algorithms and identifiers to be used with this specification and defines registries for additional such algorithms. Specifically, Section 4.1 specifies a set of `alg` (algorithm) header parameter values and Section 4.2 specifies a set of `enc` (encryption method) header parameter values intended for use this specification. It also describes the

semantics and operations that are specific to these algorithms and algorithm families.

Public keys employed for encryption can be identified using the Header Parameter methods described in **Section 4.1** or can be distributed using methods that are outside the scope of this specification.

---

9. IANA Considerations

TOC

9.1. Registration of JWE Header Parameter Names

TOC

This specification registers the Header Parameter Names defined in **Section 4.1** in the IANA JSON Web Signature and Encryption Header Parameters registry **[JWS]**.

9.1.1. Registry Contents

TOC

- Header Parameter Name: `alg`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.1** of [[this document]]

- Header Parameter Name: `enc`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.2** of [[this document]]

- Header Parameter Name: `epk`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.3** of [[this document]]

- Header Parameter Name: `zip`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.4** of [[this document]]

- Header Parameter Name: `jku`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.5** of [[this document]]

- Header Parameter Name: `jwk`
- Change Controller: IETF
- Specification document(s): **Section 4.1.6** of [[this document]]

- Header Parameter Name: `x5u`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.7** of [[this document]]

- Header Parameter Name: `x5t`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.8** of [[this document]]

- Header Parameter Name: `x5c`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.9** of [[this document]]

- Header Parameter Name: `kid`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.10** of [[this document]]

- Header Parameter Name: `typ`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.11** of [[this document]]

- Header Parameter Name: `cty`

- Change Controller: IETF
- Specification Document(s): **Section 4.1.12** of [[this document]]

- Header Parameter Name: `apu`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.13** of [[this document]]

- Header Parameter Name: `apv`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.14** of [[this document]]

- Header Parameter Name: `epu`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.15** of [[this document]]

- Header Parameter Name: `epv`
- Change Controller: IETF
- Specification Document(s): **Section 4.1.16** of [[this document]]

9.2. JSON Web Signature and Encryption Type Values Registration

TOC

9.2.1. Registry Contents

TOC

This specification registers the `JWE` type value in the IANA JSON Web Signature and Encryption Type Values registry **[JWS]**:

- "typ" Header Parameter Value: `JWE`
- Abbreviation for MIME Type: application/jwe
- Change Controller: IETF
- Specification Document(s): **Section 4.1.11** of [[this document]]

9.3. Media Type Registration

TOC

9.3.1. Registry Contents

TOC

This specification registers the `application/jwe` Media Type **[RFC2046]** in the MIME Media Type registry **[RFC4288]** to indicate that the content is a JWE using the Compact Serialization.

- Type Name: application
- Subtype Name: jwe
- Required Parameters: n/a
- Optional Parameters: n/a
- Encoding considerations: JWE values are encoded as a series of base64url encoded values (some of which may be the empty string) separated by period ('.') characters
- Security Considerations: See the Security Considerations section of this document
- Interoperability Considerations: n/a
- Published Specification: [[this document]]
- Applications that use this media type: OpenID Connect and other applications using encrypted JWTs
- Additional Information: Magic number(s): n/a, File extension(s): n/a, Macintosh file type code(s): n/a
- Person & email address to contact for further information: Michael B. Jones, mbj@microsoft.com
- Intended Usage: COMMON

- Restrictions on Usage: none
- Author: Michael B. Jones, mbj@microsoft.com
- Change Controller: IETF

10. Security Considerations

TOC

All of the security issues faced by any cryptographic application must be faced by a JWS/JWE/JWK agent. Among these issues are protecting the user's private key, preventing various attacks, and helping the user avoid mistakes such as inadvertently encrypting a message for the wrong recipient. The entire list of security considerations is beyond the scope of this document, but some significant concerns are listed here.

All the security considerations in the JWS specification also apply to this specification. Likewise, all the security considerations in **XML Encryption 1.1** [W3C.CR-xmlenc-core1-20120313] also apply to JWE, other than those that are XML specific.

11. References

TOC

11.1. Normative References

TOC

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[JWK] **Jones, M.**, "**JSON Web Key (JWK)**," November 2012.

[JWS] **Jones, M.**, **Bradley, J.**, and **N. Sakimura**, "**JSON Web Signature (JWS)**," November 2012.

[RFC1421] **Linn, J.**, "**Privacy Enhancement for Internet Electronic Mail: Part I: Message Encryption and Authentication Procedures**," RFC 1421, February 1993 (**TXT**).

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[RFC2046] **Freed, N.** and **N. Borenstein**, "**Multipurpose Internet Mail Extensions (MIME) Part Two: Media Types**," RFC 2046, November 1996 (**TXT**).

[RFC2119] **Bradner, S.**, "**Key words for use in RFCs to Indicate Requirement Levels**," BCP 14, RFC 2119, March 1997 (**TXT**, **HTML**, **XML**).

[RFC2818] Rescorla, E., "**HTTP Over TLS**," RFC 2818, May 2000 (**TXT**).

[RFC3629] Yergeau, F., "**UTF-8, a transformation format of ISO 10646**," STD 63, RFC 3629, November 2003 (**TXT**).

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[RFC5116] McGrew, D., "**An Interface and Algorithms for Authenticated Encryption**," RFC 5116, January 2008 (**TXT**).

[RFC5246] Dierks, T. and E. Rescorla, "**The Transport Layer Security (TLS) Protocol Version 1.2**," RFC 5246, August 2008 (**TXT**).

[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, May 2008 (**TXT**).

[W3C.CR-xmlenc-core1-20120313] Eastlake, D., Reagle, J., Roessler, T., and F. Hirsch, "**XML Encryption Syntax and Processing Version 1.1**," World Wide Web Consortium CR CR-xmlenc-core1-20120313, March 2012 (**HTML**).

11.2. Informative References

TOC

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[JSE]	Bradley, J. and N. Sakimura (editor), "**JSON Simple Encryption**," September 2010.
[JWE-JS]	**Jones, M.**, "**JSON Web Encryption JSON Serialization (JWE-JS)**," November 2012.
[RFC4122]	**Leach, P.**, **Mealling, M.**, and **R. Salz**, "**A Universally Unique IDentifier (UUID) URN Namespace**," RFC 4122, July 2005 (**TXT**, **HTML**, **XML**).
[RFC5652]	Housley, R., "**Cryptographic Message Syntax (CMS)**," STD 70, RFC 5652, September 2009 (**TXT**).

TOC

Appendix A. JWE Examples

This section provides examples of JWE computations.

TOC

A.1. Example JWE using RSAES OAEP and AES GCM

This example encrypts the plaintext "Live long and prosper." to the recipient using RSAES OAEP and AES GCM. The AES GCM algorithm has an integrated integrity check. The representation of this plaintext is:

[76, 105, 118, 101, 32, 108, 111, 110, 103, 32, 97, 110, 100, 32, 112, 114, 111, 115, 112, 101, 114, 46]

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A.1.1. JWE Header

The following example JWE Header declares that:

- the Content Master Key is encrypted to the recipient using the RSAES OAEP algorithm to produce the JWE Encrypted Key and
- the Plaintext is encrypted using the AES GCM algorithm with a 256 bit key to produce the Ciphertext.

```
{"alg":"RSA-OAEP","enc":"A256GCM"}
```

TOC

A.1.2. Encoded JWE Header

Base64url encoding the bytes of the UTF-8 representation of the JWE Header yields this Encoded JWE Header value:

```
eyJhbGciOiJSU0EtT0FFUCIsImVuYyI6IkEyNTZHQ00ifQ
```

TOC

A.1.3. Content Master Key (CMK)

Generate a 256 bit random Content Master Key (CMK). In this example, the value is:

[177, 161, 244, 128, 84, 143, 225, 115, 63, 180, 3, 255, 107, 154, 212, 246, 138, 7, 110, 91, 112, 46, 34, 105, 47, 130, 203, 46, 122, 234, 64, 252]

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A.1.4. Key Encryption

Encrypt the CMK with the recipient's public key using the RSAES OAEP algorithm to produce the JWE Encrypted Key. In this example, the RSA key parameters are:

Parameter	

Parameter Name	Value
Modulus	[161, 168, 84, 34, 133, 176, 208, 173, 46, 176, 163, 110, 57, 30, 135, 227, 9, 31, 226, 128, 84, 92, 116, 241, 70, 248, 27, 227, 193, 62, 5, 91, 241, 145, 224, 205, 141, 176, 184, 133, 239, 43, 81, 103, 9, 161, 153, 157, 179, 104, 123, 51, 189, 34, 152, 69, 97, 69, 78, 93, 140, 131, 87, 182, 169, 101, 92, 142, 3, 22, 167, 8, 212, 56, 35, 79, 210, 222, 192, 208, 252, 49, 109, 138, 173, 253, 210, 166, 201, 63, 102, 74, 5, 158, 41, 90, 144, 108, 160, 79, 10, 89, 222, 231, 172, 31, 227, 197, 0, 19, 72, 81, 138, 78, 136, 221, 121, 118, 196, 17, 146, 10, 244, 188, 72, 113, 55, 221, 162, 217, 171, 27, 57, 233, 210, 101, 236, 154, 199, 56, 138, 239, 101, 48, 198, 186, 202, 160, 76, 111, 234, 71, 57, 183, 5, 211, 171, 136, 126, 64, 40, 75, 58, 89, 244, 254, 107, 84, 103, 7, 236, 69, 163, 18, 180, 251, 58, 153, 46, 151, 174, 12, 103, 197, 181, 161, 162, 55, 250, 235, 123, 110, 17, 11, 158, 24, 47, 133, 8, 199, 235, 107, 126, 130, 246, 73, 195, 20, 108, 202, 176, 214, 187, 45, 146, 182, 118, 54, 32, 200, 61, 201, 71, 243, 1, 255, 131, 84, 37, 111, 211, 168, 228, 45, 192, 118, 27, 197, 235, 232, 36, 10, 230, 248, 190, 82, 182, 140, 35, 204, 108, 190, 253, 186, 186, 27]
Exponent	[1, 0, 1]
Private Exponent	[144, 183, 109, 34, 62, 134, 108, 57, 44, 252, 10, 66, 73, 54, 16, 181, 233, 92, 54, 219, 101, 42, 35, 178, 63, 51, 43, 92, 119, 136, 251, 41, 53, 23, 191, 164, 164, 60, 88, 227, 229, 152, 228, 213, 149, 228, 169, 237, 104, 71, 151, 75, 88, 252, 216, 77, 251, 231, 28, 97, 88, 193, 215, 202, 248, 216, 121, 195, 211, 245, 250, 112, 71, 243, 61, 129, 95, 39, 244, 122, 225, 217, 169, 211, 165, 48, 253, 220, 59, 122, 219, 42, 86, 223, 32, 236, 39, 48, 103, 78, 122, 216, 187, 88, 176, 89, 24, 1, 42, 177, 24, 99, 142, 170, 1, 146, 43, 3, 108, 64, 194, 121, 182, 95, 187, 134, 71, 88, 96, 134, 74, 131, 167, 69, 106, 143, 121, 27, 72, 44, 245, 95, 39, 194, 179, 175, 203, 122, 16, 112, 183, 17, 200, 202, 31, 17, 138, 156, 184, 210, 157, 184, 154, 131, 128, 110, 12, 85, 195, 122, 241, 79, 251, 229, 183, 117, 21, 123, 133, 142, 220, 153, 9, 59, 57, 105, 81, 255, 138, 77, 82, 54, 62, 216, 38, 249, 208, 17, 197, 49, 45, 19, 232, 157, 251, 131, 137, 175, 72, 126, 43, 229, 69, 179, 117, 82, 157, 213, 83, 35, 57, 210, 197, 252, 171, 143, 194, 11, 47, 163, 6, 253, 75, 252, 96, 11, 187, 84, 130, 210, 7, 121, 78, 91, 79, 57, 251, 138, 132, 220, 60, 224, 173, 56, 224, 201]

The resulting JWE Encrypted Key value is:

[51, 101, 241, 165, 179, 145, 41, 236, 202, 75, 60, 208, 47, 255, 121, 248, 104, 226, 185, 212, 65, 78, 169, 255, 162, 100, 188, 207, 220, 96, 161, 22, 251, 47, 66, 112, 229, 75, 4, 111, 25, 173, 200, 121, 246, 79, 189, 102, 173, 146, 228, 142, 14, 12, 167, 200, 27, 133, 138, 37, 180, 249, 4, 56, 123, 192, 162, 156, 246, 231, 235, 217, 240, 45, 158, 213, 195, 154, 2, 142, 86, 61, 198, 210, 34, 225, 92, 7, 128, 227, 4, 227, 55, 183, 69, 0, 59, 162, 71, 145, 98, 238, 0, 70, 40, 123, 159, 37, 115, 18, 16, 157, 236, 138, 117, 166, 18, 45, 181, 125, 112, 170, 168, 82, 129, 80, 166, 242, 150, 97, 17, 217, 109, 251, 51, 35, 39, 236, 107, 95, 43, 154, 4, 227, 206, 187, 75, 13, 51, 231, 115, 79, 67, 72, 145, 54, 225, 164, 60, 195, 120, 188, 69, 113, 3, 182, 21, 189, 79, 82, 122, 46, 196, 199, 254, 252, 7, 119, 5, 32, 144, 143, 173, 11, 99, 205, 120, 106, 231, 51, 231, 77, 73, 252, 197, 221, 142, 254, 151, 7, 6, 203, 65, 108, 117, 121, 15, 95, 43, 111, 13, 94, 242, 226, 150, 94, 121, 72, 144, 251, 69, 93, 137, 178, 13, 216, 8, 227, 125, 110, 180, 157, 250, 207, 184, 232, 222, 164, 193, 70, 232, 16, 65, 109, 29, 251, 164, 119, 50, 205, 236, 109, 245, 234, 78, 1]

A.1.5. Encoded JWE Encrypted Key

TOC

Base64url encode the JWE Encrypted Key to produce the Encoded JWE Encrypted Key. This result (with line breaks for display purposes only) is:

```
M2XxpbORKezKSzzQL_95-GjiudRBTqn_omS8z9xgoRb7L0Jw5UsEbxmtyHn2T71m
rZLkjg4Mp8gbhYoltPkEOHvAopz25-vZ8C2e1cOaAo5WPcbSIuFcB4DjBOM3t0UA
O6JHkWLuAEYoe58lcxIQneyKdaYSLbV9cKqoUoFQpvKWYRHZbfszIyfsa18rmgTj
zrtLDTPnc09DSJE24aQ8w3i8RXEDthW9T1J6LsTH_vwHdwUgkI-tC2PNeGrnM-dN
SfzF3Y7-lwcGy0FsdXkPXytvDV7y4pZeeUiQ-0VdibIN2AjjfW60nfrPuOjepMFG
6BBBbR37pHcyzext9epOAQ
```

TOC

A.1.6. Initialization Vector

TOC

Generate a random 96 bit JWE Initialization Vector. In this example, the value is:

[227, 197, 117, 252, 2, 219, 233, 68, 180, 225, 77, 219]

Base64url encoding this value yields the Encoded JWE Initialization Vector value:

```
48V1_ALb6US04U3b
```

A.1.7. "Additional Authenticated Data" Parameter

TOC

Concatenate the Encoded JWE Header value, a period character ('.'), the Encoded JWE Encrypted Key, a second period character ('.'), and the Encoded JWE Initialization Vector to create the "additional authenticated data" parameter for the AES GCM algorithm. This result (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0EtT0FFUCIsImVuYyI6IkEyNTZHQ00ifQ.
M2XxpbORKezKSzzQL_95-GjiudRBTqn_omS8z9xgoRb7L0Jw5UsEbxmtyHn2T71m
rZLkjg4Mp8gbhYoltPkEOHvAopz25-vZ8C2e1cOaAo5WPcbSIuFcB4DjBOM3t0UA
O6JHkWLuAEYoe58lcxIQneyKdaYSLbV9cKqoUoFQpvKWYRHZbfszIyfsa18rmgTj
zrtLDTPnc09DSJE24aQ8w3i8RXEDthW9T1J6LsTH_vwHdwUgkI-tC2PNeGrnM-dN
SfzF3Y7-lwcGy0FsdXkPXytvDV7y4pZeeUiQ-0VdibIN2AjjfW60nfrPuOjepMFG
6BBBbR37pHcyzext9epOAQ.
48V1_ALb6US04U3b
```

The representation of this value is:

[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 83, 85, 48, 69, 116, 84, 48, 70, 70, 85, 67, 73, 115, 73, 109, 86, 117, 89, 121, 73, 54, 73, 107, 69, 121, 78, 84, 90, 72, 81, 48, 48, 105, 102, 81, 46, 77, 50, 88, 120, 112, 98, 79, 82, 75, 101, 122, 75, 83, 122, 122, 81, 76, 95, 57, 53, 45, 71, 106, 105, 117, 100, 82, 66, 84, 113, 110, 95, 111, 109, 83, 56, 122, 57, 120, 103, 111, 82, 98, 55, 76, 48, 74, 119, 53, 85, 115, 69, 98, 120, 109, 116, 121, 72, 110, 50, 84, 55, 49, 109, 114, 90, 76, 107, 106, 103, 52, 77, 112, 56, 103, 98, 104, 89, 111, 108, 116, 80, 107, 69, 79, 72, 118, 65, 111, 112, 122, 50, 53, 45, 118, 90, 56, 67, 50, 101, 49, 99, 79, 97, 65, 111, 53, 87, 80, 99, 98, 83, 73, 117, 70, 99, 66, 52, 68, 106, 66, 79, 77, 51, 116, 48, 85, 65, 79, 54, 74, 72, 107, 87, 76, 117, 65, 69, 89, 111, 101, 53, 56, 108, 99, 120, 73, 81, 110, 101, 121, 75, 100, 97, 89, 83, 76, 98, 86, 57, 99, 75, 113, 111, 85, 111, 70, 81, 112, 118, 75, 87, 89, 82, 72, 90, 98, 102, 115, 122, 73, 121, 102, 115, 97, 49, 56, 114, 109, 103, 84, 106, 122, 114, 116, 76, 68, 84, 80, 110, 99, 48, 57, 68, 83, 74, 69, 50, 52, 97, 81, 56, 119, 51, 105, 56, 82, 88, 69, 68, 116, 104, 87, 57, 84, 49, 74, 54, 76, 115, 84, 72, 95, 118, 119, 72, 100, 119, 85, 103, 107, 73, 45, 116, 67, 50, 80, 78, 101, 71, 114, 110, 77, 45, 100, 78, 83, 102, 122, 70, 51, 89, 55, 45, 108, 119, 99, 71, 121, 48, 70, 115, 100, 88, 107, 80, 88, 121, 116, 118, 68, 86, 55, 121, 52, 112, 90, 101, 101, 85, 105, 81, 45, 48, 86, 100, 105, 98, 73, 78, 50, 65, 106, 106, 102, 87, 54, 48, 110, 102, 114, 80, 117, 79, 106, 101, 112, 77, 70, 71, 54, 66, 66, 66, 98, 82, 51, 55, 112, 72, 99, 121, 122, 101, 120, 116, 57, 101, 112, 79, 65, 81, 46, 52, 56, 86, 49, 95, 65, 76, 98, 54, 85, 83, 48, 52, 85, 51, 98]

A.1.8. Plaintext Encryption

TOC

Encrypt the Plaintext with AES GCM using the CMK as the encryption key, the JWE Initialization Vector, and the "additional authenticated data" value above, requesting a 128 bit "authentication tag" output. The resulting Ciphertext is:

[253, 237, 181, 180, 97, 161, 105, 207, 233, 120, 65, 100, 45, 122, 246, 116, 195, 212, 102, 37, 36, 175]

The resulting "authentication tag" value is:

[237, 94, 89, 14, 74, 52, 191, 249, 159, 216, 240, 28, 224, 147, 34, 82]

A.1.9. Encoded JWE Ciphertext

TOC

Base64url encode the resulting Ciphertext to create the Encoded JWE Ciphertext. This result is:

```
  _e21tGGhac_peEFkLXr2dMPUZiUkrw
```

A.1.10. Encoded JWE Integrity Value

TOC

Base64url encode the resulting "authentication tag" to create the Encoded JWE Integrity Value. This result is:

```
  7V5ZDko0v_mf2PAc4JMiUg
```

A.1.11. Complete Representation

TOC

Assemble the final representation: The Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Integrity Value in that order, with the five strings being separated by four period ('.') characters.

The final result in this example (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0EtT0FFUCIsImVuYyI6IkEyNTZHQ00ifQ.
M2XxpbORKezKSzzQL_95-GjiudRBTqn_omS8z9xgoRb7L0Jw5UsEbxmtyHn2T71m
rZLkjg4Mp8gbhYoltPkEOHvAopz25-vZ8C2e1cOaAo5WPcbSIuFcB4DjBOM3t0UA
O6JHkWLuAEYoe58lcxIQneyKdaYSLbV9cKqoUoFQpvKWYRHZbfszIyfsa18rmgTj
zrtLDTPnc09DSJE24aQ8w3i8RXEDthW9T1J6LsTH_vwHdwUgkI-tC2PNeGrnM-dN
SfzF3Y7-lwcGy0FsdXkPXytvDV7y4pZeeUiQ-0VdibIN2AjjfW60nfrPuOjepMFG
6BBBbR37pHcyzext9epOAQ.
48V1_ALb6US04U3b.
_e21tGGhac_peEFkLXr2dMPUZiUkrw.
7V5ZDko0v_mf2PAc4JMiUg
```

A.1.12. Validation

TOC

This example illustrates the process of creating a JWE with an AEAD algorithm. These results can be used to validate JWE decryption implementations for these algorithms. Note that since the RSAES OAEP computation includes random values, the encryption results above will not be completely reproducible. However, since the AES GCM computation is deterministic, the JWE Encrypted Ciphertext values will be the same for all encryptions performed using these inputs.

A.2. Example JWE using RSAES-PKCS1-V1_5 and AES CBC

TOC

This example encrypts the plaintext "No matter where you go, there you are." to the recipient using RSAES-PKCS1-V1_5 and AES CBC. AES CBC does not have an integrated integrity check, so a separate integrity check calculation is performed using HMAC SHA-256, with separate encryption and integrity keys being derived from a master key using the Concat

KDF with the SHA-256 digest function. The representation of this plaintext is:

[78, 111, 32, 109, 97, 116, 116, 101, 114, 32, 119, 104, 101, 114, 101, 32, 121, 111, 117, 32, 103, 111, 44, 32, 116, 104, 101, 114, 101, 32, 121, 111, 117, 32, 97, 114, 101, 46]

A.2.1. JWE Header

TOC

The following example JWE Header (with line breaks for display purposes only) declares that:

- the Content Master Key is encrypted to the recipient using the RSAES-PKCS1-V1_5 algorithm to produce the JWE Encrypted Key and
- the Plaintext is encrypted using the AES CBC algorithm with a 128 bit key to produce the Ciphertext, with the integrity of the Ciphertext and the parameters used to create it being secured with the HMAC SHA-256 algorithm.

```
{"alg":"RSA1_5","enc":"A128CBC+HS256"}
```

A.2.2. Encoded JWE Header

TOC

Base64url encoding the bytes of the UTF-8 representation of the JWE Header yields this Encoded JWE Header value:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDK0hTMjU2In0
```

A.2.3. Content Master Key (CMK)

TOC

Generate a 256 bit random Content Master Key (CMK). In this example, the key value is:

[4, 211, 31, 197, 84, 157, 252, 254, 11, 100, 157, 250, 63, 170, 106, 206, 107, 124, 212, 45, 111, 107, 9, 219, 200, 177, 0, 240, 143, 156, 44, 207]

A.2.4. Key Encryption

TOC

Encrypt the CMK with the recipient's public key using the RSAES-PKCS1-V1_5 algorithm to produce the JWE Encrypted Key. In this example, the RSA key parameters are:

Parameter Name	Value
Modulus	[177, 119, 33, 13, 164, 30, 108, 121, 207, 136, 107, 242, 12, 224, 19, 226, 198, 134, 17, 71, 173, 75, 42, 61, 48, 162, 206, 161, 97, 108, 185, 234, 226, 219, 118, 206, 118, 5, 169, 224, 60, 181, 90, 85, 51, 123, 6, 224, 4, 122, 29, 230, 151, 12, 244, 127, 121, 25, 4, 85, 220, 144, 215, 110, 130, 17, 68, 228, 129, 138, 7, 130, 231, 40, 212, 214, 17, 179, 28, 124, 151, 178, 207, 20, 14, 154, 222, 113, 176, 24, 198, 73, 211, 113, 9, 33, 178, 80, 13, 25, 21, 25, 153, 212, 206, 67, 154, 147, 70, 194, 192, 183, 160, 83, 98, 236, 175, 85, 23, 97, 75, 199, 177, 73, 145, 50, 253, 206, 32, 179, 254, 236, 190, 82, 73, 67, 129, 253, 252, 220, 108, 136, 138, 11, 192, 1, 36, 239, 228, 55, 81, 113, 17, 25, 140, 63, 239, 146, 3, 172, 96, 60, 227, 233, 64, 255, 224, 173, 225, 228, 229, 92, 112, 72, 99, 97, 26, 87, 187, 123, 46, 50, 90, 202, 117, 73, 10, 153, 47, 224, 178, 163, 77, 48, 46, 154, 33, 148, 34, 228, 33, 172, 216, 89, 46, 225, 127, 68, 146, 234, 30, 147, 54, 146, 5, 133, 45, 78, 254, 85, 55, 75, 213, 86, 194, 218, 215, 163, 189, 194, 54, 6, 83, 36, 18, 153, 53, 7, 48, 89, 35, 66, 144, 7, 65, 154, 13, 97, 75, 55, 230, 132, 3, 13, 239, 71]
Exponent	[1, 0, 1]
	[84, 80, 150, 58, 165, 235, 242, 123, 217, 55, 38, 154, 36, 181, 221, 156, 211, 215,

Private Exponent	100, 164, 90, 88, 40, 228, 83, 148, 54, 122, 4, 16, 165, 48, 76, 194, 26, 107, 51, 53, 179, 165, 31, 18, 198, 173, 78, 61, 56, 97, 252, 158, 140, 80, 63, 25, 223, 156, 36, 203, 214, 252, 120, 67, 180, 167, 3, 82, 243, 25, 97, 214, 83, 133, 69, 16, 104, 54, 160, 200, 41, 83, 164, 187, 70, 153, 111, 234, 242, 158, 175, 28, 198, 48, 211, 45, 148, 58, 23, 62, 227, 74, 52, 117, 42, 90, 41, 249, 130, 154, 80, 119, 61, 26, 193, 40, 125, 10, 152, 174, 227, 225, 205, 32, 62, 66, 6, 163, 100, 99, 219, 19, 253, 25, 105, 80, 201, 29, 252, 157, 237, 69, 1, 80, 171, 167, 20, 196, 156, 109, 249, 88, 0, 3, 152, 38, 165, 72, 87, 6, 152, 71, 156, 214, 16, 71, 30, 82, 51, 103, 76, 218, 63, 9, 84, 163, 249, 91, 215, 44, 238, 85, 101, 240, 148, 1, 82, 224, 91, 135, 105, 127, 84, 171, 181, 152, 210, 183, 126, 24, 46, 196, 90, 173, 38, 245, 219, 186, 222, 27, 240, 212, 194, 15, 66, 135, 226, 178, 190, 52, 245, 74, 65, 224, 81, 100, 85, 25, 204, 165, 203, 187, 175, 84, 100, 82, 15, 11, 23, 202, 151, 107, 54, 41, 207, 3, 136, 229, 134, 131, 93, 139, 50, 182, 204, 93, 130, 89]

The resulting JWE Encrypted Key value is:

[102, 105, 229, 169, 104, 35, 95, 42, 176, 142, 190, 220, 92, 124, 172, 240, 94, 253, 106, 114, 20, 35, 162, 118, 81, 103, 64, 201, 20, 4, 112, 96, 84, 248, 163, 199, 177, 227, 204, 247, 93, 63, 70, 132, 195, 26, 237, 72, 91, 141, 3, 159, 71, 111, 113, 213, 68, 142, 146, 92, 60, 243, 72, 111, 53, 156, 51, 16, 226, 215, 125, 68, 141, 232, 62, 111, 197, 98, 91, 150, 23, 230, 132, 93, 97, 216, 145, 226, 3, 18, 12, 48, 119, 153, 185, 8, 156, 195, 84, 21, 63, 143, 43, 144, 174, 101, 25, 199, 7, 106, 212, 43, 151, 225, 62, 225, 122, 92, 90, 139, 45, 144, 134, 229, 15, 235, 38, 110, 132, 189, 236, 126, 92, 183, 13, 64, 2, 77, 107, 95, 186, 8, 133, 53, 217, 104, 247, 152, 241, 49, 199, 15, 111, 110, 123, 16, 13, 78, 193, 224, 23, 230, 133, 220, 162, 126, 82, 192, 236, 7, 185, 100, 106, 21, 70, 93, 192, 255, 252, 139, 61, 124, 81, 140, 113, 97, 164, 231, 131, 167, 246, 157, 199, 195, 114, 122, 49, 121, 115, 63, 114, 12, 165, 11, 186, 3, 108, 12, 199, 101, 29, 226, 80, 56, 193, 149, 45, 134, 146, 102, 221, 202, 63, 166, 150, 53, 42, 133, 3, 83, 199, 14, 15, 181, 209, 199, 174, 76, 75, 106, 254, 243, 196, 227, 225, 173, 122, 254, 13, 224, 174, 4, 185, 217, 99, 225]

A.2.5. Encoded JWE Encrypted Key

TOC

Base64url encode the JWE Encrypted Key to produce the Encoded JWE Encrypted Key. This result (with line breaks for display purposes only) is:

```
ZmnlqWgjXyqwjr7cXHys8F79anIUI6J2UWdAyRQEcGBU-KPHsePM910_RoTDGu1I
W40Dn0dvcdVEjpJcPPNIbzWcMxDi131Ejeg-b8ViW5YX5oRdYdiR4gMSDDB3mbkI
nMNUFT-PK5CuZRnHB2rUK5fhPuF6XFqLLZCG5Q_rJm6Evex-XLcNQAJNa1-6CIU1
2Wj3mPExxw9vbnsQDU7B4BfmhdyiflLA7Ae5ZGoVRl3A__yLPXxRjHFhpOeDp_ad
x8NyejF5cz9yDKULugNsDMdlHeJQOMGVLYaSZt3KP6aWNSqFA1PHDg-10ceuTEtq
_vPE4-Gtev4N4K4Eudlj4Q
```

A.2.6. Key Derivation

TOC

Use the Concat key derivation function to derive Content Encryption Key (CEK) and Content Integrity Key (CIK) values from the CMK. The details of this derivation are shown in **Appendix A.4**. The resulting CEK value is:

[203, 165, 180, 113, 62, 195, 22, 98, 91, 153, 210, 38, 112, 35, 230, 236]

The resulting CIK value is:

[218, 24, 160, 17, 160, 50, 235, 35, 216, 209, 100, 174, 155, 163, 10, 117, 180, 111, 172, 200, 127, 201, 206, 173, 40, 45, 58, 170, 35, 93, 9, 60]

A.2.7. Initialization Vector

TOC

Generate a random 128 bit JWE Initialization Vector. In this example, the value is:

[3, 22, 60, 12, 43, 67, 104, 105, 108, 108, 105, 99, 111, 116, 104, 101]

Base64url encoding this value yields the Encoded JWE Initialization Vector value:

```
AxY8DCtDaGlsbGljb3RoZQ
```

TOC

A.2.8. Plaintext Encryption

Encrypt the Plaintext with AES CBC using the CEK and the JWE Initialization Vector to produce the Ciphertext. The resulting Ciphertext is:

[71, 27, 35, 131, 163, 200, 19, 23, 38, 25, 33, 123, 46, 116, 132, 144, 58, 150, 32, 167, 192, 195, 92, 25, 207, 101, 233, 105, 181, 121, 63, 4, 44, 162, 82, 176, 17, 171, 150, 97, 147, 68, 245, 13, 97, 100, 145, 25]

TOC

A.2.9. Encoded JWE Ciphertext

Base64url encode the resulting Ciphertext to create the Encoded JWE Ciphertext. This result is:

```
RxsjG6PIExcmGSF7LnSEkDqWIKfAw1wZz2XpabV5PwQsolKwEauWYZNE9Q1hZJEZ
```

TOC

A.2.10. Secured Input Value

Concatenate the Encoded JWE Header value, a period character ('.'), the Encoded JWE Encrypted Key, a second period character, the Encoded JWE Initialization Vector, a third period ('.') character, and the Encoded JWE Ciphertext to create the value to integrity protect. This result (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDK0hTMjU2In0.
ZmnlqWgjXyqwjr7cXHys8F79anIUI6J2UWdAyRQEcGBU-KPHsePM910_RoTDGu1I
W40Dn0dvcdVEjpJcPPNIbzWcMxDi131Ejeg-b8ViW5YX5oRdYdiR4gMSDDB3mbkI
nMNUFT-PK5CuZRnHB2rUK5fhPuF6XFqLLZCG5Q_rJm6Evex-XLcNQAJNa1-6CIU1
2Wj3mPExxw9vbnsQDU7B4BfmhdyiflLA7Ae5ZGoVRl3A__yLPXxRjHFhpOeDp_ad
x8NyejF5cz9yDKULugNsDMdlHeJQOMGVLYaSZt3KP6aWNSqFA1PHDg-10ceuTEtq
_vPE4-Gtev4N4K4Eudlj4Q.
AxY8DCtDaGlsbGljb3RoZQ.
RxsjG6PIExcmGSF7LnSEkDqWIKfAw1wZz2XpabV5PwQsolKwEauWYZNE9Q1hZJEZ
```

The representation of this value is:

[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 83, 85, 48, 69, 120, 88, 122, 85, 105, 76, 67, 74, 108, 98, 109, 77, 105, 79, 105, 74, 66, 77, 84, 73, 52, 81, 48, 74, 68, 75, 48, 104, 84, 77, 106, 85, 50, 73, 110, 48, 46, 90, 109, 110, 108, 113, 87, 103, 106, 88, 121, 113, 119, 106, 114, 55, 99, 88, 72, 121, 115, 56, 70, 55, 57, 97, 110, 73, 85, 73, 54, 74, 50, 85, 87, 100, 65, 121, 82, 81, 69, 99, 71, 66, 85, 45, 75, 80, 72, 115, 101, 80, 77, 57, 49, 48, 95, 82, 111, 84, 68, 71, 117, 49, 73, 87, 52, 48, 68, 110, 48, 100, 118, 99, 100, 86, 69, 106, 112, 74, 99, 80, 80, 78, 73, 98, 122, 87, 99, 77, 120, 68, 105, 49, 51, 49, 69, 106, 101, 103, 45, 98, 56, 86, 105, 87, 53, 89, 88, 53, 111, 82, 100, 89, 100, 105, 82, 52, 103, 77, 83, 68, 68, 66, 51, 109, 98, 107, 73, 110, 77, 78, 85, 70, 84, 45, 80, 75, 53, 67, 117, 90, 82, 110, 72, 66, 50, 114, 85, 75, 53, 102, 104, 80, 117, 70, 54, 88, 70, 113, 76, 76, 90, 67, 71, 53, 81, 95, 114, 74, 109, 54, 69, 118, 101, 120, 45, 88, 76, 99, 78, 81, 65, 74, 78, 97, 49, 45, 54, 67, 73, 85, 49, 50, 87, 106, 51, 109, 80, 69, 120, 120, 119, 57, 118, 98, 110, 115, 81, 68, 85, 55, 66, 52, 66, 102, 109, 104, 100, 121, 105, 102, 108, 76, 65, 55, 65, 101, 53, 90, 71, 111, 86, 82, 108, 51, 65, 95, 95, 121, 76, 80, 88, 120, 82, 106, 72, 70, 104, 112, 79, 101, 68, 112, 95, 97, 100, 120, 56,

78, 121, 101, 106, 70, 53, 99, 122, 57, 121, 68, 75, 85, 76, 117, 103, 78, 115, 68, 77, 100, 108, 72, 101, 74, 81, 79, 77, 71, 86, 76, 89, 97, 83, 90, 116, 51, 75, 80, 54, 97, 87, 78, 83, 113, 70, 65, 49, 80, 72, 68, 103, 45, 49, 48, 99, 101, 117, 84, 69, 116, 113, 95, 118, 80, 69, 52, 45, 71, 116, 101, 118, 52, 78, 52, 75, 52, 69, 117, 100, 108, 106, 52, 81, 46, 65, 120, 89, 56, 68, 67, 116, 68, 97, 71, 108, 115, 98, 71, 108, 106, 98, 51, 82, 111, 90, 81, 46, 82, 120, 115, 106, 103, 54, 80, 73, 69, 120, 99, 109, 71, 83, 70, 55, 76, 110, 83, 69, 107, 68, 113, 87, 73, 75, 102, 65, 119, 49, 119, 90, 122, 50, 88, 112, 97, 98, 86, 53, 80, 119, 81, 115, 111, 108, 75, 119, 69, 97, 117, 87, 89, 90, 78, 69, 57, 81, 49, 104, 90, 74, 69, 90]

TOC

A.2.11. JWE Integrity Value

Compute the HMAC SHA-256 of this value using the CIK to create the JWE Integrity Value. This result is:

[240, 181, 234, 49, 221, 9, 44, 107, 49, 49, 160, 121, 186, 131, 90, 50, 152, 59, 185, 69, 191, 167, 141, 17, 149, 166, 71, 11, 3, 8, 203, 57]

TOC

A.2.12. Encoded JWE Integrity Value

Base64url encode the resulting JWE Integrity Value to create the Encoded JWE Integrity Value. This result is:

```
8LXqMd0JLGsxMaB5uoNaMpg7uUW_p40RlaZHCwMIyzk
```

TOC

A.2.13. Complete Representation

Assemble the final representation: The Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Integrity Value in that order, with the five strings being separated by four period ('.') characters.

The final result in this example (with line breaks for display purposes only) is:

```
eyJhbGciOiJSU0ExXzUiLCJlbmMiOiJBMTI4Q0JDK0hTMjU2In0.
ZmnlqWgjXyqwjr7cXHys8F79anIUI6J2UWdAyRQEcGBU-KPHsePM910_RoTDGu1I
W40Dn0dvcdVEjpJcPPNIbzWcMxDi131Ejeg-b8ViW5YX5oRdYdiR4gMSDDB3mbkI
nMNUFT-PK5CuZRnHB2rUK5fhPuF6XFqLLZCG5Q_rJm6Evex-XLcNQAJNa1-6CIU1
2Wj3mPExxw9vbnsQDU7B4BfmhdyiflLA7Ae5ZGoVRl3A__yLPXxRjHFhpOeDp_ad
x8NyejF5cz9yDKULugNsDMdlHeJQOMGVLYaSZt3KP6aWNSqFA1PHDg-10ceuTEtq
_vPE4-Gtev4N4K4Eudlj4Q.
AxY8DCtDaGlsbGljb3RoZQ.
Rxsjg6PIExcmGSF7LnSEkDqWIKfAw1wZz2XpabV5PwQsolKwEauWYZNE9Q1hZJEZ.
8LXqMd0JLGsxMaB5uoNaMpg7uUW_p40RlaZHCwMIyzk
```

TOC

A.2.14. Validation

This example illustrates the process of creating a JWE with a composite AEAD algorithm created from a non-AEAD algorithm by adding a separate integrity check calculation. These results can be used to validate JWE decryption implementations for these algorithms. Note that since the RSAES-PKCS1-V1_5 computation includes random values, the encryption results above will not be completely reproducible. However, since the AES CBC computation is deterministic, the JWE Encrypted Ciphertext values will be the same for all encryptions performed using these inputs.

A.3. Example JWE using AES Key Wrap and AES GCM

TOC

This example encrypts the plaintext "The true sign of intelligence is not knowledge but imagination." to the recipient using AES Key Wrap and AES GCM. The representation of this plaintext is:

[84, 104, 101, 32, 116, 114, 117, 101, 32, 115, 105, 103, 110, 32, 111, 102, 32, 105, 110, 116, 101, 108, 108, 105, 103, 101, 110, 99, 101, 32, 105, 115, 32, 110, 111, 116, 32, 107, 110, 111, 119, 108, 101, 100, 103, 101, 32, 98, 117, 116, 32, 105, 109, 97, 103, 105, 110, 97, 116, 105, 111, 110, 46]

A.3.1. JWE Header

TOC

The following example JWE Header declares that:

- the Content Master Key is encrypted to the recipient using the AES Key Wrap algorithm with a 128 bit key to produce the JWE Encrypted Key and
- the Plaintext is encrypted using the AES GCM algorithm with a 128 bit key to produce the Ciphertext.

```
{"alg":"A128KW","enc":"A128GCM"}
```

A.3.2. Encoded JWE Header

TOC

Base64url encoding the bytes of the UTF-8 representation of the JWE Header yields this Encoded JWE Header value:

```
eyJhbGciOiJBMTI4S1ciLCJlbmMiOiJBMTI4R0NNIn0
```

A.3.3. Content Master Key (CMK)

TOC

Generate a 128 bit random Content Master Key (CMK). In this example, the value is:

[64, 154, 239, 170, 64, 40, 195, 99, 19, 84, 192, 142, 192, 238, 207, 217]

A.3.4. Key Encryption

TOC

Encrypt the CMK with the shared symmetric key using the AES Key Wrap algorithm to produce the JWE Encrypted Key. In this example, the shared symmetric key value is:

[25, 172, 32, 130, 225, 114, 26, 181, 138, 106, 254, 192, 95, 133, 74, 82]

The resulting JWE Encrypted Key value is:

[164, 255, 251, 1, 64, 200, 65, 200, 34, 197, 81, 143, 43, 211, 240, 38, 191, 161, 181, 117, 119, 68, 44, 80]

A.3.5. Encoded JWE Encrypted Key

TOC

Base64url encode the JWE Encrypted Key to produce the Encoded JWE Encrypted Key. This result is:

```
pP_7AUDIQcgixVGPK9PwJr-htXV3RCxQ
```

A.3.6. Initialization Vector

TOC

Generate a random 96 bit JWE Initialization Vector. In this example, the value is:

[253, 220, 80, 25, 166, 152, 178, 168, 97, 99, 67, 89]

Base64url encoding this value yields the Encoded JWE Initialization Vector value:

```
_dxQGaaYsqhhY0NZ
```

A.3.7. "Additional Authenticated Data" Parameter

TOC

Concatenate the Encoded JWE Header value, a period character ('.'), the Encoded JWE Encrypted Key, a second period character ('.'), and the Encoded JWE Initialization Vector to create the "additional authenticated data" parameter for the AES GCM algorithm. This result (with line breaks for display purposes only) is:

```
eyJhbGciOiJBMTI4S1ciLCJlbmMiOiJBMTI4R0NNIn0.
pP_7AUDIQcgixVGPK9PwJr-htXV3RCxQ.
_dxQGaaYsqhhY0NZ
```

The representation of this value is:

[101, 121, 74, 104, 98, 71, 99, 105, 79, 105, 74, 66, 77, 84, 73, 52, 83, 49, 99, 105, 76, 67, 74, 108, 98, 109, 77, 105, 79, 105, 74, 66, 77, 84, 73, 52, 82, 48, 78, 78, 73, 110, 48, 46, 112, 80, 95, 55, 65, 85, 68, 73, 81, 99, 103, 105, 120, 86, 71, 80, 75, 57, 80, 119, 74, 114, 45, 104, 116, 88, 86, 51, 82, 67, 120, 81, 46, 95, 100, 120, 81, 71, 97, 97, 89, 115, 113, 104, 104, 89, 48, 78, 90]

A.3.8. Plaintext Encryption

TOC

Encrypt the Plaintext with AES GCM using the CMK as the encryption key, the JWE Initialization Vector, and the "additional authenticated data" value above, requesting a 128 bit "authentication tag" output. The resulting Ciphertext is:

[227, 12, 89, 132, 185, 16, 248, 93, 145, 87, 53, 130, 95, 115, 62, 104, 138, 96, 109, 71, 124, 211, 165, 103, 202, 99, 21, 193, 4, 226, 84, 229, 254, 106, 144, 241, 39, 86, 148, 132, 160, 104, 88, 232, 228, 109, 85, 7, 86, 80, 134, 106, 166, 24, 92, 199, 210, 188, 153, 187, 218, 69, 227]

The resulting "authentication tag" value is:

[154, 35, 80, 107, 37, 148, 81, 6, 103, 4, 60, 206, 171, 165, 113, 67]

A.3.9. Encoded JWE Ciphertext

TOC

Base64url encode the resulting Ciphertext to create the Encoded JWE Ciphertext. This result (with line breaks for display purposes only) is:

```
4wxZhLkQ-F2RVzWCX3M-aIpgbUd806VnymMVwQTiVOX-apDxJ1aUhKBoWOjkbVUH
VlCGaqYYXMfSvJm72kXj
```

TOC

A.3.10. Encoded JWE Integrity Value

Base64url encode the resulting "authentication tag" to create the Encoded JWE Integrity Value. This result is:

```
miNQayWUUQZnBDzOq6VxQw
```

TOC

A.3.11. Complete Representation

Assemble the final representation: The Compact Serialization of this result is the concatenation of the Encoded JWE Header, the Encoded JWE Encrypted Key, the Encoded JWE Initialization Vector, the Encoded JWE Ciphertext, and the Encoded JWE Integrity Value in that order, with the five strings being separated by four period ('.') characters.

The final result in this example (with line breaks for display purposes only) is:

```
eyJhbGciOiJBMTI4S1ciLCJlbmMiOiJBMTI4R0NNIn0.
pP_7AUDIQcgixVGPK9PwJr-htXV3RCxQ.
_dxQGaaYsqhhY0NZ.
4wxZhLkQ-F2RVzWCX3M-aIpgbUd806VnymMVwQTiVOX-apDxJ1aUhKBoWOjkbVUH
VlCGaqYYXMfSvJm72kXj.
miNQayWUUQZnBDzOq6VxQw
```

TOC

A.3.12. Validation

This example illustrates the process of creating a JWE with symmetric key wrap and an AEAD algorithm. These results can be used to validate JWE decryption implementations for these algorithms. Also, since both the AES Key Wrap and AES GCM computations are deterministic, the resulting JWE value will be the same for all encryptions performed using these inputs. Since the computation is reproducible, these results can also be used to validate JWE encryption implementations for these algorithms.

TOC

A.4. Example Key Derivation for "enc" value "A128CBC+HS256"

This example uses the Concat KDF to derive the Content Encryption Key (CEK) and Content Integrity Key (CIK) from the Content Master Key (CMK) in the manner described in Section 4.8.1 of **[JWA]**. In this example, a 256 bit CMK is used to derive a 128 bit CEK and a 256 bit CIK.

The CMK value used is:

[4, 211, 31, 197, 84, 157, 252, 254, 11, 100, 157, 250, 63, 170, 106, 206, 107, 124, 212, 45, 111, 107, 9, 219, 200, 177, 0, 240, 143, 156, 44, 207]

TOC

A.4.1. CEK Generation

These values are concatenated to produce the round 1 hash input:

- the round number 1 as a 32 bit big endian integer ([0, 0, 0, 1]),

- the CMK value (as above),
- the output bit size 128 as a 32 bit big endian number ([0, 0, 0, 128]),
- the bytes of the UTF-8 representation of the enc value A128CBC+HS256 -- [65, 49, 50, 56, 67, 66, 67, 43, 72, 83, 50, 53, 54],
- the Datalen value of zero for the omitted epu (encryption PartyUInfo) value ([0, 0, 0, 0]),
- the Datalen value of zero for the omitted epv (encryption PartyVInfo) value ([0, 0, 0, 0]),
- the bytes of the ASCII representation of the label "Encryption" -- [69, 110, 99, 114, 121, 112, 116, 105, 111, 110].

Thus the round 1 hash input is:

[0, 0, 0, 1, 4, 211, 31, 197, 84, 157, 252, 254, 11, 100, 157, 250, 63, 170, 106, 206, 107, 124, 212, 45, 111, 107, 9, 219, 200, 177, 0, 240, 143, 156, 44, 207, 0, 0, 0, 128, 65, 49, 50, 56, 67, 66, 67, 43, 72, 83, 50, 53, 54, 0, 0, 0, 0, 0, 0, 0, 0, 69, 110, 99, 114, 121, 112, 116, 105, 111, 110]

The SHA-256 hash of this value, which is the round 1 hash output, is:

[203, 165, 180, 113, 62, 195, 22, 98, 91, 153, 210, 38, 112, 35, 230, 236, 181, 193, 129, 233, 251, 107, 70, 80, 36, 150, 216, 251, 182, 29, 104, 150]

Given that 128 bits are needed for the CEK and the hash has produced 256 bits, the CEK value is the first 128 bits of that value:

[203, 165, 180, 113, 62, 195, 22, 98, 91, 153, 210, 38, 112, 35, 230, 236]

A.4.2. CIK Generation

TOC

These values are concatenated to produce the round 1 hash input:

- the round number 1 as a 32 bit big endian integer ([0, 0, 0, 1]),
- the CMK value (as above),
- the output bit size 256 as a 32 bit big endian number ([0, 0, 1, 0]),
- the bytes of the UTF-8 representation of the enc value A128CBC+HS256 -- [65, 49, 50, 56, 67, 66, 67, 43, 72, 83, 50, 53, 54],
- the Datalen value of zero for the omitted epu (encryption PartyUInfo) value ([0, 0, 0, 0]),
- the Datalen value of zero for the omitted epv (encryption PartyVInfo) value ([0, 0, 0, 0]),
- the bytes of the ASCII representation of the label "Integrity" -- [73, 110, 116, 101, 103, 114, 105, 116, 121].

Thus the round 1 hash input is:

[0, 0, 0, 1, 4, 211, 31, 197, 84, 157, 252, 254, 11, 100, 157, 250, 63, 170, 106, 206, 107, 124, 212, 45, 111, 107, 9, 219, 200, 177, 0, 240, 143, 156, 44, 207, 0, 0, 1, 0, 65, 49, 50, 56, 67, 66, 67, 43, 72, 83, 50, 53, 54, 0, 0, 0, 0, 0, 0, 0, 0, 73, 110, 116, 101, 103, 114, 105, 116, 121]

The SHA-256 hash of this value, which is the round 1 hash output, is:

[218, 24, 160, 17, 160, 50, 235, 35, 216, 209, 100, 174, 155, 163, 10, 117, 180, 111, 172, 200, 127, 201, 206, 173, 40, 45, 58, 170, 35, 93, 9, 60]

Given that 256 bits are needed for the CIK and the hash has produced 256 bits, the CIK value is that same value:

[218, 24, 160, 17, 160, 50, 235, 35, 216, 209, 100, 174, 155, 163, 10, 117, 180, 111, 172, 200, 127, 201, 206, 173, 40, 45, 58, 170, 35, 93, 9, 60]

A.5. Example Key Derivation for "enc" value "A256CBC+HS512"

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This example uses the Concat KDF to derive the Content Encryption Key (CEK) and Content Integrity Key (CIK) from the Content Master Key (CMK) in the manner described in Section 4.8.1 of **[JWA]**. In this example, a 512 bit CMK is used to derive a 256 bit CEK and a 512 bit CIK.

The CMK value used is:

[148, 116, 199, 126, 2, 117, 233, 76, 150, 149, 89, 193, 61, 34, 239, 226, 109, 71, 59, 160, 192, 140, 150, 235, 106, 204, 49, 176, 68, 119, 13, 34, 49, 19, 41, 69, 5, 20, 252, 145, 104, 129, 137, 138, 67, 23, 153, 83, 81, 234, 82, 247, 48, 211, 41, 130, 35, 124, 45, 156, 249, 7, 225, 168]

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A.5.1. CEK Generation

These values are concatenated to produce the round 1 hash input:

- the round number 1 as a 32 bit big endian integer ([0, 0, 0, 1]),
- the CMK value (as above),
- the output bit size 256 as a 32 bit big endian number ([0, 0, 1, 0]),
- the bytes of the UTF-8 representation of the `enc` value `A256CBC+HS512` -- [65, 50, 53, 54, 67, 66, 67, 43, 72, 83, 53, 49, 50],
- the Datalen value of zero for the omitted `epu` (encryption PartyUInfo) value ([0, 0, 0, 0]),
- the Datalen value of zero for the omitted `epv` (encryption PartyVInfo) value ([0, 0, 0, 0]),
- the bytes of the ASCII representation of the label "Encryption" -- [69, 110, 99, 114, 121, 112, 116, 105, 111, 110].

Thus the round 1 hash input is:

[0, 0, 0, 1, 148, 116, 199, 126, 2, 117, 233, 76, 150, 149, 89, 193, 61, 34, 239, 226, 109, 71, 59, 160, 192, 140, 150, 235, 106, 204, 49, 176, 68, 119, 13, 34, 49, 19, 41, 69, 5, 20, 252, 145, 104, 129, 137, 138, 67, 23, 153, 83, 81, 234, 82, 247, 48, 211, 41, 130, 35, 124, 45, 156, 249, 7, 225, 168, 0, 0, 1, 0, 65, 50, 53, 54, 67, 66, 67, 43, 72, 83, 53, 49, 50, 0, 0, 0, 0, 0, 0, 0, 0, 69, 110, 99, 114, 121, 112, 116, 105, 111, 110]

The SHA-512 hash of this value, which is the round 1 hash output, is:

[157, 19, 75, 205, 31, 190, 110, 46, 117, 217, 137, 19, 116, 166, 126, 60, 18, 244, 226, 114, 38, 153, 78, 198, 26, 0, 181, 168, 113, 45, 149, 89, 107, 213, 109, 183, 207, 164, 86, 131, 51, 105, 214, 29, 229, 32, 243, 46, 40, 53, 123, 4, 13, 7, 250, 48, 227, 207, 167, 211, 147, 91, 0, 171]

Given that 256 bits are needed for the CEK and the hash has produced 512 bits, the CEK value is the first 256 bits of that value:

[157, 19, 75, 205, 31, 190, 110, 46, 117, 217, 137, 19, 116, 166, 126, 60, 18, 244, 226, 114, 38, 153, 78, 198, 26, 0, 181, 168, 113, 45, 149, 89]

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A.5.2. CIK Generation

These values are concatenated to produce the round 1 hash input:

- the round number 1 as a 32 bit big endian integer ([0, 0, 0, 1]),
- the CMK value (as above),
- the output bit size 512 as a 32 bit big endian number ([0, 0, 2, 0]),
- the bytes of the UTF-8 representation of the `enc` value `A256CBC+HS512` -- [65, 50, 53, 54, 67, 66, 67, 43, 72, 83, 53, 49, 50],
- the Datalen value of zero for the omitted `epu` (encryption PartyUInfo) value ([0, 0, 0, 0]),
- the Datalen value of zero for the omitted `epv` (encryption PartyVInfo) value ([0, 0, 0, 0]),
- the bytes of the ASCII representation of the label "Integrity" -- [73, 110, 116, 101,

103, 114, 105, 116, 121].

Thus the round 1 hash input is:

[0, 0, 0, 1, 148, 116, 199, 126, 2, 117, 233, 76, 150, 149, 89, 193, 61, 34, 239, 226, 109, 71, 59, 160, 192, 140, 150, 235, 106, 204, 49, 176, 68, 119, 13, 34, 49, 19, 41, 69, 5, 20, 252, 145, 104, 129, 137, 138, 67, 23, 153, 83, 81, 234, 82, 247, 48, 211, 41, 130, 35, 124, 45, 156, 249, 7, 225, 168, 0, 0, 2, 0, 65, 50, 53, 54, 67, 66, 67, 43, 72, 83, 53, 49, 50, 0, 0, 0, 0, 0, 0, 0, 0, 73, 110, 116, 101, 103, 114, 105, 116, 121]

The SHA-512 hash of this value, which is the round 1 hash output, is:

[81, 249, 131, 194, 25, 166, 147, 155, 47, 249, 146, 160, 200, 236, 115, 72, 103, 248, 228, 30, 130, 225, 164, 61, 105, 172, 198, 31, 137, 170, 215, 141, 27, 247, 73, 236, 125, 113, 151, 33, 0, 251, 72, 53, 72, 63, 146, 117, 247, 13, 49, 20, 210, 169, 232, 156, 118, 1, 16, 45, 29, 21, 15, 208]

Given that 512 bits are needed for the CIK and the hash has produced 512 bits, the CIK value is that same value:

[81, 249, 131, 194, 25, 166, 147, 155, 47, 249, 146, 160, 200, 236, 115, 72, 103, 248, 228, 30, 130, 225, 164, 61, 105, 172, 198, 31, 137, 170, 215, 141, 27, 247, 73, 236, 125, 113, 151, 33, 0, 251, 72, 53, 72, 63, 146, 117, 247, 13, 49, 20, 210, 169, 232, 156, 118, 1, 16, 45, 29, 21, 15, 208]

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Appendix B. Acknowledgements

Solutions for encrypting JSON content were also explored by **JSON Simple Encryption** [JSE] and **JavaScript Message Security Format** [I-D.rescorla-jsms], both of which significantly influenced this draft. This draft attempts to explicitly reuse as many of the relevant concepts from **XML Encryption 1.1** [W3C.CR-xmlenc-core1-20120313] and **RFC 5652** [RFC5652] as possible, while utilizing simple compact JSON-based data structures.

Special thanks are due to John Bradley and Nat Sakimura for the discussions that helped inform the content of this specification and to Eric Rescorla and Joe Hildebrand for allowing the reuse of text from **[I-D.rescorla-jsms]** in this document.

Thanks to Axel Nennker, Emmanuel Raviart, Brian Campbell, and Edmund Jay for validating the examples in this specification.

Jim Schaad and Karen O'Donoghue chaired the JOSE working group and Sean Turner and Stephen Farrell served as Security area directors during the creation of this specification.

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Appendix C. Open Issues

[[to be removed by the RFC editor before publication as an RFC]]

The following items remain to be considered or done in this draft:

- Should we define optional nonce, timestamp, and/or uninterpreted string header parameter(s)?

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Appendix D. Document History

[[to be removed by the RFC editor before publication as an RFC]]

-07

- Added a data length prefix to PartyUInfo and PartyVInfo values.
- Updated values for example AES CBC calculations.
- Made several local editorial changes to clean up loose ends left over from to the

decision to only support block encryption methods providing integrity. One of these changes was to explicitly state that the `enc` (encryption method) algorithm must be an AEAD algorithm with a specified key length.

-06

- Removed the `int` and `kdf` parameters and defined the new composite AEAD algorithms `A128CBC+HS256` and `A256CBC+HS512` to replace the former uses of AES CBC, which required the use of separate integrity and key derivation functions.
- Included additional values in the Concat KDF calculation -- the desired output size and the algorithm value, and optionally PartyUInfo and PartyVInfo values. Added the optional header parameters `apu` (agreement PartyUInfo), `apv` (agreement PartyVInfo), `epu` (encryption PartyUInfo), and `epv` (encryption PartyVInfo). Updated the KDF examples accordingly.
- Promoted Initialization Vector from being a header parameter to being a top-level JWE element. This saves approximately 16 bytes in the compact serialization, which is a significant savings for some use cases. Promoting the Initialization Vector out of the header also avoids repeating this shared value in the JSON serialization.
- Changed `x5c` (X.509 Certificate Chain) representation from being a single string to being an array of strings, each containing a single base64 encoded DER certificate value, representing elements of the certificate chain.
- Added an AES Key Wrap example.
- Reordered the encryption steps so CMK creation is first, when required.
- Correct statements in examples about which algorithms produce reproducible results.

-05

- Support both direct encryption using a shared or agreed upon symmetric key, and the use of a shared or agreed upon symmetric key to key wrap the CMK.
- Added statement that "StringOrURI values are compared as case-sensitive strings with no transformations or canonicalizations applied".
- Updated open issues.
- Indented artwork elements to better distinguish them from the body text.

-04

- Refer to the registries as the primary sources of defined values and then secondarily reference the sections defining the initial contents of the registries.
- Normatively reference **XML Encryption 1.1** [W3C.CR-xmlenc-core1-20120313] for its security considerations.
- Reference draft-jones-jose-jwe-json-serialization instead of draft-jones-json-web-encryption-json-serialization.
- Described additional open issues.
- Applied editorial suggestions.

-03

- Added the `kdf` (key derivation function) header parameter to provide crypto agility for key derivation. The default KDF remains the Concat KDF with the SHA-256 digest function.
- Reordered encryption steps so that the Encoded JWE Header is always created before it is needed as an input to the AEAD "additional authenticated data" parameter.
- Added the `cty` (content type) header parameter for declaring type information about the secured content, as opposed to the `typ` (type) header parameter, which declares type information about this object.
- Moved description of how to determine whether a header is for a JWS or a JWE from the JWT spec to the JWE spec.
- Added complete encryption examples for both AEAD and non-AEAD algorithms.
- Added complete key derivation examples.
- Added "Collision Resistant Namespace" to the terminology section.
- Reference ITU.X690.1994 for DER encoding.
- Added Registry Contents sections to populate registry values.
- Numerous editorial improvements.

-02

- When using AEAD algorithms (such as AES GCM), use the "additional authenticated data" parameter to provide integrity for the header, encrypted key, and ciphertext and use the resulting "authentication tag" value as the JWE Integrity Value.
- Defined KDF output key sizes.
- Generalized text to allow key agreement to be employed as an alternative to key wrapping or key encryption.
- Changed compression algorithm from gzip to DEFLATE.
- Clarified that it is an error when a `kid` value is included and no matching key is found.
- Clarified that JWEs with duplicate Header Parameter Names MUST be rejected.
- Clarified the relationship between `typ` header parameter values and MIME types.
- Registered application/jwe MIME type and "JWE" typ header parameter value.
- Simplified JWK terminology to get replace the "JWK Key Object" and "JWK Container Object" terms with simply "JSON Web Key (JWK)" and "JSON Web Key Set (JWK Set)" and to eliminate potential confusion between single keys and sets of keys. As part of this change, the header parameter name for a public key value was changed from `jpk` (JSON Public Key) to `jwk` (JSON Web Key).
- Added suggestion on defining additional header parameters such as `x5t#S256` in the future for certificate thumbprints using hash algorithms other than SHA-1.
- Specify RFC 2818 server identity validation, rather than RFC 6125 (paralleling the same decision in the OAuth specs).
- Generalized language to refer to Message Authentication Codes (MACs) rather than Hash-based Message Authentication Codes (HMACs) unless in a context specific to HMAC algorithms.
- Reformatted to give each header parameter its own section heading.

-01

- Added an integrity check for non-AEAD algorithms.
- Added `jpk` and `x5c` header parameters for including JWK public keys and X.509 certificate chains directly in the header.
- Clarified that this specification is defining the JWE Compact Serialization. Referenced the new JWE-JS spec, which defines the JWE JSON Serialization.
- Added text "New header parameters should be introduced sparingly since an implementation that does not understand a parameter MUST reject the JWE".
- Clarified that the order of the encryption and decryption steps is not significant in cases where there are no dependencies between the inputs and outputs of the steps.
- Made other editorial improvements suggested by JOSE working group participants.

-00

- Created the initial IETF draft based upon draft-jones-json-web-encryption-02 with no normative changes.
- Changed terminology to no longer call both digital signatures and HMACs "signatures".

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