

## **Digital Imaging and Communications in Medicine (DICOM)**

### *Supplement 208: DICOM Encapsulation of OBJ Models for 3D Manufacturing and Virtual Reality*

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## Scope and Field of Application

This supplement extends the DICOM Standard to better address medical 3D manufacturing and uses of Virtual Reality, Augmented Reality, and Mixed Reality.

40 These extensions fall in three areas:

- 1) Support for a new 3D model type: Object File (OBJ)
- 2) Identification of models for assembly into a larger object
- 3) Capturing a preferred color for manufacturing or display of a model

### **OBJ Encapsulation**

45 The supplement incorporates not just Object Files (OBJ), and also any supporting Material Library Files (MTL) and texture map files (JPG or PNG) on which an OBJ may rely.

As with Encapsulated STL, the new Encapsulated OBJ, Encapsulated MTL and texture image IODs allow 3D manufacturing models to be exchanged between various types of equipment using DICOM messages. This adds the ability to store, query and retrieve complete OBJ models as DICOM Instances. Updates are  
50 addressed by storing new instances, with reference back to earlier instances in a manner similar to the IOD for STL encapsulation.

## Changes to NEMA Standards Publication PS 3.2-2019e

### Digital Imaging and Communications in Medicine

#### Part 2: Conformance

55

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

The SOP Classes are categorized as follows:

60

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

<b>UID Value</b>	<b>UID NAME</b>	<b>Category</b>
...	...	...
<b><u>1.2.840.10008.5.1.4.1.1.104.4</u></b>	<b><u>Encapsulated OBJ Storage SOP Class</u></b>	<b><u>Transfer</u></b>
<b><u>1.2.840.10008.5.1.4.1.1.104.5</u></b>	<b><u>Encapsulated MTL Storage SOP Class</u></b>	<b><u>Transfer</u></b>
...	...	...

## Changes to NEMA Standards Publication PS 3.3-2019e

### Digital Imaging and Communications in Medicine (DICOM)

#### 2 Normative References

65

*Item: Add normative reference*

#### 2.6 Other References

...

70 **[OBJ]: Wavefront Technologies. 1992. Advanced Visualizer. B1. Object Files (.obj).**

**Available from:** [http://www.cs.utah.edu/~boulos/cs3505/obj\\_spec.pdf](http://www.cs.utah.edu/~boulos/cs3505/obj_spec.pdf)

*Modify Section A.1-10 Composite Information Object Modules Overview - Encapsulated Documents – Insert 2 new IODs and update Enc STL to optionally include ICC Profile module*

75

**Table A.1-10  
Composite Information Object Modules Overview - Encapsulated Documents**

IODs Modules	Enc PDF	Enc CDA	Enc STL	Enc OBJ	Enc MTL
Patient	M	M	M	<u>M</u>	<u>M</u>
Clinical Trial Subject	U		U	<u>U</u>	<u>U</u>
General Study	M		M	<u>M</u>	<u>M</u>
Patient Study	U		U	<u>U</u>	<u>U</u>
Clinical Trial Study	U		U	<u>U</u>	<u>U</u>
Clinical Trial Series	U		U	<u>U</u>	<u>U</u>
Encapsulated Document Series	M		M	<u>M</u>	<u>M</u>
Frame of Reference			M	<u>M</u>	
General Equip.	M	M	M	<u>M</u>	<u>M</u>
Enhanced General Equip.			M	<u>M</u>	<u>M</u>
SC Equipment	M	M			
Encapsulated Document	M	M	M	<u>M</u>	<u>M</u>
Manufacturing 3D Model			M	<u>M</u>	<u>M</u>
<b>ICC Profile</b>			<u>U</u>	<u>U</u>	<u>U</u>
SOP Common	M	M	<u>M</u>	<u>M</u>	<u>M</u>
Common Instance Reference			C	<u>C</u>	<u>C</u>

*Modify Section A.8.5.4 Allow for TEXTUREMAP modality designation, when images are texture maps*

#### **A.8.5.4 Multi-frame True Color SC Image IOD Content Constraints**

The VOI LUT Module shall not be present.

80 **For images being referenced as texture maps that are not clinical images, a modality value of TEXTUREMAP may be used as the value of Modality (0008,0060).**

...

*Modify Annex A.85.1.3 – Add optional ICC Profile module to Encapsulated STL modules*

85 **A.85.1.3 Encapsulated STL IOD Module Table**

Table A.85.1-1 specifies the Encapsulated STL IOD Modules.

**Table A.85.1-1  
Encapsulated STL IOD MODULES**

<b>IE</b>	<b>Module</b>	<b>Reference</b>	<b>Usage</b>
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	Encapsulated Document Series	C.24.1	M
	Clinical Trial Series	C.7.3.2	U
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.35.1	M
	SOP Common	C.12.1	M
	<b>ICC Profile</b>	<b>C.11.15</b>	<b>U</b>
	Common Instance Reference	C.12.2	C - Required if other instances are referenced

*Modify Annex A.85 – Insert new section for Encapsulated OBJ and MTL IODs after A.85.1 (STL)*

## **A.85.2 Encapsulated OBJ IOD**

### **A.85.2.1 Encapsulated OBJ IOD Description**

95 The Encapsulated OBJ Information Object Definition (IOD) describes a 3D model in OBJ format. Any supporting material library file (MTL) and supporting 2D texture map image files are addressed in other distinct IODs (see A.85.3.1 and A.8.5.4).

### **A.85.2.2 Encapsulated OBJ Entity-Relationship Model**

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

### **A.85.2.3 Encapsulated OBJ IOD Module Table**

100 Table A.85.2-1 specifies the Encapsulated OBJ IOD Modules.

**Table A.85.2-1  
Encapsulated OBJ IOD MODULES**

<b>IE</b>	<b>Module</b>	<b>Reference</b>	<b>Usage</b>
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	Encapsulated Document Series	C.24.1	M
	Clinical Trial Series	C.7.3.2	U
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.35.1	M
	ICC Profile	C.11.15	U
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	C - Required if other instances are referenced

### **A.85.2.4 Encapsulated OBJ IOD Content Constraints**

#### **A.85.2.4.1 Encapsulated Document**

The Encapsulated Document (0042,0011) Attribute shall contain an ASCII OBJ byte stream [OBJ].

Note.

The Frame of Reference UID (0020,0052) is an identifier for the origin and axes implicit in the OBJ data.



**A.85.2.4.2 MIME Type of Encapsulated Document**

Enumerated Values:

**model/obj**

**A.85.2.4.3 Modality**

115 Enumerated Values:

**M3D**

**A.85.3 Encapsulated MTL IOD**

**A.85.3.1 Encapsulated MTL IOD Description**

120 The Encapsulated MTL Information Object Definition (IOD) describes in MTL format a materials library used by an Encapsulated OBJ 3D model (see A.85.2.1).

**A.85.3.2 Encapsulated MTL Entity-Relationship Model**

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

**A.85.3.3 Encapsulated MTL IOD Module Table**

125 Table A.85.3-1 specifies the Encapsulated MTL IOD Modules.

**Table A.85.3-1  
Encapsulated MTL IOD Modules**

<b>IE</b>	<b>Module</b>	<b>Reference</b>	<b>Usage</b>
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	Encapsulated Document Series	C.24.1	M
	Clinical Trial Series	C.7.3.2	U
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.35.1	M
	ICC Profile	C.11.15	U
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	C - Required if other instances are referenced

**A.85.3.4 Encapsulated MTL IOD Content Constraints**

130 **A.85.3.4.1 Encapsulated Document**

The Encapsulated Document (0042,0011) Attribute shall contain an ASCII MTL byte stream [OBJ].

**A.85.3.4.2 MIME Type of Encapsulated Document**

Enumerated Values:

**model/mtl**

135 **A.85.3.4.3 Modality**

Enumerated Values:

**M3D**

*Modify PS3.3 C.7.3.1.1.1 Modality – add new defined term.*

**C.7.3.1.1 General Series Attribute Descriptions**

140 **C.7.3.1.1.1 MODALITY**

Defined Terms:

...

STAIN Automated Slide Stainer

**TEXTUREMAP Texture Map**

145 TG Thermography

...

*Extend PS3.3 Annex C.24.2 to add conditionally required Referenced Image Sequence and Referenced Instance Sequence attributes and a per UID URI for preserving file names of referenced instances, so referential integrity of the encapsulated file and supporting files can be maintained.*

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

Attribute Name	Tag	Type	Attribute Description
...			
Source Instance Sequence	(0042,0013)	1C	<p>A sequence that identifies the set of Instances that were used to derive the encapsulated document.</p> <p>One or more Items shall be included in this Sequence.</p> <p>Required if derived from one or more DICOM Instances. May be present otherwise.</p> <p>Note</p> <p>Unlike other uses of Source Instance Sequence (0042,0013), such as in the General Reference Module, references to images are permitted in this Module. This Module does not include the Source Image Sequence (0008,2112). The Defined Context Group for Purpose of Reference Code Sequence (0040,A170) includes an appropriate concept.</p>
>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 single Item is permitted in this Sequence.
>>Include Table 8.8-1 "Code Sequence Macro Attributes"			Defined CID 7013 "Source Instance Purposes of Reference".
<u>Referenced Image Sequence</u>	<u>(0008,1140)</u>	<u>3</u>	<u>The set of image instances referenced in the encapsulated document.</u> <u>One or more Items are permitted in this Sequence.</u>
<u>&gt;Include Table 10-3 "Image SOP Instance Reference Macro Attributes"</u>			
<u>&gt;Relative URI Reference Within Encapsulated Document</u>	<u>(0068,7005)</u>	<u>1C</u>	<u>The relative URI reference used in the encapsulated document to reference the image instance in this Item.</u> <u>This may be used to maintain referential integrity between a set of related encapsulated documents.</u>  <u>Required if the Encapsulated Document (0008,114A) contains a reference to the image instance in this Item.</u>  <u>See C.24.2.4.</u>
<u>Referenced Instance Sequence</u>	<u>(0008,114A)</u>	<u>3</u>	<u>The set of non-image SOP Instances referenced in the encapsulated document.</u> <u>One or more Items are permitted in this Sequence.</u>
<u>&gt;Include Table 10-11 "SOP Instance Reference Macro Attributes"</u>			
<u>&gt;Relative URI Reference Within Encapsulated Document</u>	<u>(0068,7005)</u>	<u>1C</u>	<u>The relative URI reference used in the encapsulated document to reference the SOP Instance in this Item.</u> <u>This may be used to maintain referential integrity between a set of related encapsulated documents.</u>  <u>Required if the Encapsulated Document (0008,114A) contains a reference to the SOP Instance in this Item.</u>  <u>See C.24.2.4.</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.
...			

...

#### **C.24.2.4 Relative URI Reference Within Encapsulated Document**

**The relative URI reference within encapsulated document value shall be encoded as a relative URI reference [RFC3986], with the following restrictions:**

- The base path (URI) to which the reference is relative is the location where the referencing file would hypothetically be written, were it to be unencapsulated and written to a file, such that the set of related encapsulated documents share the same base path.

- The path shall not begin with a slash or two slashes.
- The path shall not refer to a higher level in the file system hierarchy (i.e., use of ".." is not permitted).
- File name extensions corresponding to executable file types (exe, dll, etc.) are not permitted.
- Embedded white space is not permitted.

160

The following are examples of valid relative URI references:

"matlist.mtl"

"materials/matlist.mtl"

"/materials/matlist.mtl"

165

The following are examples of invalid relative URI references:

"file:///matlist.mtl" (not a relative reference)

"/matlist.mtl" (initial slash not permitted)

"/matlist.mtl" (initial slashes not permitted)

"c:/matlist.mtl" (not a relative reference)

"/matlist.mtl" (".." not permitted)

"mat list.mtl" (embedded spaces not permitted)

"materials\matlist.mtl" (backslash not permitted)

170

175

*Modify PS3.3 Annex C.27 to remove ambiguity while maintaining conformance with current conventions.*

#### **C.27.1.1.3 Recommended Presentation**

Recommended Presentation Opacity (0066,000C) is a fraction between 0.0 and 1.0 encoded as a float value representing the blending proportion of the rendering of the surface relative to underlying features. **A value of 0.0 is interpreted as complete transparency, while a value of 1.0 is interpreted as fully opaque.**

180

Modify PS3.3 Annex C.35 to broaden language to cover new encapsulations, add new attributes and define associated terms.

**C.35.1 Manufacturing 3D Model Module**

Table C.35.1-1 defines attributes specific to models used in medical 3D manufacturing.

**Table C.35.1-1 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 <b>STL 3D Manufacturing Model</b> file Only a single Item shall be included in this Sequence.
>Include Table 8.8-1 "Code Sequence Macro Attributes"			DCID 7063 "Model Scale Units".
Model Modification	(0068,7001)	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: <b>YES</b> <b>NO</b>
Model Mirroring	(0068,7002)	3	Specifies whether mirroring of anatomy from the other side of the patient was used to create the model  Enumerated Values: <b>YES</b> <b>NO</b>
Model Usage Code Sequence	(0068,7003)	3	Specifies the use for which the manufactured object is intended. Only a single Item shall be permitted in this Sequence.
>Include Table 8.8-1 "Code Sequence Macro Attributes"			BCID 7064 "Model Usage".
Content Description	(0070,0081)	3	A description of the model.
Icon Image Sequence	(0088,0200)	3	A preview image representing the rendered model. Only a single item shall be permitted in this Sequence.
>Include Table 7-11b "Image Pixel Macro Attributes"			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.
>Include Table 10-19 "Algorithm Identification Macro Attributes"			
<b>Model Group UID</b>	<b>(0068,7004)</b>	<b>3</b>	<b>Uniquely identifies a group to which the model belongs. Manufacturing models that share the same Model Group UID are considered distinct parts within the same assembly.</b>
<b>Recommended Display CIE Lab Value</b>	<b>(0062,000D)</b>	<b>3</b>	<b>Specifies the color recommended to be used for the model. This color applies both when digitally displaying</b>

			<p><u>the model and when selecting material for manufacturing.</u></p> <p><u>This would typically be used to visually distinguish between models that are part of the same assembly and/or provide best analog to real world appearance.</u></p> <p><u>This value may be superseded by individual colors that have been specified inside the encapsulated model (when the encapsulated format allows this).</u></p> <p><u>The units are specified in PCS-Values, and the value is encoded as CIE Lab. See section C.10.7.1.1.</u></p>
<p><b><u>Recommended Presentation Opacity</u></b></p>	<p><b><u>(0066,000C)</u></b></p>	<p><b><u>3</u></b></p>	<p><b><u>Specifies the opacity recommended to be used for the model. This opacity applies both when digitally displaying the model and when selecting material for manufacturing.</u></b></p> <p><b><u>A non-opaque value would typically be specified when either (a) another model grouped in the same assembly needs to be visible behind or inside this model, or (b) the model represents anatomy that is not fully opaque. If not present, then it is assumed the model should be presented and manufactured as opaque. See Section C.27.1.1.3.</u></b></p>

## Changes to NEMA Standards Publication PS 3.4-2019e

### Digital Imaging and Communications in Medicine (DICOM)

#### Part 4: Service Class Specifications

195

*Modify Annex B.5 Standard SOP Classes – add 3 new items*

#### B.5 STANDARD SOP CLASSES

Table B.5-1  
STANDARD SOP CLASSES

SOP Class Name	SOP Class UID	IOD (See PS 3.3)
...		
<b>Encapsulated OBJ Storage</b>	<b>1.2.840.10008.5.1.4.1.1.104.4</b>	<b>Encapsulated OBJ IOD</b>
<b>Encapsulated MTL Storage</b>	<b>1.2.840.10008.5.1.4.1.1.104.5</b>	<b>Encapsulated MTL IOD</b>
...		

200

**Changes to NEMA Standards Publication PS 3.6-2019e**

**Digital Imaging and Communications in Medicine (DICOM)**

**Part 6: Data Dictionary**

205

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

210

**Table 6-1. Registry of DICOM Data Elements**

Tag	Name	Keyword	VR	VM	
...	...	...	...	...	
<b>(0068,7004)</b>	<b>Model Group UID</b>	<b>ModelGroupUID</b>	<b>UI</b>	<b>1</b>	
<b>(0068,7005)</b>	<b>URI Within Encapsulated Document</b>	<b>URIWithinEncapsulatedDocument</b>	<b>UR</b>	<b>1</b>	
...					

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

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

215

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.

**Table A-1  
 UID VALUES**

UID Value	UID NAME	UID TYPE	Part
...			
<b>1.2.840.10008.5.1.4.1.1.104.4</b>	<b>Encapsulated OBJ Storage</b>	<b>SOP Class</b>	<b>PS 3.4</b>
<b>1.2.840.10008.5.1.4.1.1.104.5</b>	<b>Encapsulated MTL Storage</b>	<b>SOP Class</b>	<b>PS 3.4</b>
...			

220



225

*Addition to PS3.16 Content Mapping Resource – Modify CID 32 Non-Acquisition Modality to include texture map.*

**CID 32 NON-ACQUISITION MODALITY**

Version: **20190327 20200118**

**Table CID 32. NON-ACQUISITION MODALITY**

Coding Scheme Designator	Code Value	Code Meaning
...	...	...
<b><u>DCM</u></b>	<b><u>TEXTUREMAP</u></b>	<b><u>Texture Map</u></b>
...	...	...

230

*Addition to PS3.16 Content Mapping Resource – Appendix D, Add new DICOM controlled terminology definition for texture map:*

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

Code Value	Code Meaning	Definition	Notes
...			
<b><u>TEXTUREMAP</u></b>	<b><u>Texture Map</u></b>	<b><u>A device, process or method that produces texture maps. E.g., for use in 3D manufacturing.</u></b>	
...			

235

## Changes to NEMA Standards Publication PS 3.17-2019e

### Digital Imaging and Communications in Medicine

#### Part 17: Informative

*Addition to PS3.17 Append new Annex containing informative information on the creation of encapsulated OBJ/MTL objects and Texture-Maps*

240

#### **RRRR Encapsulated OBJ, 3D Model Grouping, & Color (Informative)**

##### **RRRR.1 Overview**

245

This section explains the encapsulation of a 3D manufacturing model file of the OBJ type inside a DICOM instance. The goal of encapsulating a model rather than transforming the data into a different representation is to facilitate preservation of the 3D file in the exact form that it is used with extant manufacturing devices. At the same time encapsulation populates DICOM header elements that record clinical information absent from the OBJ format, including unambiguously associating it with the patient for whose care the model was created. Encapsulation also makes it possible to link to the images from which the model was derived, even if these came from different studies.

250 The OBJ encapsulation case is slightly more complicated than that of STL (Annex III). The OBJ has supporting files (material library and texture maps). The relationship between the multiple original files and the corresponding DICOM instances is shown in the diagram below.

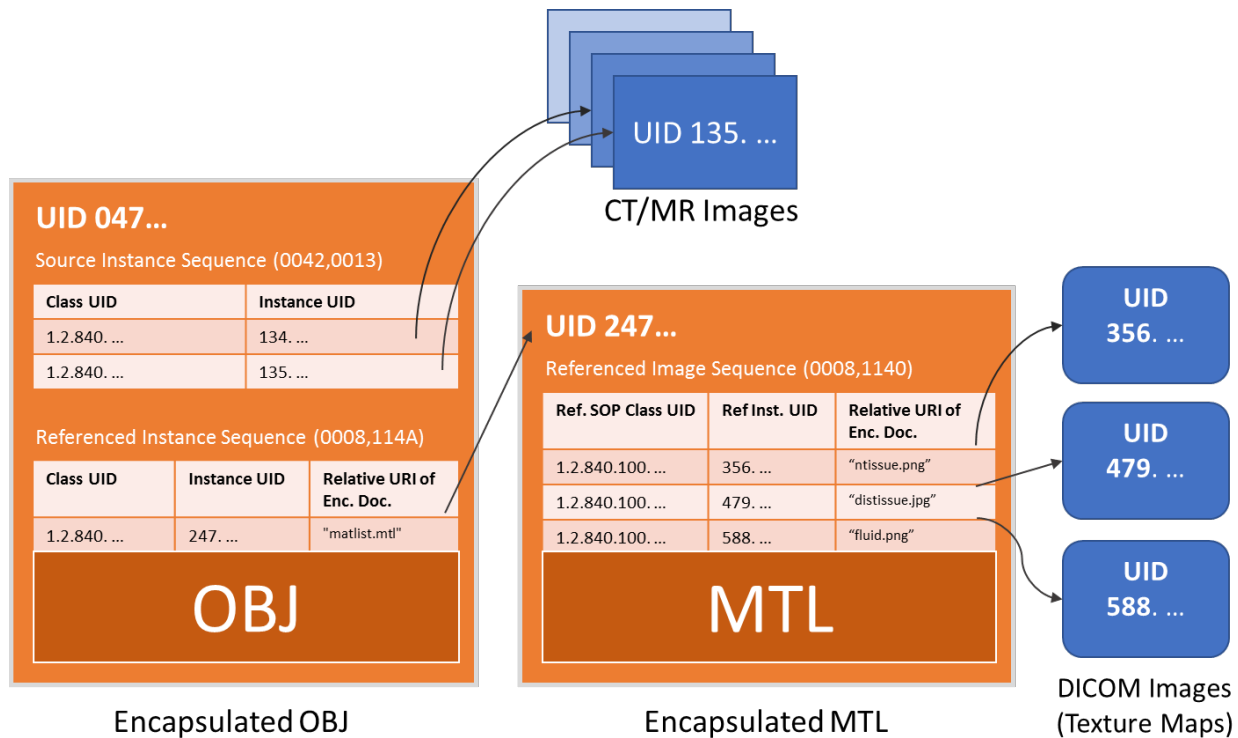


Figure RRRR.1-1 - Relationship between OBJ, MTL and Texture Map image files and corresponding DICOM Instances

255

### RRRR.2 Example Encoding of OBJ & MTL

This Section contains example excerpts for encoding OBJ files and associated preview icons [optional], materials library file (MTL) [optional], and texture map images [optional].

#### 260 Example A:

A patient, Kevin Franz-Lopez, with Medical Record Number 547892459, will shortly be undergoing a complex partial nephrectomy to remove lesions on their left kidney. A 3D manufacturing model (encoded in OBJ) was created to manufacture a surgical planning aid representing the patient's unique anatomy.

265 A model was constructed from a CT dataset (CT1). The model was created on July 16, 2017 at 1:04:34 PM. The model was expressed as a single OBJ file (kidneymodel.obj) which makes use of two texture maps encoded using PNG (ntissue.png and fluid.png) and one texture map encoded using JPEG (distissue.jpg). The relationship between the OBJ and texture maps is captured in the materials list file (matlist.mtl). This set of files corresponds to the Encapsulated MTL and DICOM Images elements in Figure RRRR.1-1.

270

A preview icon was created showing the rendered 3D object for inclusion with the OBJ file when encapsulated.

Table RRRR.2-1 shows the Encapsulated OBJ.

**Table RRRR.2-1  
Encapsulated OBJ Example A**

<b>Attribute Name</b>	<b>Tag</b>	<b>Example Value</b>	<b>Comments</b>
Content Date	(0008,0023)	20170716	
Acquisition DateTime	(0008,002A)	20170716 13:00:34	
Content Time	(0008,0033)	13:00:34	
...			
Modality	(0008,0060)	M3D	
...			
Series Description	(0008,103E)	Nephrectomy Planning Models	
Referenced Instance Sequence	(0008,114A)		
%item			
>Referenced SOP Class UID	(0008,1150)	1.2.840.10008.5.1.4.1.1.104.5	Encapsulated MTL file SOP class
>Referenced SOP Instance UID	(0008,1155)	2.999.89235.5951.35894.751	UID of the encapsulated MTL file (see below) supporting this OBJ model
>Relative URI Reference Within Encapsulated Document	(0068,7005)	"matlist.mtl"	Relative URI that preserved the MTL file's original filename as referenced from within the OBJ file.
%enditem			
...			
Patient Name	(0010,0010)	Franz-Lopez^Kevin	
Patient ID	(0010,0020)	547892459	
...			
Image Laterality	(0020,0062)	L	
Burned In Annotation	(0028,0301)	YES	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.
Recognizable Visual Features	(0028,0302)	NO	
MIME Type of Encapsulated Document	(0040,0012)	model/obj	
%item			

Attribute Name	Tag	Example Value	Comments
>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 CT1
%enditem			
...			
Measurement Units Code Sequence	(0040,08EA)		
%item			
		(mm, UCUM, "mm")	
%enditem			
...			
Document Title	(0042,0010)	Kidney Model	
Encapsulated Document	(0042,0011)	Byte stream representing the OBJ file.	
Source Instance Sequence	(0042,0013)	A sequence referencing CT1 source images	
Model Modification	(0068,7001)	NO	
Model Mirroring	(0068,7002)	NO	
Model Usage Code Sequence	(0068,7003)		
%item			
		(129013, DCM, "Planning Intent")	
%enditem			
Icon Image Sequence	(0088,0200)	Sequence containing an image	A pre-rendered view of the model

Since the above OBJ file contains a reference to a materials library (MTL) file, the MTL's contents must likewise be encapsulated in DICOM, as shown in Table RRRR.2-2.

280

**Table RRRR.2-2  
Encapsulated MTL Example A**

Attribute Name	Tag	Example Value	Comments
SOP Instance UID	(0008,0018)	2.999.89235.5951.35894.751	UID referenced in the Referenced Instance Sequence of the Encapsulated OBJ object in the table above
...			

<b>Attribute Name</b>	<b>Tag</b>	<b>Example Value</b>	<b>Comments</b>
Modality	(0008,0060)	M3D	
...			
Series Description	(0008,103E)	Nephrectomy Planning Models	
...			
Content Date	(0008,0023)	20170716	
Content Time	(0008,0033)	13:00:34	
...			
Referenced Image Sequence	(0008,1140)		
%item			
>>Referenced SOP Class UID	(0008,1150)	1.2.840.10008.5.1.4.1.1.7.4	Multi-frame True Color Secondary Capture SOP class
>>Referenced SOP Instance UID	(0008,1155)	2.999.89235.5951.35894.841	UID reference to texture image used for normal kidney tissue (Multi-frame True Color Secondary Capture Instance)
>>Referenced SOP Class UID	(0008,1150)	1.2.840.10008.5.1.4.1.1.7.4	Multi-frame True Color Secondary Capture SOP class
>>Relative URI Reference Within Encapsulated Document	(0068,7005)	"ntissue.png"	Relative URI that preserved the first texture map's original filename as referenced from within the MTL file.
>>Referenced SOP Instance UID	(0008,1155)	2.999.89235.5951.35894.842	UID reference to texture image used for diseased kidney tissue (Multi-frame True Color Secondary Capture Instance)
>>Relative URI Reference Within Encapsulated Document	(0068,7005)	"distissue.png"	Relative URI that preserved the second texture map's original filename as referenced from within the MTL file.
>>Referenced SOP Class UID	(0008,1150)	1.2.840.10008.5.1.4.1.1.7.4	Multi-frame True Color Secondary Capture SOP class
>>Referenced SOP Instance UID	(0008,1155)	2.999.89235.5951.35894.843	UID reference to texture image used for fluid (Multi-frame True Color Secondary Capture Instance)
>>Relative URI Reference Within	(0068,7005)	"fluid.jpg"	Relative URI that preserved the third texture map's original filename as

Attribute Name	Tag	Example Value	Comments
Encapsulated Document			referenced from within the MTL file.
%enditem			
...			
Patient Name	(0010,0010)	Franz-Lopez^Kevin	
Patient ID	(0010,0020)	547892459	
...			
MIME Type of Encapsulated Document	(0040,0012)	model/mtl	
Document Title	(0042,0010)	Kidney Model Materials	
Encapsulated Document	(0042,0011)	Byte stream representing the MTL file.	
...			

285

The example MTL file contains references to three texture images (see Referenced Image Sequence above) and these likewise need to be encoded in DICOM (if they are not natively DICOM). The Multi-frame True Color Secondary Capture Instance is used to represent such texture images in DICOM, regardless of the original format in which the texture map image was stored.

In our example, the pixel data is read from the PNG files “ntissue.png” and “distissue.png”, and the JPEG file “fluid.jpg”. Corresponding DICOM Multi-Frame True Color Secondary capture images are created for

each of these texture maps, as is shown in Figure RRRR.2-1. The original filenames are preserved in the URI Within Encapsulated Document values within the Encapsulated MTL’s Referenced Image Sequence.

290

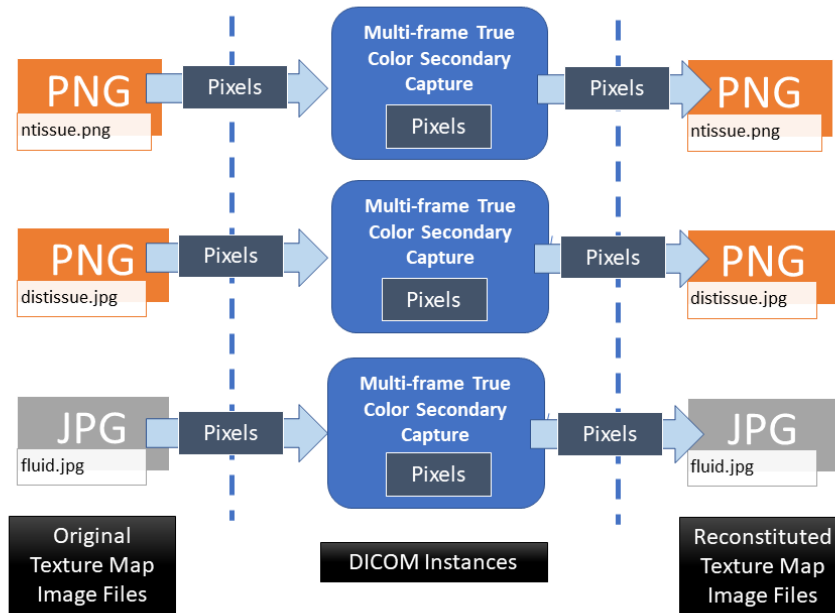


Figure RRRR.2-1 - Example of Converting Texture Map Images into DICOM Images and back again

An abbreviated version of the first of these three object’s DICOM headers is shown in Table RRRR.2-3, focusing on how these relate to use with an MTL Instance.

295

**Table RRRR.2-3**  
**Multi-frame True Color Secondary Capture Texture Map Example A**

Attribute Name	Tag	Example Value	Comments
...			
Modality	(0008,0060)	TEXTUREMAP	Indicates that the image is a texture map, and not some other image taken of the patient
...			

300

It is important to note that when de-encapsulating MTL file, the texture map images must be restored to both their original file name and file format (as indicated by the corresponding URI Within Encapsulated Document attribute values contained in the Encapsulated MTL instance that references the texture map images. This is done so that the file name references inside the MTL, which will be read by downstream OBJ-capable software, will still be valid. Thus, in our example, our first texture map DICOM image must be converted back into a PNG (as indicated by the file extension in Relative URI Reference Within Encapsulated Document value) and saved to the file system as “ntissue.png” in the same location as the OBJ and MTL files.

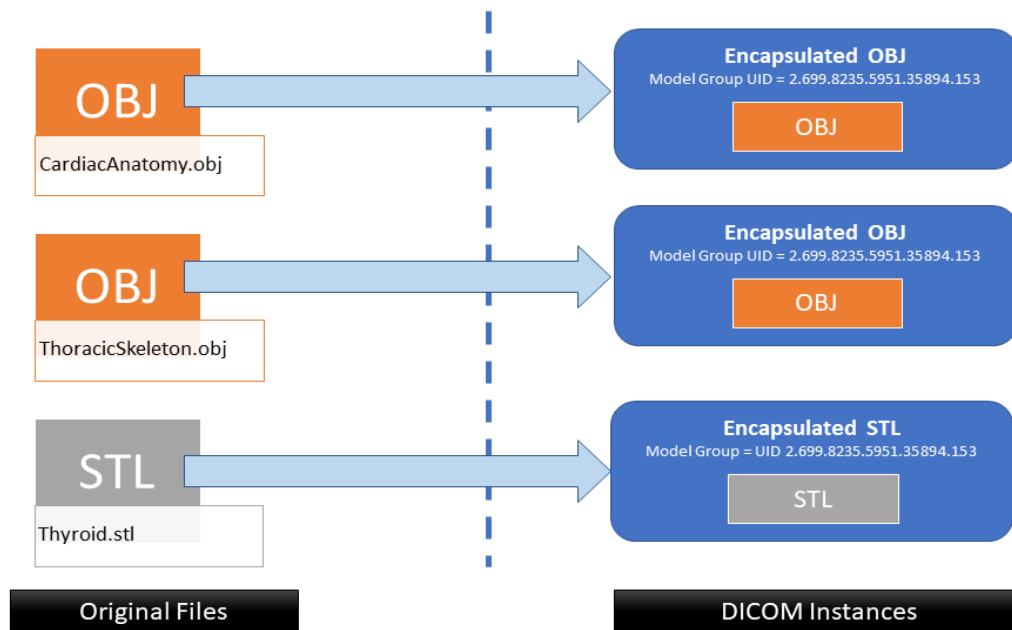
305

The two other texture map images would be encoded in a manner like the one above.



### RRRR.3 Manufacturing Model Grouping, Color & Opacity (Informative)

310 This example explains how to group manufacturing models together to indicate that they are intended to be assembled into a single unit (either after production, or as part of production on a multi-material printer). As shown in Figure RRRR.3-1, a group of models can include a mix of both STL and OBJ encapsulations (CardiacAnatomy.obj, ThoracicSkeleton.obj, and Thyroid.stl). All that is required to indicate grouping is that the Model Group UID (0068,7004) be set to the same UID value for all objects in the group. In this example the optional material file was not needed by the OBJ.



315 *Figure RRRR.3-1 - Example of Model Group UID Usage*

320 It is possible to specify preferred color and opacity of Manufacturing 3D Models using Recommended Display CIELab Value (0062,000D) and Recommended Presentation Opacity (0066,000C). One particular use of these attributes is in combination with model grouping, as it allows the use of non-opaque materials to allow viewing of interior parts of the grouped assembly. An example of such use is shown in Figure RRRR.3-2, where the AorticCalcifications.obj model is intended to be assembled inside the Aorta.stl model. Therefore, the DICOM Encapsulated STL of the aorta is designated as having a recommended

presentation of semi-transparent red, while DICOM Encapsulated OBJ of the calcifications is fully opaque white.

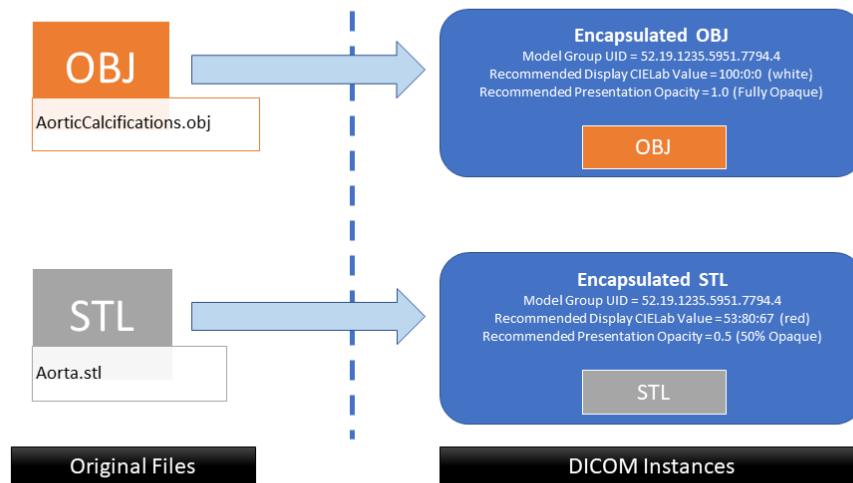


Figure RRRR.3-2 - Example of Model Color and Opacity