

Digital Imaging and Communications in Medicine (DICOM)

Supplement 205: DICOM Encapsulation of STL Models for 3D Manufacturing

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Scope and Field of Application

40 This supplement adds a new DICOM IOD to encapsulate Stereolithography (STL) 3D model file formats.

The new IOD allows 3D manufacturing models to be exchanged between various types of equipment using DICOM. This adds the ability to store, query and retrieve 3D models as DICOM objects. Updates are addressed by storing new instances, with reference back to earlier instances.

45 The 3D model files are a type of document that contains geometric instructions on how an object could be created by a 3D printer, milling machine, or other type of device capable of manufacturing a physical object.

To exchange these 3D models in an efficient manner in an imaging environment, especially as part of patient care planning and the patient's imaging record, it is useful to be able to "wrap" these model documents in a DICOM container.

50 Additionally, the identity of the patient (and any source image series) of the encapsulated 3D models can be ascertained through the attributes that the DICOM information model adds on top of the 3D model's general purpose geometric information.

55 Since its introduction, the STL file format has been used for a variety of applications, including 3D manufacturing. STL is the most prevalent file format in the 3D printing community and enjoys wide support by existing systems.

STL supports both an ASCII and binary encoding. In the interest of simplicity and minimizing SOP Instance size, **only the binary encoding of STL is supported** for DICOM encapsulation.

Changes to NEMA Standards Publication PS 3.2-2018x

60

Digital Imaging and Communications in Medicine

Part 2: Conformance

Item: Add to table A.1-2 categorizing SOP Classes:

The SOP Classes are categorized as follows:

65

**Table A.1-2
UID VALUES**

UID Value	UID NAME	Category
...
<u>1.2.840.10008.5.1.4.1.1.xxx</u>	<u>Encapsulated STL Storage SOP Class</u>	<u>Transfer</u>
...

Changes to NEMA Standards Publication PS 3.3-2018x

Digital Imaging and Communications in Medicine (DICOM)

70

2 Normative References

Item: Add normative reference and symbols & abbreviations

2.6 Other References

75 ...

[STL 1989] 3D Systems, Inc. 1989. StereoLithography Interface Specification,

4 Symbols and Abbreviations

STL StereoLithography data format

Modify Section A.1.4 Overview of the Composite IOD Module Content – Insert Encapsulated STL

80

**Table A.1-3
 COMPOSITE INFORMATION OBJECT MODULES OVERVIEW – MORE NON-IMAGES**

IODs Modules	...	<u>Enc STL</u>	...
Patient		<u>M</u>	
Clinical Trial Subject		<u>U</u>	
General Study		<u>M</u>	
Patient Study		<u>U</u>	
Clinical Trial Study		<u>U</u>	
Clinical Trial Series		<u>U</u>	
...			
Encapsulated Document Series		<u>M</u>	
...			
Frame of Reference		<u>M</u>	
General Equip.		<u>M</u>	
Enhanced General Equipment		<u>M</u>	
...			
Common Instance Reference		<u>C</u>	
...			
Encapsulated Document		<u>M</u>	
...			
SOP Common		<u>M</u>	

<u>Manufacturing 3D Model</u>		<u>M</u>	
-------------------------------	--	----------	--

Modify Annex A – Insert new section for Encapsulated STL IOD

A.X Encapsulated 3D Manufacturing Models

85 **A.X.1 Encapsulated STL Information Object Definition**

A.X.1.1 Encapsulated STL IOD Description

The Encapsulated STL Information Object Definition (IOD) describes a 3D model in Stereolithography (STL) format that has been encapsulated within a DICOM information object.

A.X.1.2 Encapsulated STL Entity-Relationship Model

90 This IOD uses the E-R Model in Section A.1.2, with only the Encapsulated Document IE below the Series IE.

A.X.1.3 Encapsulated STL IOD Module Table

Table A.X.1-1 specifies the Encapsulated STL IOD Modules.

**Table A.X.1-1
Encapsulated STL IOD MODULES**

95

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	Clinical Trial Series	C.7.3.2	U
	Encapsulated Document Series	C.24.1	M
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Encapsulated Document	Encapsulated Document	C.24.2	M
	Manufacturing 3D Model	C.24.Y	M
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	C - Required if other instances are referenced

A.X.1.4 Encapsulated STL IOD Content Constraints

The Encapsulated Document (0042,0011) attribute shall contain a binary STL byte stream [STL 1989]. The encapsulated document may include negative vertex coordinates.

100 **Note:** The original STL specification in 1989 required that all 3 vertex coordinates of each triangle be located in the positive quadrant. This restriction was later relaxed by the creators of the standard (3D Systems) and negative coordinates allowed. It is common practice in medical usage for STL models to align with the coordinate system of the source DICOM data, which will often result in negative vertex coordinates.

105 The MIME Type of Encapsulated Document (0042,0012) value shall be “model/stl”.

The value of the Modality (0008,0060) shall be “M3D”.

Modify Section C.7.3.1.1 General Series Attribute Descriptions – Insert Model in alphabetical order

C.7.3.1.1 General Series Attribute Descriptions

C.7.3.1.1.1 Modality

110 Defined Terms:

...

M3D Model for 3D Manufacturing

...

Modify Annex C.24 – Clarifications for Encapsulated STL 3D Manufacturing 3D Model

115 *Note: CP 1763 proposes changes to the use of Source Instance Sequence, which impact this supplement. These changes have been incorporated in-line by drawing on CP1763’s text*

C.24.2 Encapsulated Document Module

Table C.24-2 defines the Encapsulated Document Attributes.

**Table C.24-2
Encapsulated Document Module Attributes**

120

Attribute Name	Tag	Type	Attribute Description
Instance Number	(0020,0013)	1	A number that identifies this SOP Instance. The value shall be unique within a series.
Content Date	(0008,0023)	2	The date the document content creation was started.
Content Time	(0008,0033)	2	The time the document content creation was started.
Acquisition DateTime	(0008,002A)	2	The date and time that the original generation of the data in the document started.
Image Laterality	(0020,0062)	3	Laterality of the (possibly paired) body part that is the subject of the encapsulated document. Enumerated Values: R right L left U unpaired B both left and right <u>If the Modality (0008,0060) is M3D, then values for this attribute shall refer to the intended placement of the created object regardless of how it was generated (see also Model Mirroring, C.24.Y.2).</u>
Burned In Annotation	(0028,0301)	1	Indicates whether or not the encapsulated document contains sufficient burned in annotation to identify the patient and date the data was acquired. Enumerated Values: YES NO Identification of patient and date as text in an encapsulated document (e.g., in an XML attribute or element) is equivalent

			to "burned in annotation". A de-identified document may use the value NO. <u>If the Modality (0008,0060) is M3D, the presence of identifying information embossed or engraved on any part of the model shall be indicated by a value of YES.</u>
Recognizable Visual Features	(0028,0302)	3	Indicates whether or not the image instance contains sufficiently recognizable visual features to allow the image instance or a reconstruction from a set of images instances to identify the patient. Enumerated Values: YES NO If this Attribute is absent, then the image instance may or may not contain recognizable visual features.
Source Instance Sequence	(0042,0013)	1C	A sequence that identifies the Instances that were used to derive the encapsulated document. One or more Items shall be included in this Sequence. Required if derived from one or more DICOM Instances. May be present otherwise. Note <u>Unlike other uses of Source Instance Sequence (0042,0013), such as in the General Reference Module, references to images are permitted in this Module, which does not include the Source Image Sequence (0008,2112), and the Defined Context Group for Purpose of Reference Code Sequence (0040,A170) includes an appropriate concept.</u>
>Include Table 10-11 "SOP Instance Reference Macro Attributes"			
>Purpose of Reference Code Sequence	(0040,A170)	3	Describes the purpose for which the reference is made, that is what role the source instances played in the derivation of this encapsulated document Only a single Item is permitted in this Sequence.
>>Include Table 8.8-1 "Code Sequence Macro Attributes"			Defined CID 7013 "Non-Image Source Instance Purposes of 3-Reference". <u>Defined 7xxx "Encapsulated Document Source Instance Purposes of Reference".</u>
Document Title	(0042,0010)	2	The title of the document. Note In the case of a PDF encapsulated document, this may be the value of the "Title" entry in the "Document Information Directory" as encoded in the PDF data.
Concept Name Code Sequence	(0040,A043)	2	A coded representation of the document title. Zero or one Item shall be included in this Sequence.
>Include Table 8.8-1 "Code Sequence Macro Attributes"			<u>For documents with Modality (0008,0060) equal to M3D the Baseline CID is 7xx1 "Model Document Titles".</u> <u>For all other Encapsulated documents use the Baseline CID 7020 "Document Titles".</u>

Document Class Code Sequence	(0040,E008)	3	Additional classifications of the document, beyond the title represented in Concept Name Code Sequence. May be equivalent Equivalent to HL7 v2.x TXA-2. One or more Items are permitted in this Sequence.
>Include Table 8.8-1 "Code Sequence Macro Attributes"			No Baseline CID is defined.
Verification Flag	(0040,A493)	3	Indicates whether the Encapsulated Document is Verified. Enumerated Values: UNVERIFIED Not attested by a legally accountable person. VERIFIED Attested to (signed) by a Verifying Observer or Legal Authenticator named in the document, who is accountable for its content.
HL7 Instance Identifier	(0040,E001)	1C	Instance Identifier of the encapsulated HL7 Structured Document, encoded as a UID (OID or UUID), concatenated with a caret ("^") and Extension value (if Extension is present in Instance Identifier). Required if encapsulated document is a CDA document.
Predecessor Documents Sequence Attribute	(0040,A360)	3	References to SOP Instances whose content has been wholly or partially included in this document with or without modification. One or more Items are permitted in this sequence.
>Include Table C.17-3 'Hierarchical SOP Instance Reference Macro'			Defined CID for the Purpose of Reference Code Sequence in the Hierarchical SOP Instance Reference Macro is; If the Modality (0008,0060) is M3D, CID 7xx2 "Purpose of Reference to Predecessor 3D Model"; otherwise, CID 7009 "Purpose of Reference to Predecessor Report";
Identical Documents Sequence	(0040,A525)	3	Duplicates of this document, stored with different SOP Instance UIDs. One or more Items are permitted in this sequence. See Section C.17.2.2 for further explanation.
>Include Table C.17-3 "Hierarchical SOP Instance Reference Macro Attributes"			
MIME Type of Encapsulated Document	(0042,0012)	1	The type of the encapsulated document stream described using the MIME Media Type (see RFC 2046).
List of MIME Types	(0042,0014)	1C	MIME Types of subcomponents of the encapsulated document. Required if the encapsulated document incorporates subcomponents with MIME types different than the primary MIME Type of the encapsulated document. <i>Note</i> An Encapsulated CDA that includes an embedded JPEG image and an embedded PDF would list "image/jpeg\application/pdf".
Encapsulated Document	(0042,0011)	1	Encapsulated Document stream, containing a document encoded according to the MIME Type.

Note

1. One could distinguish four stages in the creation of the Encapsulated Document Object, identified by the following Attributes:

- 125 1. Measurement and/or data collection, identified by Acquisition DateTime (0008,002A) in the Encapsulated Document Module.
2. Creation of the original documentation of the data collection, identified by Content Date (0008,0023) and Content Time (0008,0033).
- 130 3. Rendering of the original documentation into the format that will be encapsulated, e.g., a PDF document. The rendering time is not captured by any DICOM Attribute, but may be encoded in the rendering.
4. Encapsulation of the rendering into a DICOM Object, identified by Instance Creation Date (0008,0012) and Instance Creation Time (0008,0013) in the SOP Common Module.
2. DICOM does not specify requirements for consistency between DICOM attribute values and data in the encapsulated document. It is expected that applications will ensure consistency in a manner appropriate to the application. For example, the Patient ID in an encapsulated CDA document may be that of a different institution, which originated the document, and it may be appropriate for the DICOM attribute value to be different.
- 135

140 *Modify PS3.3 Annex C.24 to insert definition of a new 3D Manufacturing module and associated defined terms.*

C.24.Y Manufacturing 3D Model Module

Table C.24.Y-1 defines attributes specific to models used in medical 3D manufacturing.

**Table C.24.Y-1
Manufacturing 3D Model Module Attributes**

Attribute Name	Tag	Type	Attribute Description
Measurement Units Code Sequence	(0040,08EA)	1	Units of distance for the coordinate system for the encapsulated STL file Only a single Item shall be included in this Sequence.
<i>>Include Table 8.8-1 "Code Sequence Macro Attributes"</i>			Defined CID 7xx3 "Model Scale Units".
Model Modification	(aaa1,bbb1)	3	Specifies whether a modification of the observed anatomy (other than mirroring) was used to create the model (e.g. simulating an expected surgical result). In the negative, the model follows the observed patient anatomy in the source data. Enumerated Values: YES NO
Model Mirroring	(aaa1,bbb2)	3	Specifies whether mirroring of anatomy from the other side of the patient was used to create the model Enumerated Values: YES NO
Model Usage Code Sequence	(aaa1,bbb3)	3	Specifies the use for which the manufactured object is intended. Only a single item is permitted in this Sequence

<i>>Include Table 8.8-1 Code Sequence Macro Attributes</i>			Baseline CID 7xx4 "Model Usage".
Content Description	(0070,0081)	3	Description of the model
Icon Image Sequence	(0088,0200)	3	A preview image representing the rendered model. Only a single Item is permitted in this Sequence.
<i>>Include Table C.7-11b "Image Pixel Macro Attributes"</i>			See Section C.7.6.1.1.6 for further explanation.
Derivation Algorithm Sequence	(0022,1612)	3	Software algorithm that created the 3D model. Only a single Item shall be included in this Sequence.
<i>>Include Table 10-19 "Algorithm Identification Macro Attributes"</i>			

Changes to NEMA Standards Publication PS 3.4-2018x

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Part 4: Service Class Specifications

Modify Annex B.5 Standard SOP Classes – add new item.

B.5 STANDARD SOP CLASSES

155

Table B.5-1
STANDARD SOP CLASSES

SOP Class Name	SOP Class UID	IOD (See PS 3.3)
...		
<u>Encapsulated STL Storage</u>	<u>1.2.840.10008.5.1.4.1.1.xxx</u>	<u>Encapsulated STL IOD</u>
...		

160

Changes to NEMA Standards Publication PS 3.6-2018x

Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

165

Modify PS3.6 Table 6-1. Registry of DICOM Data Elements to add the following elements in the correct order.

Table 6-1. Registry of DICOM Data Elements

Tag	Name	Keyword	VR	VM	
...	
<u>(aaa1,bbb1)</u>	<u>Model Modification</u>	<u>ModelModification</u>	<u>CS</u>	<u>1</u>	
<u>(aaa1,bbb2)</u>	<u>Model Mirroring</u>	<u>ModelMirroring</u>	<u>CS</u>	<u>1</u>	
<u>(aaa1,bbb3)</u>	<u>Model Usage Code Sequence</u>	<u>ModelUsageCodeSequence</u>	<u>SQ</u>	<u>1</u>	
...					

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Modify PS3.6 Annex A Registry of DICOM unique identifiers (UID) – add new item.

Annex A Registry of DICOM unique identifiers (UID) (Normative)

Table A-1 lists the UID values that are registered and used throughout the Parts of the DICOM Standard. This central registry ensures that when additional UIDs are assigned, non-duplicate values are assigned.

175

**Table A-1
UID VALUES**

UID Value	UID NAME	UID TYPE	Part
...			
<u>1.2.840.10008.5.1.4.1.1.xxx</u>	<u>Encapsulated STL Storage</u>	<u>SOP Class</u>	<u>PS 3.4</u>
...			

Changes to NEMA Standards Publication PS 3.16-2018x

Digital Imaging and Communications in Medicine

Part 16: Content Mapping Resource

180

Addition to PS3.16 Content Mapping Resource – Modify CID 30 DICOM Devices to include M3D in the correct location.

CID 30 DICOM DEVICES

This Context Group includes codes that may be used to identify a class of equipment that uses DICOM.

185

Resources: HTML | FHIR JSON | FHIR XML | IHE SVS XML
Type: Extensible
Version: YYYYMMDD
UID: 1.2.840.10008.6.1.20

Table CID 30. DICOM Devices

190

Coding Scheme Designator	Code Value	Code Meaning
...
<u>DCM</u>	<u>M3D</u>	<u>Computer-aided 3D Manufacturing Modeling System</u>
...

Include new CID 7xxx Encapsulated Document Source Purposes of Reference as defined by CP1763,

CID 7XXX ENCAPSULATED DOCUMENT SOURCE PURPOSES OF REFERENCE

Resources: HTML | FHIR JSON | FHIR XML | IHE SVS XML
Type: Extensible
Version: YYYYMMDD
UID: 1.2.840.10008.6.1.xxxx

195

Table CID 7xxx. Encapsulated Document Source Purposes of Reference

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-CT Concept ID	UMLS Concept Unique ID
DCM	121324	Source image		

Include CID 7013 “Non-Image Source Instance Purposes of Reference”

200

Addition to PS3.16 Content Mapping Resource – Add 4 new CIDs.

CID 7XX1 Model Document Titles

Resources: HTML | FHIR JSON | FHIR XML | IHE SVS XML
Type: Extensible
Version: YYYYMMDD
UID: 1.2.840.10008.6.1.xx1

Table CID 7XX1. Model Document Titles

Coding Scheme Designator	Code Value	Code Meaning
LN	85041-2	MR 3D CAM model
LN	85040-4	CT 3D CAM model
DCM	abcdefg01	US 3D CAM model
DCM	abcdefg02	Mixed Modality 3D CAM model
DCM	abcdefg13	Photogrammetric Imaging 3D CAM model
DCM	abcdefg14	Laser Scanning 3D CAM model

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CID 7XX2 Purpose of Reference to Predecessor 3D Model

Resources: HTML | FHIR JSON | FHIR XML | IHE SVS XML
Type: Extensible
Version: YYYYMMDD
UID: 1.2.840.10008.6.1.xx2

Context Group ID 7xx2 comprises reasons that a prior 3D model may be referenced by a later instance.

Table CID 7XX2. Purpose of Reference to Predecessor 3D Model

Coding Scheme Designator	Code Value	Code Meaning
DCM	abcdefg03	Edited Model
DCM	abcdefg04	Component Model

CID 7XX3 Model Scale Units

Resources: HTML | FHIR JSON | FHIR XML | IHE SVS XML
Type: Non-extensible
Version: YYYYMMDD
UID: 1.2.840.10008.6.1.xx3

225

Context Group ID 7xx3 comprises all valid scale units that may be used in a 3D model.

Table CID 7XX3. Model Scale Units

Coding Scheme Designator	Code Value	Code Meaning
UCUM	m	meter
UCUM	cm	centimeter

UCUM	mm	millimeter
UCUM	um	micrometer

CID 7XX4 Model Usage

230 **Resources:** HTML | FHIR JSON | FHIR XML | IHE SVS XML
Type: Extensible
Version: YYYYMMDD
UID: 1.2.840.10008.6.1.xx4

235 Context Group ID 7xx4 comprises intended uses for objects manufactured from a 3D model. The intended use can help to distinguish similar-appearing models.

Table CID 7XX4. Model Usage

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-CT Concept ID	UMLS Concept Unique ID
DCM	abcdefg15	Educational Intent		
SRT	R-408C3	Diagnostic Intent	261004008	C0348026
DCM	abcdefg06	Planning Intent		
DCM	abcdefg07	Tool Fabrication		
DCM	abcdefg08	Prosthetic Fabrication		
DCM	abcdefg09	Implant Fabrication		
DCM	113680	Quality Control Intent		
DCM	abcdefg11	Simulation Intent		

240 *Addition to PS3.16 Content Mapping Resource – Appendix D, Add new DICOM controlled terminology definitions introduced in CIDs 30, 7202, 7XX1, 7XX2, and 7XX4 above.*

D DICOM CONTROLLED TERMINOLOGY DEFINITIONS (NORMATIVE)

This Annex specifies the meanings of codes defined in DICOM, either explicitly or by reference to another part of DICOM or an external reference document or standard.

245 The contents of this table are available in OWL format at <ftp://medical.nema.org/medical/dicom/resources/ontology/dcm/dcm.owl> and in Bioportal.

**Table D-1. DICOM Controlled Terminology Definitions (Coding Scheme Designator "DCM"
Coding Scheme Version "01")**

Code Value	Code Meaning	Definition	Notes
...			
<u>M3D</u>	<u>3D Manufacturing Modeling System</u>	<u>A device, process or method that produces data sets (models) for use in 3D manufacturing.</u>	
...			
<u>abcdefg01</u>	<u>US 3D CAM model</u>	<u>A 3D model based on ultrasound imaging.</u>	
<u>abcdefg02</u>	<u>Mixed Modality 3D CAM model</u>	<u>A 3D model based on images from multiple different modalities</u>	
<u>abcdefg03</u>	<u>Edited Model</u>	<u>A reference to a predecessor model that has been edited to produce the current model.</u> <u>For example: inclusion of more organs, completion of a partial segmentation, insertion of a bisection plane to allow interior inspection, or addition of support material.</u>	
<u>abcdefg04</u>	<u>Component Model</u>	<u>A reference to a predecessor model that contributed to the creation of the current combined model.</u> <u>This includes simple assembly of discrete pieces as well as more complex combination. For example: by Boolean mathematical and similar operations.</u>	
<u>abcdefg15</u>	<u>Educational Intent</u>	<u>Intended for educational purposes.</u> <u>For example: patient or care-giver education/informed consent, or training residents and fellows.</u>	
<u>abcdefg06</u>	<u>Planning Intent</u>	<u>Intended to be used to assist with procedure planning.</u>	
<u>abcdefg07</u>	<u>Tool Fabrication</u>	<u>Intended to be used to manufacture a patient-matched tool that is employed during a medical procedure.</u>	

		<u>For example: drill/cutting guides, immobilizers, radiation shields, and plate bending templates.</u>	
<u>abcdefg08</u>	<u>Prosthetic Fabrication</u>	<u>Intended to be used to manufacture a fully external prosthetic/orthotic.</u>	
<u>abcdefg09</u>	<u>Implant Fabrication</u>	<u>Intended to be used to manufacture a wholly or partially internal implant.</u>	
<u>abcdefg11</u>	<u>Simulation Intent</u>	<u>Intended to be used for simulation and/or practice of a surgery or other medical procedure. "Simulation" is not used for patient-matched simulation, as this would be covered by "Diagnostic Intent" or "Planning Intent".</u>	
<u>abcdefg13</u>	<u>Photogrammetric Imaging 3D CAM model</u>	<u>A 3D model derived from measurements made from photographs, which is used for manufacturing.</u>	
<u>abcdefg14</u>	<u>Laser Scanning 3D CAM model</u>	<u>A 3D model derived from laser scanning measurements, which is used for manufacturing.</u>	

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Changes to NEMA Standards Publication PS 3.17-2018x

Digital Imaging and Communications in Medicine

Part 17: Informative

255

Addition to PS3.17 Append new Annex containing informative information on the creation of encapsulated STL objects

HHHH Encapsulated STL (Informative)

260

The goal of encapsulating an Stereolithography (STL) 3D manufacturing model file inside a DICOM instance rather than transforming the data into a different representation is to facilitate preservation of the STL file in the exact form that it is used with extant manufacturing devices, while at the same time unambiguously associating it with the patient for whose care the model was created and the images from which the model was derived.

Below are tables showing example excerpts for encoding of STL files and associated preview bitmap images (the latter being optional) for two patients.

265

HHHH.1 EXAMPLE OF CT DERIVED ENCAPSULATED STL

In the first example, the patient requires replacement implant due to a large piece of skull on the left side of his head. A 3D manufacturing model (encoded in binary STL) was created to by mirroring the corresponding section of the patient's right skull hemisphere, and then modified by trimming to fit the specific implantation area.

270

A preview image was created showing the rendered 3D object.

The model used as input data a series of CT images (CT-01). The STL file in this example is the first version, having no predecessor. The STL was created on November 22, 2017 at 7:10:14 AM, while the CT images were acquired weeks earlier.

275

The resulting STL was created in the coordinate system of CT-01; so they share the same Frame of Reference value.

No burned in annotation identifying the patient was included. The region of the skull reconstructed in the model contains no distinguishing facial features of the patient.

**Table HHHH.1-1
Encapsulated STL Example (Encapsulated Document Series and Document Values)**

Attribute Name	Tag	Example Value	Comments
Modality	(0008,0060)	M3D	
...			
Series Description	(0008,103E)	Skull plate	

Attribute Name	Tag	Example Value	Comments
...			
Content Date	(0008,0023)	20171122	
Content Time	(0008,0033)	07:10:14	
Acquisition DateTime	(0008,002A)	20171122 07:10:14	
Image Laterality	(0020,0062)	L	
Burned In Annotation	(0028,0301)	NO	
Recognizable Visual Features	(0028,0302)	NO	
Source Instance Sequence	(0042,0013)	A sequence referencing the CT-01 source images	
%item			
>Referenced SOP Class UID	(0008,1150)	1.2.840.10008.5.1.4.1.1.2.1	Referenced object is an Enhanced CT Image Storage
>Referenced SOP Instance UID	(0008,1155)	2.999.89235.5951.35894.155	The multi-frame CT image from study CT-01
%item			
>>Purpose of Reference Code Sequence	(0040,A170)		
%item			
		(121324, DCM, "Source image")	From CID 7xxx Encapsulated Document Source Purposes of Reference
%enditem			
%enditem			
%enditem			
Document Title	(0042,0010)	CT 3D CAM model	
Concept Name Code Sequence	(0040,A043)		
%item			
		(85040-4, LN, "CT 3D CAM model")	From CID 7xx1. LOINC code for CT derived 3D model
%enditem			
MIME Type of Encapsulated Document	(0040,0012)	model/stl	
Encapsulated Document	(0042,0011)	Byte stream representing the binary STL file.	Note that ASCII STL files are not supported.

Attribute Name	Tag	Example Value	Comments
Content Description	(0070,0081)	Mirrored and trimmed skull plate model from CT	Description of the model
Icon Image Sequence	(0088,0200)	Sequence containing an image	The pre-rendered preview image
%item			
		See Table C.7-11b "Image Pixel Macro Attributes"	
%enditem			

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**Table HHHH.1-2
Encapsulated STL Example (Manufacturing 3D Model Module Values)**

Attribute Name	Tag	Example Value	Comments
Model Modification	(aaa1,bbb1)	YES	
Model Mirroring	(aaa1,bbb2)	YES	In this example, mirroring (from the right side) was performed to create the object.
Model Usage Code Sequence	(aaa1,bbb3)		
%item			
		(abcdefg09, DCM, "Implant Fabrication")	In this example, the goal is to implant the object in the patient, so the value is "Implant Fabrication". See CID 7XX4 for other Defined Terms.
%enditem			
Measurement Units Code Sequence	(0040,08EA)		
%item			
		(mm, UCUM, "mm")	
%enditem			

285 **HHHH.2 EXAMPLE OF FUSED CT/MR DERIVED ENCAPSULATED STL**

The second example is slightly more elaborate. The patient will shortly be undergoing a complex cardiac surgery. A 3D manufacturing model (encoded in binary STL) was created to manufacture a surgical : planning aid representing the patient's unique anatomy.

290 The model used, as input data, a series of CT images (CT-02) and MR images (MR-01) that were registered and fused. The model was created on July 16, 2017 at 1:04:34 PM, while the CT and MR data were acquired at earlier dates.

The STL file in this example is a second version; the surgical team requested modification of an earlier STL model (also encapsulated as DICOM) to include less of the heart's surrounding anatomy.

295 The creator of the model registered CT-02 and MR-01, using CT-02's frame of reference as the base coordinate system. The resulting STL was created in the coordinate system of CT-02; so they share the same Frame of Reference value.

Note: Mapping to other Frames of Reference of secondary source series would be handled via registration objects.

A preview image was created showing the rendered 3D object.

300 In this example, the creator of the model inscribed the patient’s medical record number on a side of the model, to avoid the possibility of a wrong patient error.

**Table HHHH.2-1
Encapsulated STL Example (Encapsulated Document Series and Document Values)**

Attribute Name	Tag	Example Value	Comments
Modality	(0008,0060)	M3D	
...			
Series Description	(0008,103E)	3DP Models	
...			
Content Date	(0008,0023)	20170716	
Content Time	(0008,0033)	13:00:34	
Acquisition DateTime	(0008,002A)	20170716 13:00:34	
Image Laterality	(0020,0062)	U	
Burned In Annotation	(0028,0301)	YES	
Recognizable Visual Features	(0028,0302)	NO	
Source Instance Sequence	(0042,0013)	A sequence referencing CT-02 source images and MR-01 source images	Images from 2 studies are included because they both provided source data.
%item			
>Referenced SOP Class UID	(0008,1150)	1.2.840.10008.5.1.4.1.1.2.1	Referenced object is an Enhanced CT Image Storage
>Referenced SOP Instance UID	(0008,1155)	2.999.89235.5951.35894.153	The multi-frame CT image from study CT-02
%item			
>>Purpose of Reference Code Sequence	(0040,A170)		
%item			
		(121324, DCM, "Source image")	From CID 7xxx Encapsulated Document Source Purposes of Reference.
%enditem			
%enditem			
%enditem			

Attribute Name	Tag	Example Value	Comments
%item			
>Referenced SOP Class UID	(0008,1150)	1.2.840.10008.5.1.4.1.1.4.1	Referenced object is an Enhanced MR Image Storage
>Referenced SOP Instance UID	(0008,1155)	2.999.89235.5951.35894.154	The multi-frame MR image from study MR-01
%item			
>>Purpose of Reference Code Sequence	(0040,A170)		
%item			
		(121324, DCM, "Source image")	From CID 7xxx Encapsulated Document Source Purposes of Reference.
%enditem			
%enditem			
%enditem			
Document Title	(0042,0010)	Mixed Modality 3D CAM model	
Concept Name Code Sequence	(0040,A043)		
%item			
		(abcdef02, DCM, "Mixed Modality 3D CAM model")	From CID 7xx1. DCM code for a derived 3D model involving multiple modalities
%enditem			
Predecessor Documents Sequence	(0040,A360)	A sequence referencing the UID of the earlier encapsulated STL	The earlier encapsulated STL is included so that end users can understand how this model relates to
%item			>Include Table C.17-3 'Hierarchical SOP Instance Reference Macro'
> Study Instance UID	(0020,000D)	2.999.1241.1515.15151.515.62	
> Reference Series Sequence	(0008,1115)		
%item			
>> Series Instance UID	(0020,000E)	2.999.89235.5951.35894.151	
>> Referenced SOP Sequence	(0008,1199)		
%item			

Attribute Name	Tag	Example Value	Comments
>>> Referenced SOP Class UID	(0008,1150)	1.2.840.10008.5.1.4.1.1.xxxx	<u>Encapsulated STL SOP Class</u>
>>> Referenced SOP Instance UID	(0008,1155)	2.999.1241.1515.15151.515.68	
%enditem			
%enditem			
%item			
>>Purpose of Reference Code Sequence	(0040,A170)		
%item			
		(abcdefg03, DCM, "Edited Model")	From CID 7xx2. This model modified the earlier one to achieve more fine-grained segmentation
%enditem			
%enditem			
%enditem			
MIME Type of Encapsulated Document	(0040,0012)	model/stl	
Encapsulated Document	(0042,0011)	Byte stream representing the binary STL file.	Note that ASCII STL files are not supported.
Content Description	(0070,0081)	Pre-surgery cardiac model from CT and MR	Description of the model
Icon Image Sequence	(0088,0200)	Sequence containing an image	The pre-rendered preview image
%item			
		See Table C.7-11b "Image Pixel Macro Attributes"	
%enditem			

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**Table HHHH.2-2
Encapsulated STL Example (Manufacturing 3D Model Module Values)**

Attribute Name	Tag	Example Value	Comments
Model Modification	(aaa1,bbb1)	NO	
Model Mirroring	(aaa1,bbb2)	NO	
Model Usage Code Sequence	(aaa1,bbb3)		
%item			

Attribute Name	Tag	Example Value	Comments
		(abcdefg06, DCM, "Planning Intent")	In this example, the goal is to help plan the surgery, so the value is "Planning Intent". See CID 7XX4 for other Defined Terms.
%enditem			
Measurement Units Code Sequence	(0040,08EA)		
%item			
		(mm, UCUM, "mm")	
%enditem			