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# 3MF Secure Content Extension

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## Specification & Reference Guide

**Version**    **0.86**

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**Status**     Draft

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## Preface

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### About this Specification

This 3MF Secure Content Extension is an extension to the core 3MF specification. This document cannot stand alone and only applies as an addendum to the core 3MF specification. Usage of this and any other 3MF extensions follow an a la carte model, defined in the core 3MF specification.

Part I, "3MF Documents," presents the details of the primarily XML-based 3MF Document format. This section describes the XML markup that defines the composition of 3D documents and the appearance of each model

within the document.

Part II, "Appendixes," contains additional technical details and schemas too extensive to include in the main body of the text as well as convenient reference information.

The information contained in this specification is subject to change. Every effort has been made to ensure its accuracy at the time of publication.

This extension **MUST** be used only with Core specification 1.x.

## Document Conventions

See [the 3MF Core Specification conventions](#).

## Language Notes

See [the 3MF Core Specification language notes](#).

## Software Conformance

See [the 3MF Core Specification software conformance](#).

# Part I: 3MF Documents

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## Chapter 1. Introduction

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This document describes a new Open Packaging Conventions (OPC) root part for securely protecting resources within a 3MF package. If not explicitly stated otherwise, each of these resources is **OPTIONAL** for producers, but **MUST** be supported by consumers that specify support for the 3MF Secure Content Extension.

This extension describes the encryption mechanism to protect the 3MF content files (OPC parts), and it should be used in coordination with other 3MF extensions that refer to content stored in different OPC parts: models, textures, etc.

In order to allow for the use of 3MF in highly secure printing environments, several additions are needed to efficiently support confidentiality of specific content in the 3MF package, providing a 3MF producer with the capability to control which consumers have access to the confidential content.

A consumer not supporting the 3MF Secure Content Extension **MAY** be able to consume the 3MF with this extension. For this purpose, the 3MF Secure Content Extension **MAY** contain alternative representation of confidential contents (See [the 3MF Production Extension](#), e.g. low-resolution information, bounding box, obfuscated model, etc., so the consumer could perform some basic tasks. For example, a consumer not supporting the current extension, should be able to render a low resolution preview or pack models in the build, without requiring access to secured content.

In order to avoid data loss while parsing, a 3MF package which uses referenced objects **MUST** enlist the Secure Content Extension as "required extension", as defined in the core specification. However, if the Secure Content Extension is not enlisted as required, any consumer which does not support the Secure Content Extension will be able to access the alternative non-confidential representation of confidential models.

A consumer that is authorized to un-protect content by reversing the above steps MUST NOT re-save the content or enable the user to save the content in an unprotected fashion (regardless of file format) without the approval (written or programmatic) of the protection authority (which might or might not be the producer).

## 1.1 Encryption scheme

The encryption model used is a 'two-level' Key Encryption Key - Data Encryption Key (KEK-DEK) model:

- Each confidential resource is encrypted using an efficient symmetric Data Encryption Method, with a randomly generated symmetric Data Encryption Key (DEK). There may be several resources in a 3MF package that requires confidentiality, so different DEKs MUST be provided for each one of them. Consumers MUST support, at a minimum the AES256 GCM (Gaulois Counter Mode).
- The DEK for each one of the confidential resources may be encrypted with one or several Key Encryption Keys (KEK), using Key Encryption Methods that ensure that only the intended consumers can decrypt and use the DEK. This means that the consumers must have an RSA2048 asymmetric private decryption key, and the corresponding public key must be made available to the producer to encrypt the DEK. Consumer MUST support, at a minimum, the asymmetric RSA2048 OAEP Key Encryption Method.
- There could be several consumers for the same 3MF file and at the same time some consumers might have more than a pair of public and private keys, e.g. for different job types. To provide simultaneous access to all authorized parties, the DEK for a confidential resource may be encrypted several times, one for each different potential consumer.

The KEK-DEK model provides efficiency because the (probably large) data in a confidential resource is encrypted/decrypted only once using an efficient symmetric encryption algorithm and KEK approach provides flexibility in controlling who can access the confidential data, by allowing encrypting the DEK with different KEKs.

The mechanism for storing the DEK in the 3MF is optional. It provides a mean to communicate the DEK for each part. However the DEKs might be transferred to the consumer by any other mean, externally to the 3MF file.

## 1.2 Parts Relationships

The primary emphasis of this extension is the possibility to protect OPC parts separated from the root model file. This structural approach enables two primary advantages for producers and consumers of 3MF packages with large numbers of individual models:

- The build directive in the root model file can be parsed by consumers without having to parse any encrypted file.
- Key Store in a separate file to be able to link to any content file, except the root model part.

When used in conjunction with the 3MF Production extension version 1.2 or above, the root model part MAY have relationships to other model parts whose resources can be referenced by the parent model stream by their file path. When any of those file paths is found in the keystore, it is identified as an encrypted OPC part.

Other content files defined in other 3MF extensions might be also encrypted, when identified by their file paths in the keystore. For example, color textures as defined in the 3MF materials and properties extension, etc.

Only non-root OPC parts MAY be encrypted. Root OPC parts and parts relationships MUST not be encrypted to be compliant with OPC.

## 1.3 Package Organization and OPC Compliance

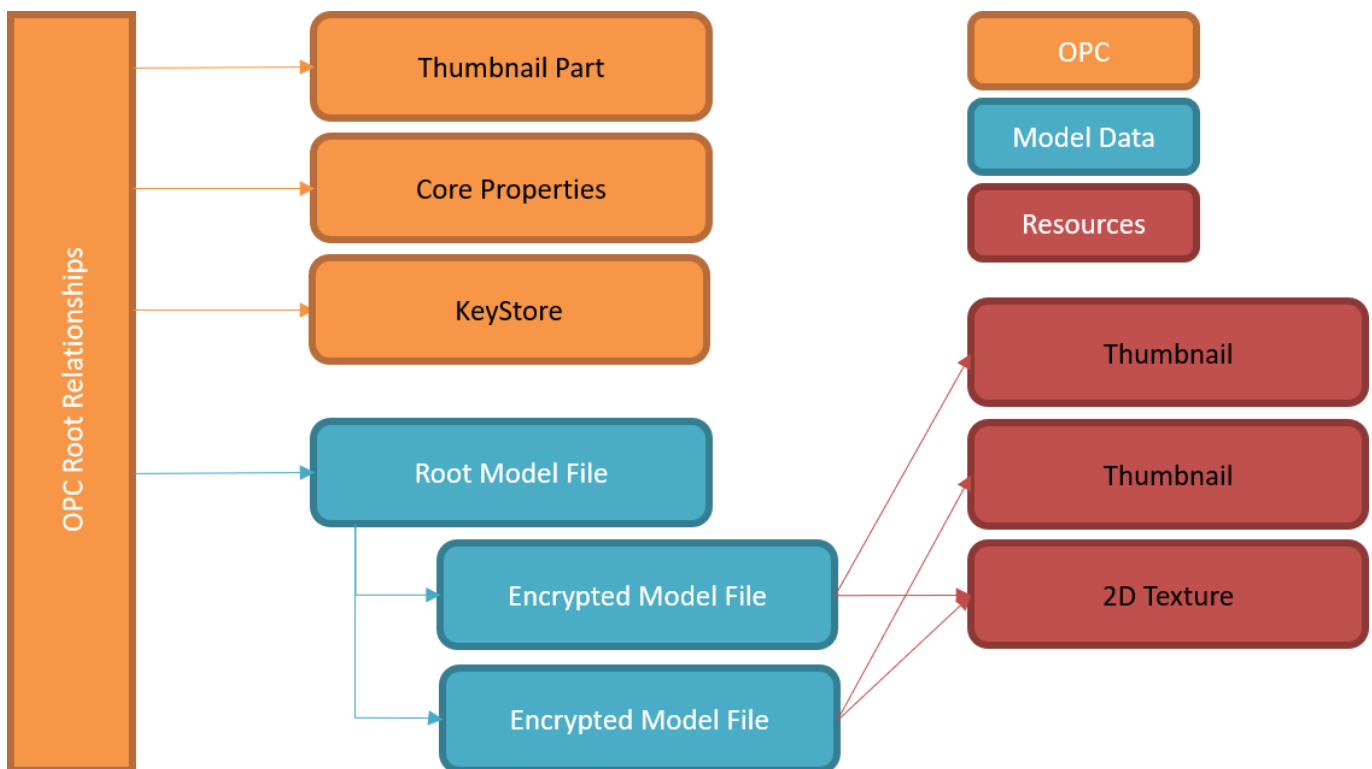
A new 3MF resource, the KeyStore, is defined to support content encryption. The KeyStore stores the encryption information for the different confidential resources in the package.

For each confidential resource, the KeyStore contains:

- Information on how the content is encrypted: the Data Encryption Method, and other information relevant to enable content decryption. For the only currently supported Data Encryption Method, the additional information is the initialization vector (IV) and tag required for decryption in the AES256 GCM Method.
- One DEK encrypted using a KEKs, with the corresponding information about the Key Encryption Method used, for each one of the consumers authorized to access confidential content.

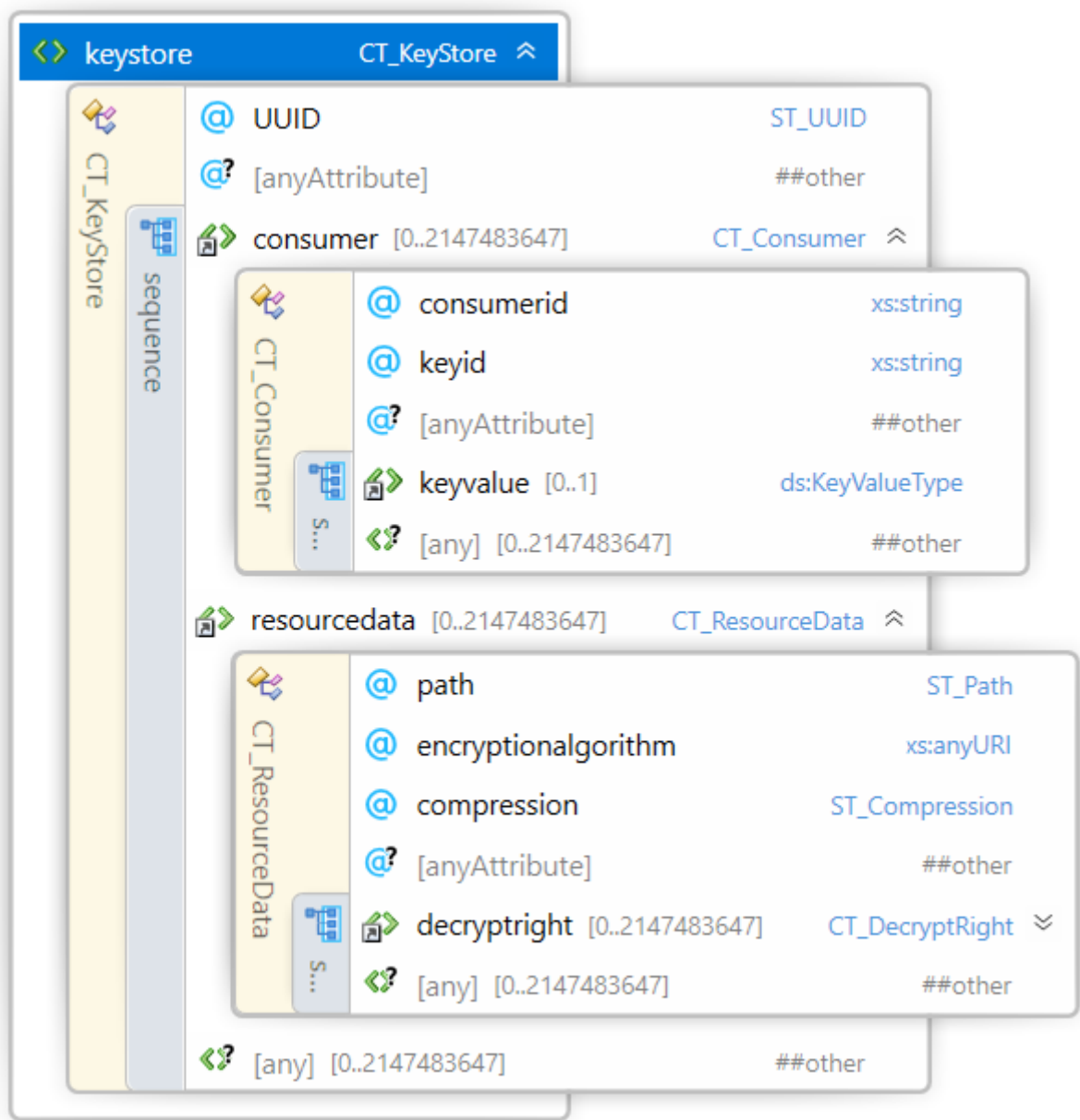
A consumer supporting the 3MF Secure Content Extension MUST support, at a minimum, the RSA2048 OAEP Key Encryption Algorithm.

**Figure 1–1. A typical 3MF Secure Content Document with multiple encrypted model streams**



## Chapter 2. Key Store

Element <keystore>



Name	Type	Use	Default	Annotation
uuid	ST_UUID	required		A universally unique ID that allows the Key Store to be identified.

@anyAttribute

The Key Store part consists of a <keystore> element that encapsulates encryption key data and references to the encrypted content.

The <keystore> element contains a set of <consumer> elements and <resourcedata> elements. Each <consumer> element contains the information to identify a consumer key and each <resourcedata> references the encrypted content and includes the information to be able to decrypt it, such as the encryption algorithm used and the data encryption key, encrypted with the key encryption key of each consumer.

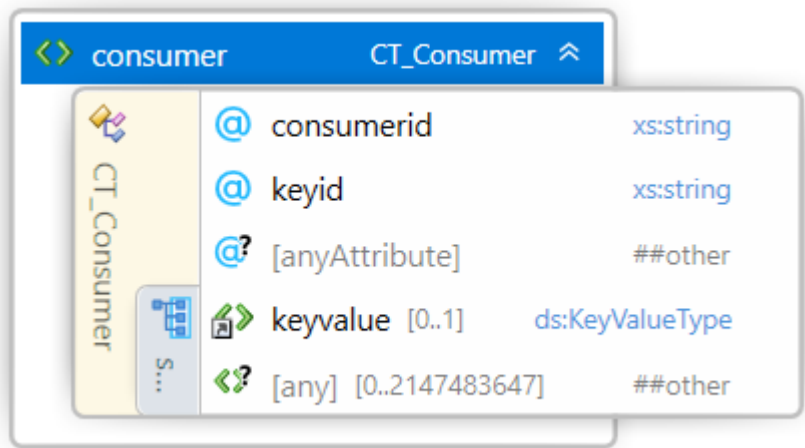
**uuid** - The KeyStore universal unique ID that allows the Key Store to be identified over time and across physical and across applications and printers.

When an editor modifies the Key Store, it MUST produce a new uuid to univocally identify the new keystore content.

**Note:** "Unique identifier" MUST be any of the four UUID variants described in IETF RFC 4122, which includes Microsoft GUIDs as well as time-based UUIDs.

## 2.1 Consumer

Element **<consumer>**



Name	Type	Use	Default	Annotation
consumerid	string	required		ID of the target consumer.
keyid	string			Optional key identifier.

@anyAttribute

The <consumer> element under a <keystore> element contains the target consumer specific information. When a <keystore> element constains more than one consumer it means that there is more than a single recipient that could decrypt the content.

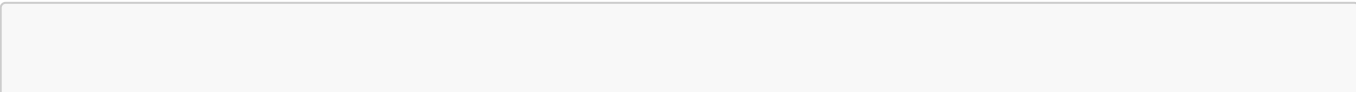
**consumerid** - The consumer ID attribute to be referenced from the <decryptright> elements from a <resourcedata> element to specify to which <consumer> is intended the encrypted content.

A consumer MUST be identified by "consumerid", an attribute in <consumer> element, where consumerid is a human readable unique identifier (Alphanumeric). Each consumer is expected to have a unique id, which is known to both producer and consumer.

**keyid** - The optional alphanumeric key identifier attribute for identifying the consumer's Key Encryption Key (KEK), which it is used for encrypting the data encryption keys targeted to this consumer.

It is possible that a consumer has different encryption key pairs. In this case, additional information about the specific key pair used as Key Encryption Key is needed. This information MAY be provided by specifying the key identification.

See the following example:



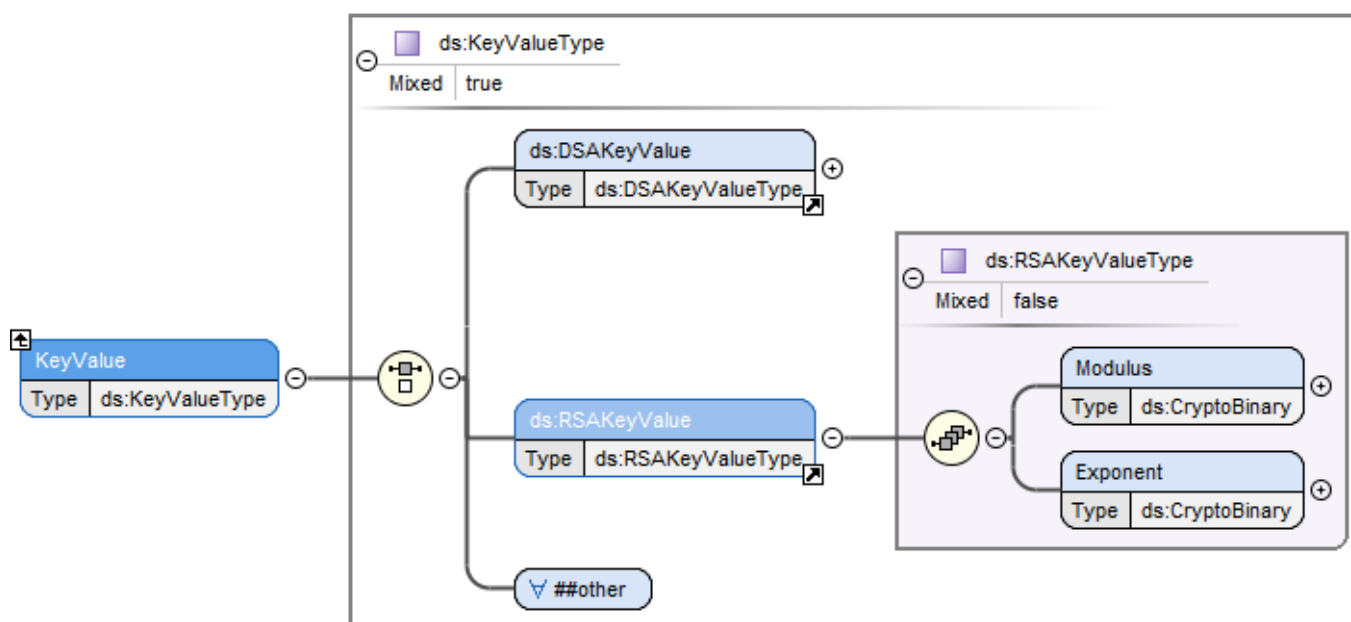
```
<consumer consumerid='HP#MOP44B#SG5693454' keyid="KEK_xxx">
<consumer consumerid='HP#MOP44B#SG1632635' keyid="KEK_yyy">
```

### 2.1.1 Key Value

#### Element <keyvalue>

Additional information about the public key used as Key Encryption Key MAY be provided using a <keyvalue> element as defined in the XML digital signature specification (<https://www.w3.org/TR/xmlsig-core1/#sec-KeyValue>). The specific key to use MUST be identified using the <ds:KeyValue> element containing the W3C XML formatted public key.

Figure 2–1. ds:KeyValue type schema diagram



For the purposes of this specification, only the <ds:RSAPublicKey> element is supported for identifying the customer key. Consumers MAY disregard any other element if present.

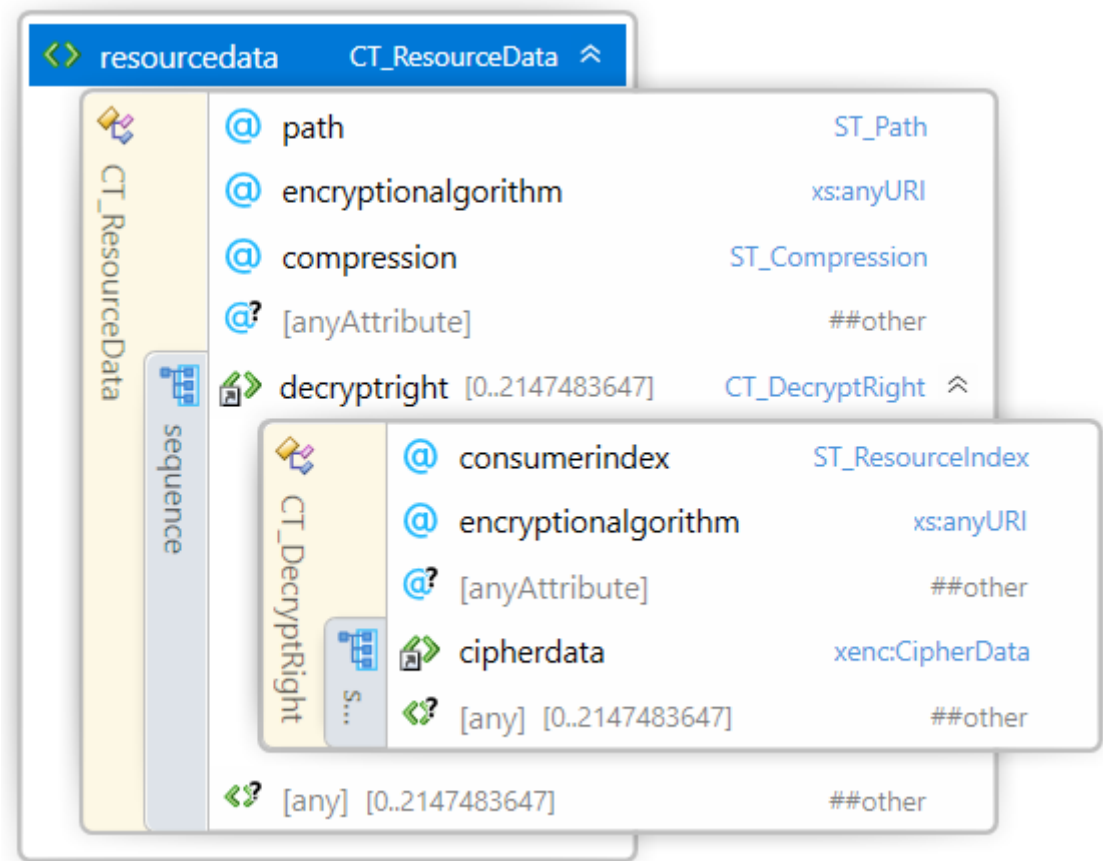
See the following example:

```
<consumer consumerid='HP#MOP44B#SG5693454' keyid="KEK_xxx">
  <keyvalue>
    <ds:RSAPublicKey>
      <ds:Modulus>
        xs1GwyPre7/knVd3CA01pyk++yp/qmBz2TekgrehYTWU7hs8bUCeVQrL2O
        B+jm/AgjdPMohWHD/tLcJy35aZgVfPI30a3gmXxdoLZrfNRbnrCm3Xr1MR
        7wnhMyBt5XXyU/FiF46g5qJ2DUIUg7teoKDNUSAN81JTIoH0KC+rZBo03t
        u9PR7H75K5G2eT6oUWkWKcZZU/4WNCDasNtizTe41Jy99BjrChww5r2ctq
        G8LvIv7UeeFaK1vHxGKaNH/7JvKJI9LbewWNtmb/nRzQg9xK3e0Hb1bW+
        o6zg5pTw+n37fS7pkXK71bRfUfaQmhoGy6ox4UWgmOgm8yPu8S4Q==
      </ds:Modulus>
      <ds:Exponent>AQAB</ds:Exponent>
    </ds:RSAPublicKey>
```

```
</keyvalue>
</consumer>
```

2.2 Resource Data

Element <resourcedata>



Name	Type	Use	Default	Annotation
path	ST_Path	required		Path to the encrypted resource file.
encryptionalgorithm	anyURI			Encryption algorithm used to encrypt the resource data.
compression	ST_Compression		none	Compression algorithm applied to content before encryption.

@anyAttribute

The <resourcedata> element under a <keystore> element contains the resource specific encryption information for an encrypted resource and the file path to the encrypted content file.

**path** - Path to the encrypted file in the OPC package. The path MUST be treated as a hash map to identify encrypted files referenced from any XML model file by their path attribute defined in 3MF extensions. A given file path must be unique; it MUST NOT show up in more than one <resourcedata> element.

When a model resource path is found in a <resourcedata> element, the content of that file MUST be encrypted.



**encryptionalgorithm** - Encryption algorithm used to encrypt the resource data.

A consumer supporting the 3MF Secure Content Extension MUST support, at a minimum, the AES256-GCM algorithm, identified with the URI <http://www.w3.org/2009/xmlenc11#aes256-gcm>:

AES-GCM [SP800-38D] is an authenticated encryption mechanism. It is equivalent to doing these two operations in one step - AES encryption followed by HMAC signing.

For the purposes of this specification, A-ES-GCM shall be used with a 96-bit Initialization Vector (IV) and a 128-bit Authentication Tag (T). The cipher text contains the IV first, followed by the encrypted octets and finally the Authentication tag. No padding should be used during encryption. During decryption the implementation should compare the authentication tag computed during decryption with the specified Authentication Tag and fail if they don't match. For details on the implementation of AES-GCM, see the publication [SP800-38D](#).

**Note:** For security, every time a file is encrypted a new Initialization Vector (IV) SHOULD be generated.

**compression** - Compression algorithm applied before encrypting the content to obtain a significant compression ratio.

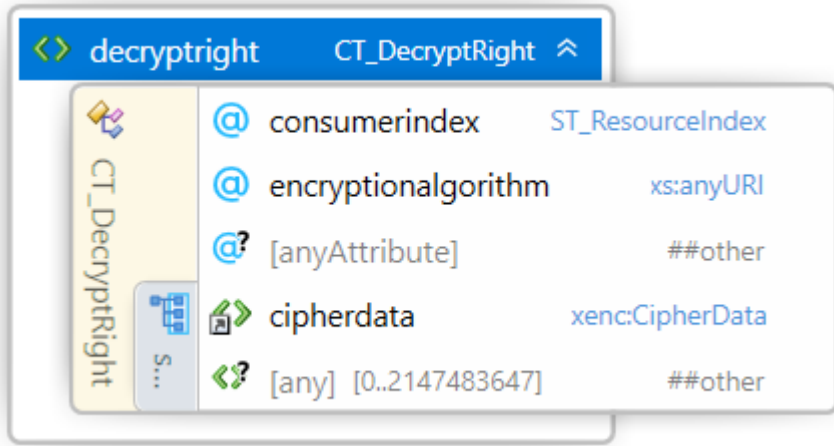
A producer MAY specify a compression "deflate" so the content is first compressed and then encrypted. When compression is "deflate", a consumer MUST first decrypt and then decompress the content.

Example of a complete <resourcedata> element for an encrypted resource that can be accessed by two different consumers:

```
<resourcedata
  path="path to encrypted file1 in package"
  encryptionalgorithm="http://www.w3.org/2009/xmlenc11#aes256-gcm"
  compression="deflate">
  <decryptright consumerindex="0"
    encryptionalgorithm="http://www.w3.org/2001/04/xmlenc#rsa-oaep-mgf1p">
    <cipherdata>
      <xenc:CipherValue><!-- base64(RSA2048_OAEP encrypted Data Encryption Key) --
    </xenc:CipherValue>
    </xenc:CipherData>
    </decryptright>
  <decryptright consumerindex="1"
    encryptionalgorithm="http://www.w3.org/2001/04/xmlenc#rsa-oaep-mgf1p">
    <cipherdata>
      <xenc:CipherValue><!-- base64(RSA2048_OAEP encrypted Data Encryption Key) --
    </xenc:CipherValue>
    </xenc:CipherData>
    </decryptright>
  </resourcedata>
```

## 2.2.1 Decrypt Right

Element <**decryptright**>



Name	Type	Use	Default	Annotation
consumerindex	<b>ST_ResourceIndex</b>	required		Zero-based index to the <customer> element containing the keys to decrypt the resource file
encryptionalgorithm	<b>anyURI</b>			Encryption algorithm used to encrypt the resource DEK.
@anyAttribute				

The <decryptright> element under a <resourcedata> element contains the consumer specific information to decrypt the content file for a specific consumer. Each <decryptright> element contains the Data Encryption Key (DEK) encrypted with the consumer's public Key Encryption Key (KEK).

**consumerindex** - Index to the <consumer> element in the Key Store to select the Customer to which the decryption key is targeted.

**encryptionalgorithm** - Encryption algorithm used to encrypt the Data Encryption Key (DEK) using the consumer's Key Encryption Key (KEK).

For this specification, the only algorithm supported for key encryption is RSA OAEP with MGF1 with SHA1 mask generation, identified with the URI <http://www.w3.org/2001/04/xmlenc#rsa-oaep-mgf1p>.

From <https://www.w3.org/TR/xmlenc-core1/#sec-RSA-OAEP>:

The RSAES-OAEP-ENCRYPT algorithm, as specified in RFC 3447 [PKCS1], has options that define the message digest function and mask generation function, as well as an optional PSourceAlgorithm parameter. Default values defined in RFC 3447 are SHA1 for the message digest and MGF1 with SHA1 for the mask generation function. Both the message digest and mask generation functions are used in the EME-OAEP-ENCODE operation as part of RSAES-OAEP-ENCRYPT.

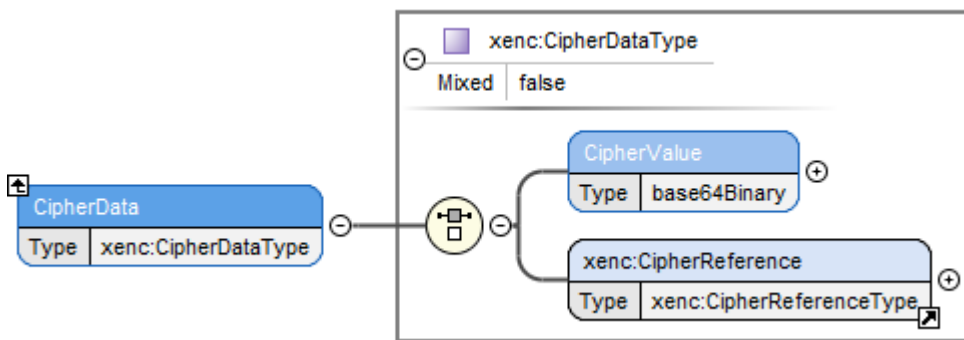
The <http://www.w3.org/2001/04/xmlenc#rsa-oaep-mgf1p> identifier defines the mask generation function as the fixed value of MGF1 with SHA1. In this case the optional xenc11:MGF element of the xenc:EncryptionMethod element MUST NOT be provided.

### 2.2.2.1 Cipher Data

Element <**cipherdata**>

The <cipherdata> element under the <decryptright> element contains the public key to decrypt the content file, which is encrypted for a specific consumer, granting its decryption rights.

**Figure 2–2. xenc:CipherData schema diagram**



The <xenc:CipherData> element contains the encrypted key payload for a specific customer. It follows the syntax defined in <http://www.w3.org/TR/xmlenc-core1/#sec-CipherData>.

For the purposes of this specification only the <xenc:CipherValue> element is supported. Consumers may disregard any other element if present.

## Chapter 3. OPC Relation and Content Types

The Key Store in a 3MF document is identified by a new content type and a new relationship.

### 3.1 Content Types

The Key Store MUST be defined in the OPC ContentTypes part by overriding the default XML definition.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<Types xmlns="http://schemas.openxmlformats.org/package/2006/content-types">
  <Default ContentType="application/vnd.openxmlformats-
package.relationships+xml" Extension="rels"/>
  <Override ContentType="application/vnd.ms-package.3dmanufacturing-3dmodel+xml"
PartName="/3D/3Dmodel.model"/>
  <Override ContentType="application/vnd.ms-package.3dmanufacturing-
keystore+xml" PartName="/Secure/keystore.xml"/>
  <Default ContentType="image/png" Extension="png"/>
</Types>
```

### 3.2 Relation Files

The Key Store file MUST always be referenced in the root .rels file in order to conform with OPC standards.

The Key Store file SHOULD be specified as a MustPreserve relationship type, in order that editors that do not support this extension are still instructed to save it back when modifying the 3MF.

Example root .rels file, where the keystore part is referenced twice: one for the KeyStore relationship type and a second for the MustPreserve relationship type.

```
<?xml version="1.0" encoding="utf-8"?>
  <Relationships
xmlns="http://schemas.openxmlformats.org/package/2006/relationships"
  <Relationship
Type="http://schemas.microsoft.com/3dmanufacturing/2013/01/3dmodel"
Target="/3D/build.model" Id="rel0" />
  <Relationship
Type="http://schemas.openxmlformats.org/package/2006/relationships/metadata/thumbnail" Target="/Metadata/thumbnail.png" Id="rel4" />
  <Relationship
Type="http://schemas.microsoft.com/3dmanufacturing/2019/04/keystore"
Target="/Secure/keystore.xml" Id="rel10" />
  <Relationship
Type="http://schemas.openxmlformats.org/package/2006/relationships/mustpreserve"
Target="/Secure/keystore.xml" Id="rel11" />
</Relationships>
```

## Part II. Appendixes

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### Appendix A. Glossary

See [the 3MF Core Specification glossary](#).

### Appendix B. 3MF XSD Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema
xmlns="http://schemas.microsoft.com/3dmanufacturing/securecontent/2019/04"
xmlns:xs="http://www.w3.org/2001/XMLSchema"
xmlns:xenc="http://www.w3.org/2001/04/xmlenc#"
xmlns:ds="http://www.w3.org/2000/09/xmldsig#"
targetNamespace="http://schemas.microsoft.com/3dmanufacturing/securecontent/2019/04" elementFormDefault="unqualified" attributeFormDefault="unqualified"
blockDefault="#all">
  <xs:import namespace="http://www.w3.org/XML/1998/namespace"
schemaLocation="http://www.w3.org/2001/xml.xsd"/>
  <xs:import namespace="http://www.w3.org/2001/04/xmlenc#"
schemaLocation="https://www.w3.org/TR/xmlenc-core1/xenc-schema.xsd"/>
  <xs:import namespace="http://www.w3.org/2000/09/xmldsig#"
schemaLocation="http://www.w3.org/TR/2002/REC-xmldsig-core-20020212/xmldsig-core-schema.xsd"/>
  <xs:annotation>
    <xs:documentation><![CDATA[ Schema notes:
```

Items within this schema follow a simple naming convention of appending a prefix

indicating the type of element for references:

Unprefixed: Element names

CT\_: Complex types

ST\_: Simple types

```

]]></xs:documentation>
</xs:annotation>
<!-- Complex Types -->
<xs:complexType name="CT_KeyStore">
  <xs:sequence>
    <xs:element ref="consumer" minOccurs="0" maxOccurs="2147483647"/>
    <xs:element ref="resourcedata" minOccurs="0" maxOccurs="2147483647"/>
    <xs:any namespace="##other" processContents="lax" minOccurs="0"
maxOccurs="2147483647"/>
  </xs:sequence>
  <xs:attribute name="UUID" type="ST_UUID" use="required"/>
  <xs:anyAttribute namespace="##other" processContents="lax"/>
</xs:complexType>
<xs:complexType name="CT_Consumer">
  <xs:sequence>
    <xs:element ref="keyvalue" minOccurs="0"/>
    <xs:any namespace="##other" processContents="lax" minOccurs="0"
maxOccurs="2147483647"/>
  </xs:sequence>
  <xs:attribute name="consumerid" type="xs:string" use="required"/>
  <xs:attribute name="keyid" type="xs:string"/>
  <xs:anyAttribute namespace="##other" processContents="lax"/>
</xs:complexType>
<xs:complexType name="CT_ResourceData">
  <xs:sequence>
    <xs:element ref="decryptright" minOccurs="0" maxOccurs="2147483647"/>
    <xs:any namespace="##other" processContents="lax" minOccurs="0"
maxOccurs="2147483647"/>
  </xs:sequence>
  <xs:attribute name="path" type="ST_Path" use="required"/>
  <xs:attribute name='encryptionalgorithm' type='xs:anyURI'/>
  <xs:attribute name="compression" type="ST_Compression" default="none"/>
  <xs:anyAttribute namespace="##other" processContents="lax"/>
</xs:complexType>
<xs:complexType name="CT_DecryptRight">
  <xs:sequence>
    <xs:element ref="cipherdata"/>
    <xs:any namespace="##other" processContents="lax" minOccurs="0"
maxOccurs="2147483647"/>
  </xs:sequence>
  <xs:attribute name="consumerindex" type="ST_ResourceIndex" use="required"/>
  <xs:attribute name='encryptionalgorithm' type='xs:anyURI'/>
  <xs:anyAttribute namespace="##other" processContents="lax"/>
</xs:complexType>
<xs:simpleType name="ST_Path">
  <xs:restriction base="xs:string"/>
</xs:simpleType>
<xs:simpleType name="ST_ResourceIndex">

```

```

    <xs:restriction base="xs:nonNegativeInteger">
      <xs:maxExclusive value="2147483648"/>
    </xs:restriction>
  </xs:simpleType>
  <xs:simpleType name="ST_Compression">
    <xs:restriction base="xs:string">
      <xs:enumeration value="none"/>
      <xs:enumeration value="deflate"/>
    </xs:restriction>
  </xs:simpleType>
  <xs:simpleType name="ST_UUID">
    <xs:restriction base="xs:string">
      <xs:pattern value="[a-f0-9]{8}-[a-f0-9]{4}-[a-f0-9]{4}-[a-f0-9]{4}-[a-f0-9]{12}"/>
    </xs:restriction>
  </xs:simpleType>
  <!-- Elements -->
  <xs:element name="keystore" type="CT_KeyStore"/>
  <xs:element name="consumer" type="CT_Consumer"/>
  <xs:element name="resourcedata" type="CT_ResourceData"/>
  <xs:element name="decryptright" type="CT_DecryptRight"/>
  <xs:element name="cipherdata" type="xenc:CipherData"/>
  <xs:element name="keyvalue" type="ds:KeyValueTypes"/>
</xs:schema>

```

## Appendix C. Standard Content Types and Relationships

---

### C.1 Content Types

Secure Content application/vnd.ms-package.3dmanufacturing-keystore+xml

### C.2 Relationships

Secure Content <http://schemas.microsoft.com/3dmanufacturing/2019/04/keystore>

## References

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### W3C XML Encryption Syntax and Processing Version 1.1

Specification for encrypting data and representing the result in XML. <https://www.w3.org/TR/xmlenc-core1/>.

### W3C XML Signature Syntax and Processing Version 1.1

Specification for XML digital signature processing rules and syntax. <http://www.w3.org/TR/xmldsig-core1/>.

**[SP800-38D]** M. Dworkin. NIST Special Publication 800-38D: Recommendation for Block Cipher Modes of Operation: Galois/Counter Mode (GCM) and GMAC. November 2007 URL: <http://csrc.nist.gov/publications/nistpubs/800-38D/SP-800-38D.pdf>

For additional references See [the 3MF Core Specification references](#).

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