Digital Imaging and Communications in Medicine (DICOM)

Supplement 43: Storage of 3D Ultrasound Images

Prepared by:

DICOM Standards Committee, Working Group 12, Ultrasound
1300 N. 17th Street, Suite 1752
Rosslyn, Virginia 22209 USA

Developed pursuant to Work Item 1998-08-C

VERSION: Final Text – 10 April 2009

Table of Contents

Scope and Field of Application

This supplement to the DICOM standard defines the storage of 3D ultrasound volume datasets and the 2D views that are derived from this volume data. A new Enhanced US IOD based on the concepts introduced with the enhanced MR SOP Classes and a new Waveform IOD for the storage of physiological waveforms acquired as part of the ultrasound procedure are defined.

Ultrasound (US) has many similarities to other imaging modalities like CT and MR, and this Supplement attempts to leverage the methods used by other modalities wherever possible. Ultrasound also has distinct characteristics, and these are specfically addressed by the supplement:

1. US images often contain multiple types of image data including (but not limited to): amplitude or intensity data representing the strength of returning echo intensity as a function of tissue heterogeneity; blood flow data representing the motion of moving scatterers in the blood, or as contrast micro-bubbles, that may displayed as a time-velocity plot or as color/brightness-coded images overlayed on amplitude images. Various display modes use overlays and split images to present this information.
2. Lack of a patient frame of reference. Images and volume data may be acquired from arbitrary orientations and acoustic windows chosen to optimize the view of patient anatomy. The lack of a patient frame of reference makes inter-comparison between images and volumes challenging.
3. The ultrasound user is accustomed to looking at different transducer topologies and ultrasound images are generally produced from non-parallel acquisition strategies. Ultrasound images often are acquired as a series of diverging scan lines sweeping across a region, and scan lines are converted to a 2D or 3D Cartesian coordinate system for display and archival. Similarly, a series of 2D ultrasound images may be acquired as a series of diverging scan planes sweeping across a volume region. These planes are then converted to a Cartesian coordinate system to create a volume for display and archival. Generally various interpolation functions are employed to produce an image, or volume, without gaps.
4. Non-image data types like physiological waveforms are a normal part of an Ultrasound exam acquisition and display.
5. Real-time imaging at a relatively high frame rate. US image and volume data may be produced at rates from 1 Hz to 150 Hz depending on study parameters.
6. There is no expectation that acquisition slice orientation is constant between images.

Other non-image data types like M-Mode and Doppler Spectral traces are also a normal part of an Ultrasound exam, but are not addressed in this Supplement.

This supplement addresses the exchange of a number of different types of Ultrasound 3D source and derived image data shown in Figure 1. It can be seen that there are two different types of data related to 3D image acquisition: the 3D volume dataset and 2D images derived from the volume dataset.

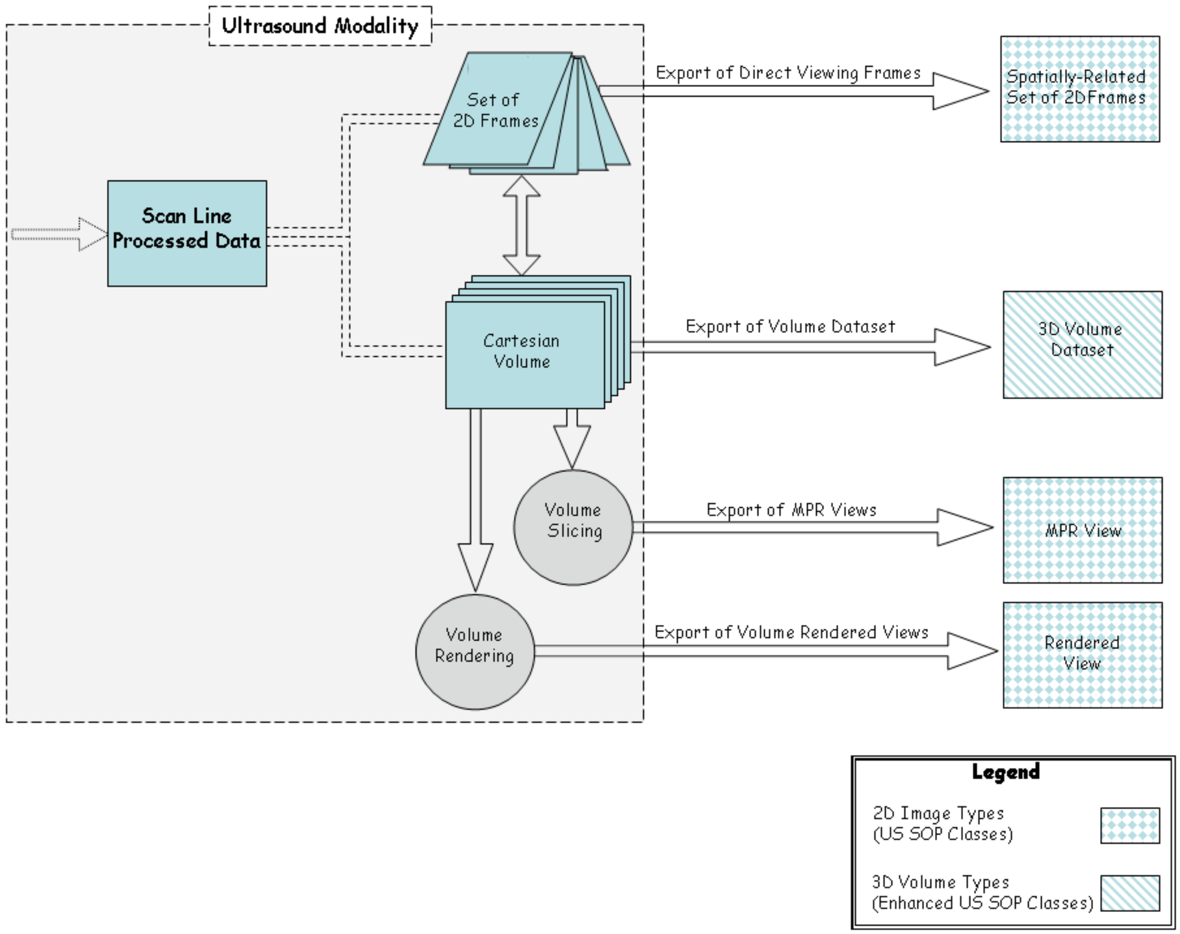

Figure 1: Types of 3D Ultrasound Source and Derived Images

The 3D volume dataset is conveyed via a new storage SOP Class defined for the Ultrasound (US) modality called Enhanced Ultrasound SOP Class, augmenting (but not retiring) the Ultrasound Image and Ultrasound Multi-frame Image SOP Classes.

Changes to NEMA Standards Publication PS 3.2-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 2: Conformance

Item #1: Add new SOP Class in Table A.1-2

Table A.1-2
UID VALUES

UID Value	UID NAME	Category
…		
1.2.840.10008.5.1.4.1.1.6.2	Enhanced US Volume Storage	Transfer
1.2.840.10008.5.1.4.1.1.9.5.1	Arterial Pulse Waveform Storage	Transfer
1.2.840.10008.5.1.4.1.1.9.6.1	Respiratory Waveform Storage	Transfer
1.2.840.10008.5.1.4.1.1.9.4.2	General Audio Waveform Storage	Transfer
…		

Changes to NEMA Standards Publication PS 3.3-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 3: Information Object Definitions

Item #2: Add new IODs to Table A.1-1

IODs Modules	Enh. US Vol
Patient	M
Clinical Trial subject	U
General Study	M
Patient Study	U
Clinical Trial Study	U
General Series	M
Enhanced US Series	M
Clinical Trial Series	U
Frame Of Reference	M
Ultrasound Frame of Reference	M
Synchronization	M
General Equipment	M
Enhanced General Equipment	M
General Image	M
Image Pixel	M
Enhanced Contrast/Bolus	C
Multi-frame Functional Groups	M
Multi-frame Dimension	M
Cardiac Synchronization	C
Respiratory Synchronization	C
Device	U
Acquisition Context	M
Specimen	U
Enhanced Palette Color Lookup Table	U
Enhanced US Image	M
IVUS Image	C
Excluded Intervals	U
SOP Common	M

IODs Modules	Pulse WF	Respiratory WF	Gen Audio WF
Patient	M	M	M
Clinical Trial subject	U	U	U
General Study	M	M	M
Patient Study	U	U	U
Clinical Trial Study	U	U	U
General Series	M	M	M
Clinical Trial Series	U	U	U
Synchronization	M	M	M
General Equipment	M	M	M
Enhanced General Equipment	M	M	M
Waveform Identification	M	M	M
Waveform	M	M	M
Acquisition Context	M	M	M
Waveform Annotation	C	C	C
SOP Common	M	M	M

Item #3: Add sections to Annex A

A.X Enhanced Ultrasound Volume Information Object Definition

A.X.1 Enhanced US Volume IOD Description

Image objects of different types may be created from a 3D Ultrasound image acquisition, illustrated in Figure A.X-1. It can be seen that there are two different types of data related to 3D image acquisition: 3D volume datasets and several kinds of 2D image derived from the volume dataset.

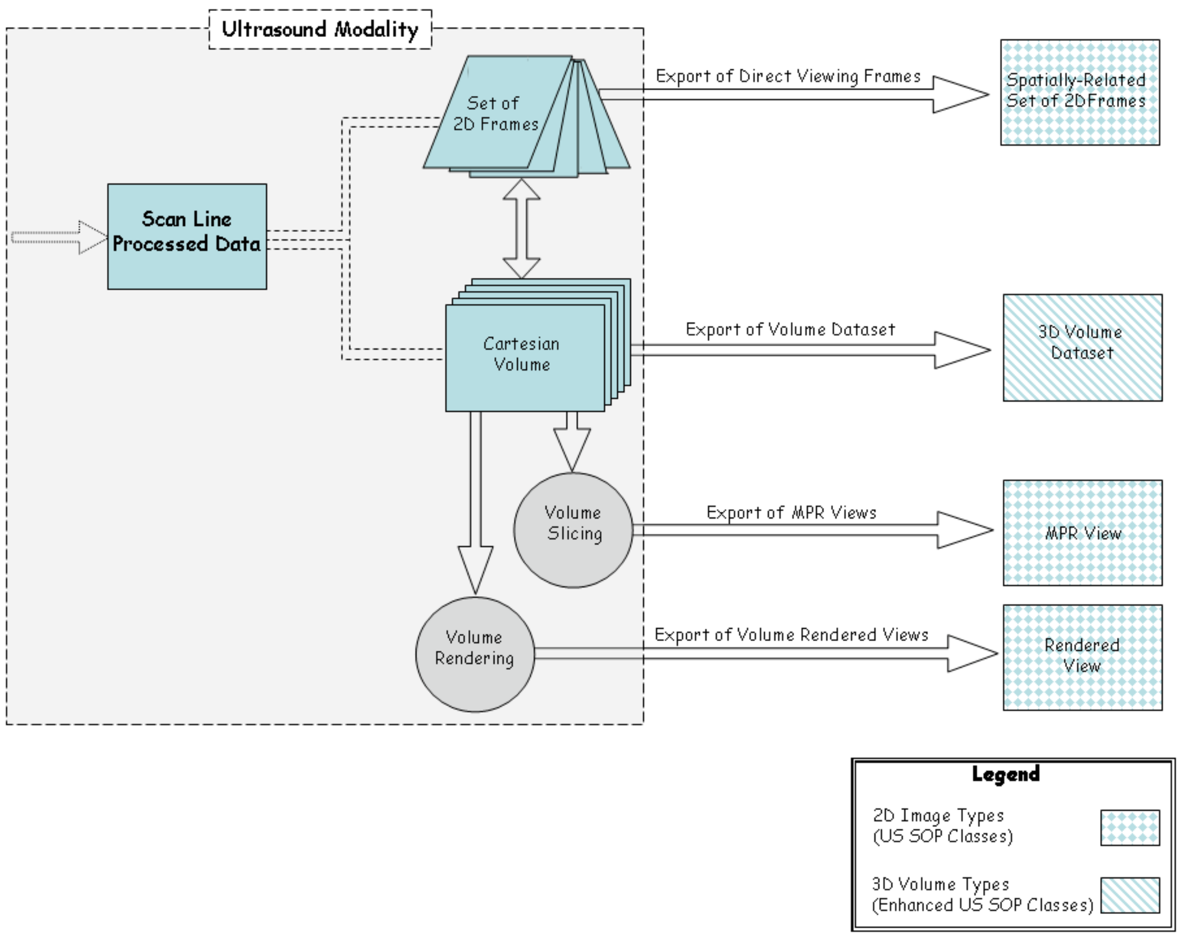

Figure A.X-1: Types of 3D Ultrasound Source and Derived Images (Informative)

The 3D volume dataset (the diagonally shaded box in Figure A.X-1) contains a Cartesian volume or two or more temporally related Cartesian volumes. 3D volume datasets are exchanged using the Enhanced US Volume SOP Class, and are suitable for subsequent Multi-Planar Reconstruction and rendering operations. Within each Enhanced US Volume instance, each Cartesian volume consists of a set of parallel planes, and each plane consists of one or more frames each of a single data type. All Cartesian volumes have the same spacing between adjacent planes.

Most acquisition devices construct the Cartesian volume by resampling data from a different acquisition geometry. The method of generation of the Cartesian volume, its relationship to spatially-related 2D frames (whether the volume was created from spatially-related frames, or spatially-related frames extracted from the Cartesian volume), and the algorithms used for Multi-Planar Reconstruction and rendering operations are outside the scope of this standard.

The 2D image types represent collections of frames that are derived from the volume dataset, namely 3D rendered views (projections), separate Multi-Planar Reconstructed (MPR) views, or sets of spatially-related source frames, either parallel or oblique (the cross-hatched boxes in Figure A.X-1). The Ultrasound Image and Ultrasound Multiframe Image IOD's are used to represent these derived images. See Section A.6 for the Ultrasound Image IOD description or section A.7 for the Ultrasound Multi-frame Image IOD description.

Note: See PS3.17 "3D Ultrasound Volumes" for an informative discussion on the use of these objects for the exchange of 3D ultrasound volume data.

A.X.2 Enhanced US Volume IOD Entity-Relationship Model

The E-R Model in section A.1.2 depicts those components of the DICOM Information Model that comprise the Enhanced US Volume IOD.

A.X.3 Enhanced US Volume IOD Module Table

Table A.X-1
ENHANCED ULTRASOUND VOLUME IOD MODULES

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	General Series	C.7.3.1	M
	Enhanced US Series	C.8.X.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
	Ultrasound Frame of Reference	C.8.X.2	M
	Synchronization	C.7.4.2	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Image	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Enhanced Contrast/Bolus	C.7.6.4b	C – Required if contrast media was applied. See Section A.X.3.1.2 for baseline context group ID.
	Multi-frame Functional Groups	C.7.6.16	M
	Multi-frame Dimension	C.7.6.17	M

IE	Module	Reference	Usage
	Cardiac Synchronization	C.7.6.18.1	C – Required if cardiac synchronization was applied.
	Respiratory Synchronization	C.7.6.18.2	C – Required if respiratory synchronization was applied.
	Device	C.7.6.12	U
	Acquisition Context	C.7.6.14	M
	Specimen	See Sup122	U
	Enhanced Palette Color Lookup Table	C.7.6.X	U
	Enhanced US Image	C.8.X.3	M
	IVUS Image	C.8.X.4	C – Required if Modality = IVUS
	Excluded Intervals	C.8.X.5	U
	SOP Common	C.12.1	M

A.X.3.1 Enhanced US Volume IOD Content Constraints

A.X.3.1.1 Associated Physiological Waveforms

The Acquisition Time Synchronized attribute (0018,1800) shall have a value of 'Y' if associated physiological waveforms are linked to the Enhanced US Volume. As described in the Synchronization Module, the same value of the Synchronization Frame of Reference UID (0020,0200) is shared between the Waveform and Enhanced US instances to indicate a common temporal frame of reference for the Acquisition Datetime (0008,002A) values in the waveform and Enhanced US instances. Further, the Frame Reference Datetime attribute (0018,9151) may be used in optimizing alignment between the displayed image and displayed physiological waveforms.

In the case of gated acquisition in which information from multiple events (such as ECG beats) are used to create sub-volumes that are "spliced" or "interleaved" together to form the volume dataset, the Excluded Intervals Module describes the timing of each of the constituent sub-volumes for correlation with the physio waveform.

Note: It is recommended that the Waveform Annotation Module in the General ECG Waveform IOD be used to indicate the times of the R-wave events within the acquisition duration. This allows the viewing application to be able to mark those R-R intervals that contributed to the acquisition of the Enhanced US Volume.

A.X.3.1.2 Contrast

Baseline context ID for the Contrast/Bolus Agent Sequence (0018,0012) in the Enhanced Contrast/Bolus Module is CID 12030.

A.X.4 Enhanced US Volume Functional Group Macros

Table A.X-2 specifies the use of the Functional Group macros used in the Multi-frame Functional Groups Module for the Enhanced US Volume IOD.

Table A.X-2
ENHANCED US VOLUME FUNCTIONAL GROUP MACROS

Functional Group Macro	Section	Usage
Frame Content	C.7.6.16.2.2	M – May not be used as a Shared Functional Group.
Plane Position (Patient)	C.7.6.16.2.3	U
Plane Orientation (Patient)	C.7.6.16.2.4	U
Referenced Image	C.7.6.16.2.5	U
Derivation Image	C.7.6.16.2.6	C – Required if the image or frame has been derived from another SOP Instance.
Cardiac Synchronization	C.7.6.16.2.7	C – Required if Cardiac Synchronization is used
Frame VOI LUT	C.7.6.16.2.10	M
Real World Value Mapping	C.7.6.16.2.11	U
Contrast/Bolus Usage	C.7.6.16.2.12	C – Required if the Enhanced Contrast/Bolus Module is present
Patient Orientation in Frame	C.7.6.16.2.15	U
Frame Display Shutter	C.7.6.16.2.16	U
Respiratory Synchronization	C.7.6.16.2.17	C – Required if Respiratory Synchronization is used
Plane Position (Volume)	C.7.6.16.2.X1	M – May not be used as a Shared Functional Group. See A.X.4.1.2.
Plane Orientation (Volume)	C.7.6.16.2.X2	M – May not be used as a Per-Frame Functional Group. See A.X.4.1.2.
Temporal Position	C.7.6.16.2.X3	C – Required if frames are temporally related and not temporally referenced to a Cardiac or Respiratory event
Image Data Type	C.7.6.16.2.X4	M
US Image Description	C.8.X.6.1	M – May not be used as a Per-Frame Functional Group

A.X.4.1 Enhanced US Volume Functional Group Macros Content Constraints

A.X.4.1.1 US Image Description Macro

The value of Volumetric Properties (0008,9206) shall be VOLUME. The value of Volume Based Calculation Technique (0008,9207) shall be NONE.

A.X.4.1.2 Plane Position (Volume) and Plane Orientation (Volume) Macros

Image Position (Volume) (0020,9301) first value (X) shall be zero and second value (Y) shall be zero. Image Orientation (Volume) (0020,9302) values shall be 1\0\0\0\1\0. This ensures that the origins of each frame lies on the Volume Frame of Reference Z_V axis, the rows of each frame are parallel to the Volume Frame of Reference X_V axis, and the columns of each frame are parallel to the Volume Frame of Reference Y_V axis.

A.34.Y Arterial Pulse Waveform Information Object Definition

A.34.Y.1 Arterial Pulse Waveform IOD Description

The Arterial Pulse Waveform IOD is the specification of digitized electrical signals from the patient arterial system collected through pulse oximetry or other means by a Pulse modality or by a Pulse acquisition function within an imaging modality.

A.34.Y.2 Arterial Pulse Waveform IOD Entity-Relationship Model

The E-R Model in Section A.34.1 of this Part applies to the Arterial Pulse Waveform IOD.

A.34.Y.3 Arterial Pulse Waveform IOD Module Table

Table A.34.Y-1
ARTERIAL PULSE WAVEFORM IOD MODULES

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	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Synchronization	C.7.4.2	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Waveform	Waveform Identification	C.10.8	M
	Waveform	C.10.9	M
	Acquisition Context	C.7.6.14	M
	Waveform Annotation	C.10.10	C – Required if annotation is present
	SOP Common	C.12.1	M

A.34.Y.4 Arterial Pulse Waveform IOD Content Constraints

A.34.Y.4.1 Modality

The value of Modality (0008,0060) shall be HD (hemodynamic waveform).

A.34.Y.4.2 Waveform Sequence

The number of Waveform Sequence (5400,0100) Items shall be 1.

A.34.Y.4.3 Number of Waveform Channels

The value of the Number of Waveform Channels (003A,0005) in the Waveform Sequence Item shall be 1.

A.34.Y.4.4 Sampling Frequency

The value of the Sampling Frequency (003A,001A) in each Waveform Sequence Item shall be less than or equal to 600 Hz.

A.34.Y.4.5 Channel Source

The Defined Context ID for the Channel Source Sequence (003A,0208) in each Channel Definition Sequence Item shall be CID 3004.

A.34.Y.4.6 Waveform Sample Interpretation

The value of the Waveform Sample Interpretation (5400,1006) in each Waveform Sequence Item shall be SB or SS.

A.34.Z Respiratory Waveform Information Object Definition

A.34.Z.1 Respiratory Waveform IOD Description

The Respiratory Waveform IOD is the specification of digitized electrical signals from the patient respiratory system, which has been acquired by a Respiratory modality or by a Respiratory acquisition function within an imaging modality.

A.34.Z.2 Respiratory Waveform IOD Entity-Relationship Model

The E-R Model in Section A.34.1 of this Part applies to the Respiratory Waveform IOD.

A.34.Z.3 Respiratory Waveform IOD Module Table

Table A.34.Z-1
RESPIRATORY WAVEFORM IOD MODULES

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	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U

Frame of Reference	Synchronization	C.7.4.2	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Waveform	Waveform Identification	C.10.8	M
	Waveform	C.10.9	M
	Acquisition Context	C.7.6.14	M
	Waveform Annotation	C.10.10	C – Required if annotation is present
	SOP Common	C.12.1	M

A.34.Z.4 Respiratory Waveform IOD Content Constraints

A.34.Z.4.1 Modality

The value of Modality (0008,0060) shall be RESP.

A.34.Z.4.2 Waveform Sequence

The number of Waveform Sequence (5400,0100) Items shall be 1.

A.34.Z.4.3 Number of Waveform Channels

The value of the Number of Waveform Channels (003A,0005) in the Waveform Sequence Item shall be 1.

A.34.Z.4.4 Sampling Frequency

The value of the Sampling Frequency (003A,001A) in each Waveform Sequence Item shall be less than or equal to 100 Hz.

A.34.Z.4.5 Channel Source

The Defined Context ID for the Channel Source Sequence (003A,0208) in each Channel Definition Sequence Item shall be CID 3005.

A.34.Z.4.6 Waveform Sample Interpretation

The value of the Waveform Sample Interpretation (5400,1006) in each Waveform Sequence Item shall be SB or SS.

A.34.W General Audio Waveform Information Object Definition

A.34.W.1 General Audio Waveform IOD Description

The General Audio Waveform IOD is the specification of one or two channel digitized audio signals.

A.34.W.2 General Audio Waveform IOD Entity-Relationship Model

The E-R Model in Section A.34.1 of this Part applies to the General Audio Waveform IOD.

A.34.W.3 General Audio Waveform IOD Module Table

Table A.34.W-1
GENERAL AUDIO WAVEFORM IOD MODULES

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	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Synchronization	C.7.4.2	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Waveform	Waveform Identification	C.10.8	M
	Waveform	C.10.9	M
	Acquisition Context	C.7.6.14	M
	Waveform Annotation	C.10.10	C – Required if annotation is present
	SOP Common	C.12.1	M

A.34.W.4 General Audio Waveform IOD Content Constraints

A.34.W.4.1 Modality

The value of Modality (0008,0060) shall be AU (audio).

A.34.W.4.2 Waveform Sequence

The number of Waveform Sequence (5400,0100) Items shall be 1.

A.34.W.4.3 Number of Waveform Channels

The value of the Number of Waveform Channels (003A,0005) in the Waveform Sequence Item shall be 1 or 2.

A.34.W.4.4 Sampling Frequency

The value of the Sampling Frequency (003A,001A) in each Waveform Sequence Item shall be less than or equal to 44,100 Hz.

A.34.W.4.5 Channel Source

The Defined Context ID for the Channel Source Sequence (003A, 0208) in each Channel Definition Sequence Item shall be CID 3000.

A.34.W.4.6 Waveform Sample Interpretation

The value of the Waveform Sample Interpretation (5400,1006) in each Waveform Sequence Item shall be SB or SS.

Item #4: Rename the existing Plane Position and Plane Orientation Macros wherever they are used.

A.36.2.4 Enhanced MR Image Functional Group Macros

Table A.36-2
ENHANCED MR IMAGE FUNCTIONAL GROUP MACROS

Functional Group Macro	Section	Usage
…		
Plane Position **(Patient)**	C.7.6.16.2.3	M
Plane Orientation **(Patient)**	C.7.6.16.2.4	M
…		

Editor Note: As in the above example, in the existing DICOM Standard:

Replace all instances of “Plane Position” referring to the Plane Position Macro with “Plane Position (Patient)”.

Replace all instances of “Plane Orientation” referring to the Plane Orientation Macro with “Plane Orientation (Patient)”.

Item #5: Add to section C.7.6.16.2: Common Functional Groups

C.7.6.16.2.X1 Plane Position (Volume) Macro

Table C.7.6.16.2.X1-1 specifies the attributes of the Plane Position (Volume) Functional Group macro.

Table C.7.6.16.2.X1-1
PLANE POSITION (VOLUME) MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Plane Position (Volume) Sequence	(0020,930E)	1	Identifies the position of the plane of this frame. Only a single Item shall be permitted in this sequence.
>Image Position (Volume)	(0020,9301)	1	The x, y, and z coordinates, in mm, of the upper left hand corner (center of the first voxel transmitted) of the plane in the Volume Frame of Reference.

C.7.6.16.2.X2 Plane Orientation (Volume) Macro

Table C.7.6.16.2.X2-1 specifies the attributes of the Plane Orientation (Volume) Functional Group macro.

Table C.7.6.16.2.X2-1
PLANE ORIENTATION (VOLUME) MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Plane Orientation (Volume) Sequence	(0020,930F)	1	Identifies orientation of the plane of this frame. Only a single Item shall be permitted in this sequence.
>Image Orientation (Volume)	(0020,9302)	1	The direction cosines of the first row and the first column of the frame with respect to the Volume Frame of Reference.

C.7.6.16.2.X3 Temporal Position Macro

Table C.7.6.16.2.X3-1 specifies the attributes of the Temporal Position Functional Group macro.

Table C.7.6.16.2.X3-1
TEMPORAL POSITION MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Temporal Position Sequence	(0020,9310)	1	Identifies the temporal position of the plane of this frame. Only a single Item shall be permitted in this sequence.

>Temporal Position Time Offset	(0020,930D)	1	Time offset of the frame in the set of frames with different temporal positions, in seconds.

C.7.6.16.2.X4 Image Data Type Macro

Table C.7.6.16.2.X4-1 specifies the attributes of the Image Data Type Functional Group macro.

Table C.7.6.16.2.X4-1
IMAGE DATA TYPE MACRO

Attribute Name	Tag	Type	Attribute Description
Image Data Type Sequence	(0018,9807)	1	Identifies the data type characteristics of this frame. Only a single Item shall be permitted in this sequence.
>Data Type	(0018,9808)	1	Identification of the data type of a frame. See C.7.6.16.2.X4.1 for Defined Terms and further explanation.
>Aliased Data Type	(0018,980B)	1	Indicates whether this data type is “aliased”. Enumerated Values: YES = data are aliased values NO = data are not aliased values See C.7.6.16.2.X4.2 for further explanation.

C.7.6.16.2.X4.1 Data Type

Data Type (0018,9808) indicates the data type of an image frame. Table C.7.6.16.2.X4.1-1 lists Defined Terms for this value.

Table C.7.6.16.2.X4.1-1
DATA TYPE DEFINED TERMS

Defined Term Name	Defined Term Description
TISSUE_INTENSITY	Tissue intensity typically displayed as grayscale (e.g. B-mode)
TISSUE_VELOCITY	Velocity (Doppler shifts) of tissue
FLOW_VELOCITY	Velocity (Doppler shifts) of blood flow
FLOW_POWER	Power contained in the Doppler signal
FLOW_VARIANCE	Statistical variance of blood velocity relative to mean
ELASTICITY	Scalar value related to the elastic properties of the tissue
PERFUSION	Scalar value related to the volume of blood perfusing into tissue
SOUND_SPEED	Speed of sound in tissue
ATTENUATION	Reduction in strength of ultrasound signal as the wave

	traverses through the medium

C.7.6.16.2.X4.2 Aliased Data Type

Some data types require special treatment when interpolating data values whose type is “aliased”, such as FLOW_VELOCITY when derived from discrete data samples as is done for PW Doppler or sampled CW Doppler. Values of these types are “cyclical” in that the maximum value should be considered adjacent to the minumum value in any interpolation algorithm. Aliased Data Type (0018,980B) indicates whether modular arithmetic is necessary for the associated data type.

Note: For example, when Data Type (0018,9808) is FLOW_VELOCITY, Aliased Data Type (0018,980B) should be set to YES indicating that an interpolation algorithm should support aliased data. When several FLOW_VELOCITY values near the maximum or minimum are interpolated, this algorithm should produce a value near the maximum or minimum. It would be incorrect to use an interpolation algorithm such as the arithmetic mean, which would erroneously produce a result near the mid-point of the range.

Item #6: Add to section C.7.3 COMMON SERIES IE MODULES

C.7.3.1.1.1 Modality

Defined Terms for the Modality (0008,0060) are:

…
RESP = Respiratory Waveform

Item #7: Modify section C.7.5 ORGANIZING LARGE SETS OF INFORMATION

7.5.2 DIMENSION ORGANIZATION

The Dimension Organization contains a set of dimensions. A dimension is a set of attributes which change on a per-frame basis in a manner which is known before the image is acquired, which are defined by the generating application and which are especially intended for presentation. Other attributes may also change on a per-frame basis but if they are not present in the Dimension Organization, they are not considered significant as a dimension for organizational purposes.

Receiving applications ~~can~~ **shall** use the order of dimensions for guidance when presenting images **if the Multi-frame Dimension Module is present.** The first item of the Dimension Index Sequence shall be the slowest varying index.

Item #8: Add to section C.7.6 COMMON IMAGE IE MODULES

C.7.6.X Enhanced Palette Color Lookup Table Module

Table C.7.6.X-1 specifies the attributes that define data flow through the Enhanced Blending and Display Pipeline. See C.7.6.X.1 for an overview of the Enhanced Blending and Display Pipeline.

Table C.7.6.X-1
ENHANCED PALETTE COLOR LOOKUP TABLE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Data Frame Assignment Sequence	(0028,1401)	1	Sequence of items each assigning frames of one particular value of Data Type (0018,9808) to a data path in the Enhanced Blending and Display Pipeline. One, two, or three items shall be included in this sequence.
>Data Type	(0018,9808)	1	Identification of the data type of frames using this data path assignment.
>Data Path Assignment	(0028,1402)	1	The data path to use for this data type in the Enhanced Blending and Display Pipeline. Enumerated vaules: PRIMARY_PVALUES PRIMARY_SINGLE SECONDARY_SINGLE SECONDARY_HIGH SECONDARY_LOW See C.7.6.X.2 for usage.
>Bits Mapped to Color Lookup Table	(0028,1403)	3	The number of most significant bits of each value of Pixel Data (7FE0,0010) from this frame contributing to the Palette Color Lookup Table input. If absent, Bits Stored (0028,0101) bits of each value of Pixel Data (7FE0,0010) from this frame contributes to the Palette Color Lookup Table input. See C.7.6.X.3 for usage.
>Include VOI LUT Macro Table C.11-2b			

Blending LUT 1 Sequence	(0028,1404)	1C	Specification of the weight of the primary path input to the Blending Operation, i.e. the value which is referred to as “Weight 1” in the Enhanced Blending and Display Pipeline. Only one item is permitted in this sequence. Required if there are one or more items of the Data Path Assignment Sequence (0028,1402) other than PRIMARY_PVALUES.
>Blending LUT 1 Transfer Function	(0028,1405)	1	Specifies the algorithm used to determine the output value of Blending LUT 1. Enumerated vaules: CONSTANT ALPHA_1 ALPHA_2 TABLE See C.7.6.X.4 for details.
>Blending Weight Constant	(0028,1406)	1C	Constant value of the Weight input to blending operation. Shall be from 0.0 to 1.0, inclusive. Required if Blending LUT 1 Transfer Function (0028,1405) is CONSTANT.
>Blending Lookup Table Descriptor	(0028,1407)	1C	Specifies the format of Blending Lookup Table Data (0028,1408) in this sequence item. The second value (first stored pixel value mapped) shall be zero. See Section C.7.6.X.5 for further explanation. Required if Blending LUT 1 Transfer Function (0028,1405) is TABLE.
>Blending Lookup Table Data	(0028,1408)	1C	Contains the Blending Lookup Table values for this Weight input to the Blending Operation. Required if Blending LUT 1 Transfer Function (0028,1405) is TABLE.
Blending LUT 2 Sequence	(0028,140C)	1C	Specification of the weight of the secondary path input to the Blending Operation, i.e. the value which is referred to as “Weight 2” in the Enhanced Blending and Display Pipeline. Only one item is permitted in this sequence. Required if there are one or more items of the Data Path Assignment Sequence (0028,1402) other than PRIMARY_PVALUES.

>Blending LUT 2 Transfer Function	(0028,140D)	1	Specifies the algorithm used to determine the output value of Blending LUT 2. Enumerated values: CONSTANT ONE_MINUS ALPHA_1 ALPHA_2 TABLE See C.7.6.X.4 for details.
>Blending Weight Constant	(0028,1406)	1C	Constant value of the Weight input to blending operation. Shall be from 0.0 to 1.0, inclusive. Required if Blending LUT 2 Transfer Function (0028,140D) is CONSTANT.
>Blending Lookup Table Descriptor	(0028,1407)	1C	Specifies the format of Blending Lookup Table Data (0028,1408) in this sequence item. The second value (first stored pixel value mapped) shall be zero. See Section C.7.6.X.5 for further explanation. Required if Blending LUT 2 Transfer Function (0028,140D) is TABLE.
>Blending Lookup Table Data	(0028,1408)	1C	Contains the Blending Lookup Table values for this Weight input to the Blending operation. Required if Blending LUT 2 Transfer Function (0028,140D) is TABLE.
Enhanced Palette Color Lookup Table Sequence	(0028,140B)	1C	This sequence contains the Palette Color Lookup Table. One or two items are allowed for this sequence. Required if Data Path Assignment (0028,1402) is present with a value other than PRIMARY_PVALUES.
>Data Path ID	(0028,140E)	1	Identifier of the data path in which this Palette Color Lookup Table is used. Enumerated values: PRIMARY SECONDARY Each item shall have a distinct value of Data Path ID.

>RGB LUT Transfer Function	(0028,140F)	1	Specifies the mapping that takes place between the input value and RGB input to the Blending Operation. Enumerated values: EQUAL_RGB Output is R=G=B=input value TABLE Output is RGB LUT values
>Alpha LUT Transfer Function	(0028,1410)	1	Specifies the transformation that is used to create the Alpha input to the Blending LUTs. Note: Depending on the values of Blending LUT 1 Transfer Function (0028,1405) and Blending LUT 2 Transfer Function (0028,140D) the Alpha LUT value may be ignored. It is recommended that IDENTITY be used if this is the case. Enumerated values: NONE IDENTITY TABLE
>Red Palette Color Lookup Table Descriptor	(0028,1101)	1C	Specifies the format of the Red Palette Color Lookup Table Data (0028,1201). The second value (first stored pixel value mapped) shall be zero. Required if RGB LUT Transfer Function (0028,140F) is TABLE.
>Green Palette Color Lookup Table Descriptor	(0028,1102)	1C	Specifies the format of the Green Palette Color Lookup Table Data (0028,1202). The second value (first stored pixel value mapped) shall be zero. Required if RGB LUT Transfer Function (0028,140F) is TABLE.
>Blue Palette Color Lookup Table Descriptor	(0028,1103)	1C	Specifies the format of the Blue Palette Color Lookup Table Data (0028,1203). The second value (first stored pixel value mapped) shall be zero. Required if RGB LUT Transfer Function (0028,140F) is TABLE.
>Alpha Palette Color Lookup Table Descriptor	(0028,1104)	1C	Specifies the format of the Alpha Palette Color Lookup Table Data. The second value (first stored pixel value mapped) shall be zero. Required if Alpha LUT Transfer Function (0028,1410) is TABLE.

>Red Palette Color Lookup Table Data	(0028,1201)	1C	Red Palette Color Lookup Table Data. Required if RGB LUT Transfer Function (0028,140F) is TABLE.
>Green Palette Color Lookup Table Data	(0028,1202)	1C	Green Palette Color Lookup Table Data. Required if RGB LUT Transfer Function (0028,140F) is TABLE.
>Blue Palette Color Lookup Table Data	(0028,1203)	1C	Blue Palette Color Lookup Table Data. Required if RGB LUT Transfer Function (0028,140F) is TABLE.
>Alpha Palette Color Lookup Table Data	(0028,1204)	1C	Alpha LUT contains the blending values for the data frames. Required if Alpha LUT Transfer Function (0028,1410) is TABLE.
ICC Profile	(0028,2000)	1C	An ICC Profile encoding the transformation of device-dependent color stored pixel values into PCS-Values. See Section C.11.15.1.1 When present, defines the color space of the output of the Enhanced Blending and Display Pipeline. Required if Data Path Assignment (0028,1402) is present and there exists any value other than PRIMARY_PVALUES.

C.7.6.X.1 Description of the Enhanced Blending and Display Pipeline

The Enhanced Blending and Display Pipeline describes a scheme for blending of data frames of different Data Types and a color/grayscale mapping for display recommended by the provider of this information. There are no requirements upon an receiving application to utilize this recommendation in the processing and display of the referenced image.

The blending transformation model in Figure C.7.6.X-1 applies for mapping images derived from one, two, or three data frames with the same image position and orientation but of different values of Data Type (0018,9808) to grayscale P-values or color PCS-values for presentation. These inputs to the pipeline are frames of pixel values obtained from Pixel Data (7FE0,0010) and structured as described by attributes of the Image Pixel Module. Co-located pixels from each data frame are processed through the Pipeline, resulting in one output sample at that location.

The model utilizes up to two data paths called the Primary and the Secondary data paths. Each input data frame may be initially processed by a Modality LUT and a VOI LUT. If not explicitly specified, the Modality LUT and VOI LUT are assumed to be identity transformations. The Primary path may be used alone to obtain only grayscale transformation without blending. In this case, the Primary data path input after going through the Modality LUT and VOI LUT is mapped through a Presentation LUT to obtain device independent grayscale values (P-values) for presentation.

Either Primary or Secondary paths alone or both paths together may be used to obtain color transformation with blending. Up to one data frame input in the Primary data path and up to two data frames input in the Secondary data path are allowed for this blending transformation. These frames may be mapped to color using one-input or two-input palette color lookup tables depending on the number of data frames input to the data path. Alternatively if a path has one data frame, values may be converted to RGB (where R=G=B) before blending, if pseudo-color presentation of this data path is not desired. RGB values from Primary and Secondary data paths are combined via a "Blending Operation" in which the RGB color components are multiplied by a corresponding blending weight function (Weight 1 and Weight 2, respectively), and for each color component the two products are added together to produce the blended output value of that component. All inputs to the Blending Operation are normalized to the range 0.0 to 1.0, inclusive, even if they are fixed integer values that had been the entries in a lookup table.

Each of the Weight inputs to the blending operation is the output of a corresponding Blending LUT Transfer Function, which is selectable as either a constant or a derivation of the data frame values as described in C.7.6.X.4.

The RGB output from the Blending Operation is clamped to limit each color component (R, G, and B) to fall within the range 0.0 to 1.0, inclusive. The clamping function simply sets the value of any color component to 1.0 if the output from the Blending operation for that component exceeds 1.0. The RGB output of the clamping function is made available for use in rendering and slicing algorithms. Further, the output of the clamping function is transformed by the Profile Connection Space Transformation to device independent color values (PCS-values) for presentation.

If the input data frame values are representative of real world data, then they can be mapped to the real world values and units using the Real World Value Mapping Macro.

Note: PS3.17 "Enhanced US Data Type Blending Examples" describes a number of examples of the Enhanced Blending and Display Pipeline with specific attribute values for each example that invoke particular data flows through the pipeline.

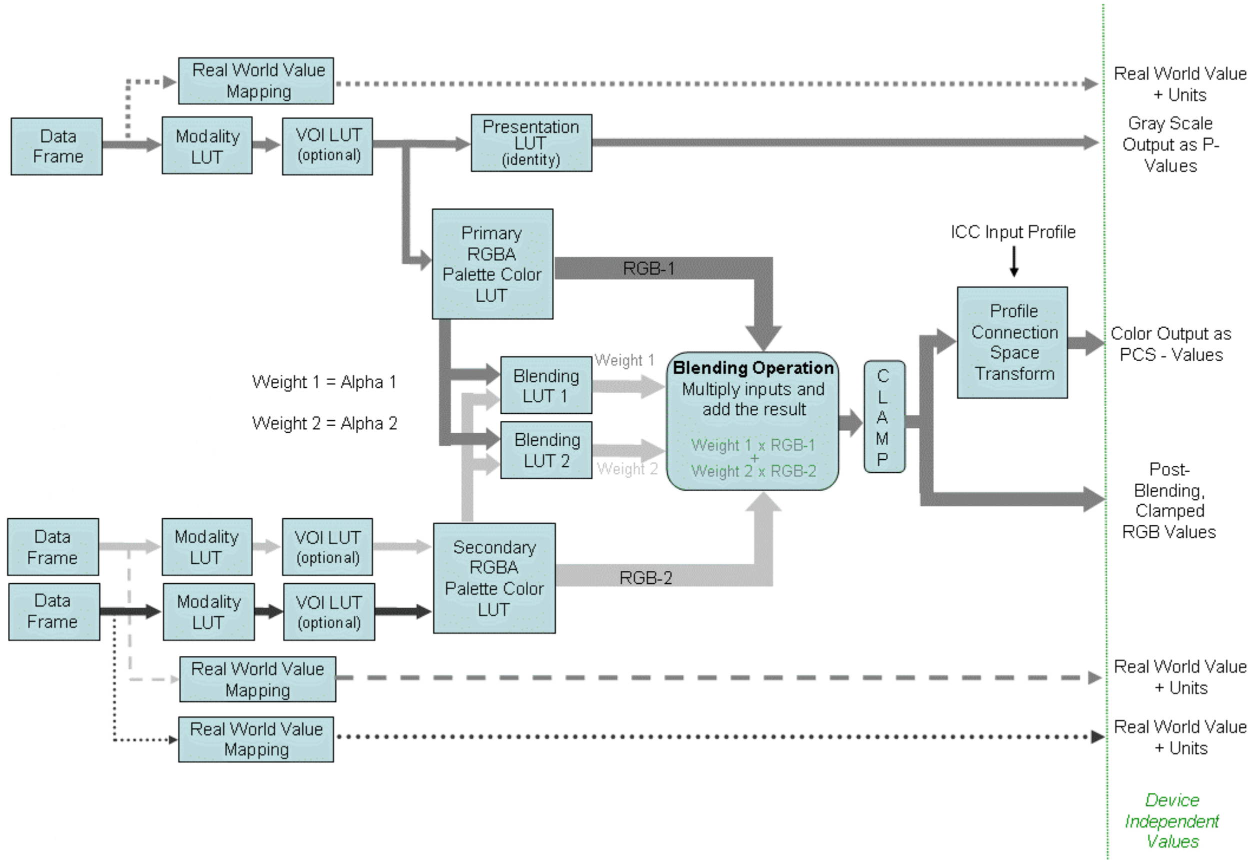

Figure C.7.6.X-1: Enhanced Blending and Display Pipeline

C.7.6.X.2 Data Path Assignment

Data Path Assignment (0028,1402) specifies the data path to use in the Enhanced Blending and Display Pipeline for each data frames of a particular data type.

Enumerated values:

PRIMARY_PVALUES Data Frame values are passed through the Presentation LUT to produce grayscale P-values. No blending is performed.

PRIMARY_SINGLE Data Frame values are inputs to the Primary Palette Color Lookup Table.

SECONDARY_SINGLE Data Frame values are inputs to the Secondary Palette Color Lookup Table.

SECONDARY_HIGH Data Frame values having Data Path Assignment (0028,1402)of SECONDARY_HIGH are concatenated as the most significant bits with Data Frame values having Data Path Assignment of SECONDARY_LOW to form inputs to the Secondary Palette Color Lookup Table.

SECONDARY_LOW Data Frame values having Data Path Assignment (0028,1402)of SECONDARY_LOW are concatenated as the least significant bits with Data Frame values having Data Path Assignment of SECONDARY_HIGH to form inputs to the Secondary Palette Color Lookup Table.

C.7.6.X.3 Bits Mapped To Color Lookup Table

The number of entries of each Palette Color Lookup Table is specified in the Palette Color Lookup Table Descriptors of the lookup table components. As described in Section C.7.6.3.1.5, a maximum of 65,536 (2^{16}) data entries is permitted, which would require input values of 16 bits to access all Palette Color Lookup Table entries. For tables with less than the maximum number of Palette Color Lookup Table entries, correspondingly smaller input values are required.

In the Enhanced Blending and Display Pipeline, the Palette Color Lookup Table input values are obtained from one or two data frames, depending on the values of the Data Path Assignment (0028,1402) attributes; for Data Path Assignment (0028,1402)= PRIMARY_SINGLE or SECONDARY_SINGLE, the input values are obtained from stored pixel values of a single data frame (after processing through the Modality LUT and/or VOI LUT), while for Data Path Assignment (0028,1402)= SECONDARY_HIGH and SECONDARY_LOW, the input values are constructed from stored pixel values of two data frames (after processing through Modality LUTs and/or VOI LUTs) as described below.

The number of bits in each data frame stored pixel value is specified by the value of Bits Stored (0028,0101). It is possible that the number of bits in the PRIMARY_SINGLE or SECONDARY_SINGLE data frame or the sum of the numbers of bits in the SECONDARY_HIGH and SECONDARY_LOW data frames is greater than the number of bits needed to address all Palette Color Lookup Table entries. The values of Bits Mapped to Color Lookup Table (0028,1403) specify the number of bits from the corresponding data frame stored pixel values that contribute to the Palette Color Lookup Table input values, as follows:

If Data Path Assignment is PRIMARY_SINGLE or SECONDARY_SINGLE, the input to the Palette Color Lookup Table is the number of most significant bits specified by Bits Mapped to Color Lookup Table (0028,1403) from the data frame stored pixel values. For Data Path Assignment SECONDARY_HIGH or SECONDARY_LOW, the number of most significant bits specified by Bits Mapped to Color Lookup Table (0028,1403) from each data frame's stored pixel values are concatenated to create the Palette Color Lookup Table input values, with the SECONDARY_HIGH frame's bits comprising the most significant part of the input value and the SECONDARY_LOW frame's bits comprising the least significant part of the input value.

If the resulting Palette Color Lookup Table input value is greater than the number of Palette Color Lookup Table entries as specified by the Palette Color Lookup Table Descriptor first value, then the output from the Palette Color Lookup Table shall be the last value in the Palette Color Lookup Table. However, it is recommended that the values of Bits Mapped To Color Lookup Table (0028,1403) and number of Palette Color Lookup Table entries be selected such that all input values are mapped to distinct entries in the Palette Color Lookup Table.

C.7.6.X.4 Blending LUT Transfer Function

The value of the Blending LUT 1 Transfer Function (0028,1405) and Blending LUT 2 Transfer Function (0028,140D) specify the algorithm used to determine the output values of the Blending LUT 1 and Blending LUT 2, respectively.

Enumerated values:

CONSTANT	A constant floating point value from 0.0 to 1.0, inclusive.
ALPHA_1	Pass-through the Alpha 1 input value from the Alpha Palette Color Lookup Table of the Primary data path.

ALPHA_2	Pass-through the Alpha 2 input value from the Alpha Palette Color Lookup Table of the Secondary data path.
TABLE	The output of a Table defining a function of the Alphas from both data paths: The Alpha 1 input value from the Alpha Palette Color Lookup Table of the Primary data path and the Alpha 2 input value from the Alpha Palette Color Lookup Table of the Secondary data are concatenated to form an index into a Lookup Table, with the Alpha 1 value providing the most significant bits of the index and the Alpha 2 value providing the least significant bits of the index. If the index is too large for the number of entries in the Lookup Table, the last value of the Lookup Table is used for any index value greater than the number of Lookup Table entries. If the index is too small for the number of entries in the Lookup Table, than not all entries in the Lookup Table are accessed. The total number of bits in the index value shall be equal to or less than 16.
ONE_MINUS	The Blending LUT 2 value is (1 – Blending LUT 1 output). Used for Blending LUT 2 Transfer Function (0028,140D) only.

C.7.6.X.5 Blending LUT Descriptor

The three values of the Blending Lookup Table Descriptor (0028,1407) describe the format of the data in Blending Lookup Table Data (0028,1408).

The first value is the number of entries in the lookup table. When the number of table entries is equal to 65,536 (2^{16}), then this value shall be 0. The number of entries shall be equal to the number of possible values in the input.

Note: For example, for 8 bit input to the Blending LUT the tables must have 256 entries, while for 16 bit input to the Blending LUT the tables must have 65,536 entries.

The second value is the first input value mapped, and shall always be 0 for an Blending LUT. This input value is mapped to the first entry in the LUT. Subsequent input values are mapped to the subsequent entries in the LUT Data up to an input value equal to number of entries + first value mapped - 1 which is mapped to the last entry in the LUT Data. There are no input values greater than number of entries – 1.

The third value specifies the number of bits for each entry in the LUT Data. This value shall be between 8 and 16, inclusive. The LUT Data shall be stored in a format equivalent to 16 bits allocated where the high bit is equal to bits stored - 1, where bits stored is the third value.

C.7.6.X.6 Lossy Compression and Palette Color Lookup Tables (Informative)

Image objects containing non-monotonic Palette Color LUTs that are lossy compressed may potentially experience a change in the index values that results in the displayed image having a significantly different appearance than the original image.

Item #9: Modifications to section C.7.6 COMMON IMAGE IE MODULES

C.7.6.3.1.5 Palette Color Lookup Table Descriptor

The ~~**three**~~ <u>**four**</u> values of Palette Color Lookup Table Descriptor (0028,1101- ~~**1103**~~ <u>**1104**</u>) describe the format of the Lookup Table Data in the corresponding Data Element (0028,1201- ~~**1203**~~ <u>**1204**</u>) or (0028,1221-1223). <u>**In this section, the term “input value” is either the Palette Color Lookup Table**</u>

input value described in the Enhanced Palette Color Lookup Table Sequence (0028,140B) or if that attribute is absent, the stored pixel value.

The first value is the number of entries in the lookup table. When the number of table entries is equal to 2^{16} then this value shall be 0. The first value shall be identical for each of the Red, Green, ~~**and**~~ Blue**, and Alpha** Palette Color Lookup Table Descriptors.

The second value is the first ~~**stored pixel**~~ **input** value mapped. This ~~**pixel**~~ **input** value is mapped to the first entry in the Lookup Table Data. All ~~**image pixel**~~ **input** values less than the first value mapped are also mapped to the first entry in the Lookup Table Data if the Photometric Interpretation is PALETTE COLOR.

Note: In the case of the Supplemental Palette Color LUT, the stored pixel values less than the second descriptor value are grayscale values.

An ~~**image pixel**~~ **input** value one greater than the first value mapped is mapped to the second entry in the Lookup Table Data. Subsequent ~~**image pixel**~~ **input** values are mapped to the subsequent entries in the Lookup Table Data up to an ~~**image pixel**~~ **input** value equal to number of entries + first value mapped – 1, which is mapped to the last entry in the Lookup Table Data. ~~**Image pixel**~~ **Input** values greater than or equal to number of entries + first value mapped are also mapped to the last entry in the Lookup Table Data. The second value shall be identical for each of the Red, Green, ~~and~~ Blue**, and Alpha** Palette Color Lookup Table Descriptors.

The third value specifies the number of bits for each entry in the Lookup Table Data. It shall take the value of 8 or 16. The LUT Data shall be stored in a format equivalent to 8 bits allocated when the number of bits for each entry is 8, and 16 bits allocated when the number of bits for each entry is 16, where in both cases the high bit is equal to bits allocated-1. The third value shall be identical for each of the Red, Green and Blue Palette Color Lookup Table Descriptors.

Note: Some implementations have encoded 8 bit entries with 16 bits allocated, padding the high bits; this can be detected by comparing the number of entries specified in the LUT Descriptor with the actual value length of the LUT Data entry. The value length in bytes should equal the number of entries if bits allocated is 8, and be twice as long if bits allocated is 16.

When the **Red, Green, or Blue** Palette Color Lookup Table Descriptor (0028,1101-1103) are used as part of the Palette Color Lookup Table Module or the Supplemental Palette Color Lookup Table Module, the third value shall be equal to 16. **When the Alpha Palette Color Lookup Table Descriptor (0028,1104) is used, the third value shall be equal to 8**.

Notes: 1. A value of 16 indicates the Lookup Table Data will range from (0,0,0) minimum intensity to (65535,65535,65535) maximum intensity.

2. Since the Palette Color Lookup Table Descriptor (0028,1101-~~**1103**~~ **1104**) attributes are multi-valued, in an Explicit VR Transfer Syntax, only one value representation (US or SS) may be specified, even though the first and third values are always by definition interpreted as unsigned. The explicit VR actually used is dictated by the VR needed to represent the second value, which will be consistent with Pixel Representation (0028,0103).

C.7.6.3.1.6 Palette Color Lookup Table Data

Palette Color Lookup Table Data (0028,1201-~~**1203**~~ **1204**) contain the lookup table data corresponding to the Lookup Table Descriptor (0028,1101- ~~**1103**~~ **1104**).

Palette color values must always be scaled across the full range of available intensities. This is indicated by the fact that there are no bits stored and high bit values for palette color data.

Note: For example, if there are 16 bits per entry specified and only 8 bits of value are truly used then the 8 bit intensities from 0 to 255 must be scaled to the corresponding 16 bit intensities from 0 to 65535. To do this for 8 bit values, simply replicate the value in both the most and least significant bytes.

These lookup tables shall be used only when there is a single sample per pixel (single image plane) in the image.

~~**These lookup tables are required when the value of Photometric Interpretation (0028,0004) is Palette Color. The semantics of these lookup tables is not defined otherwise.**~~

C.7.6.16.2.2 Frame Content Macro

…

Table C.7.6.16-3
FRAME CONTENT MACRO ATTRIBUTES

Attribute Name	Taq	Type	Attribute Description
…	…	…	…
>Dimension Index Values	(0020,9157)	1C	Contains the values of the indices defined in the Dimension Index Sequence (0020,9222) for this multi-frame header frame. The number of values is equal to the number of Items of the Dimension Index Sequence and shall be applied in the same order. See section C.7.6.17.1 for a description. Required if the value of the Dimension Index Sequence (0020,9222) ~~**contains Items**~~**exists**.
…	…	…	

C.7.6.17 Multi-frame Dimension Module

…

Table C.7.6.17-1
MULTI-FRAME DIMENSION MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Dimension Organization Sequence	(0020,9221)	~~2~~1	Sequence that lists the Dimension Organization UIDs referenced by the containing SOP Instance. See section

			C.7.6.17.2 for further explanation. ~~Zero~~ <u>One</u> or more Items shall be included in this Sequence.
>Dimension Organization UID	(0020,9164)	1	Uniquely identifies a set of dimensions referenced within the containing SOP Instance. See section C.7.6.17.2 for further explanation.
<u>**Dimension Organization Type**</u>	<u>**(0020,9311)**</u>	<u>**3**</u>	<u>**Dimension organization of the instance.**</u> <u>**Defined Terms:**</u> <u>**3D**</u> <u>**Spatial Multi-frame image of parallel planes (3D volume set)**</u> <u>**3D_TEMPORAL**</u> <u>**Temporal loop of parallel-plane 3D volume sets.**</u>
Dimension Index Sequence	(0020,9222)	~~2~~<u>1</u>	Identifies the sequence containing the indices used to specify the dimension of the multi-frame object. ~~Zero~~ <u>One</u> or more Items shall be included in this sequence.
>Dimension Index Pointer	(0020,9165)	1	Contains the Data Element Tag that is used to identify the Attribute connected with the index. See section C.7.6.17.1 for further explanation.
>Dimension Index Private Creator	(0020,9213)	1C	Identification of the creator of a group of private data elements. Required if the Dimension Index Pointer (0020,9165) value is the Data Element Tag of a Private Attribute.
>Functional Group Pointer	(0020,9167)	1C	Contains the Data Element Tag of the Functional Group Sequence that contains the Attribute that is referenced by the Dimension Index Pointer (0020,9165). See section C.7.6.17.1 for further explanation. Required if the value of the Dimension Index Pointer (0020,9165) is the Data Element Tag of an Attribute that is contained within a Functional Group Sequence.
>Functional Group Private Creator	(0020,9238)	1C	Identification of the creator of a group of private data elements. Required if the Functional Group Pointer (0020,9167) value is the Data Element Tag of a Private Attribute.
>Dimension Organization UID	(0020,9164)	1C	Uniquely identifies a set of dimensions referenced within the

			containing SOP Instance. In particular the dimension…

Item #10: Add to section C.8 MODALITY SPECIFIC MODULES

C.8.X Enhanced US Volume Modules and Functional Group Macros

C.8.X.1 Enhanced US Series Module

Table C.8.X.1-1 specifies attributes for the Enhanced US Series Module, including specialization of attributes in the General Series Module for use in the Enhanced US Series Module.

Table C.8.X.1-1
ENHANCED US SERIES MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0060)	1	Type of equipment that originally acquired the data used to create the images in this Series. Enumerated Values: US IVUS See section C.7.3.1.1.1 for further explanation.
Referenced Performed Procedure Step Sequence	(0008,1111)	1C	Uniquely identifies the Performed Procedure Step SOP Instance to which the Series is related (e.g. a Modality or General-Purpose Performed Procedure Step SOP Instance). The Sequence shall have one Item. Required if the Modality Performed Procedure Step SOP Class or General Purpose Performed Procedure Step SOP Class is supported.
>Include 'SOP Instance Reference Macro' Table 10-11			
Performed Protocol Code Sequence	(0040,0260)	1C	Sequence describing a Protocol being followed for this Procedure Step. This Sequence shall contain only one item. Required if a Protocol is controlling the creation of this Series. May be included otherwise.
>Include 'Code Sequence Macro' Table 8.8-1			Baseline Context ID 12001

>Protocol Context Sequence	(0040,0440)	3	Sequence that specifies the context for the Performed Protocol Code Sequence Item. One or more items may be included in this sequence.
>>Include 'Content Item Macro' Table 10-2			No Baseline Template is defined.
>>Content Item Modifier Sequence	(0040,0441)	3	Sequence that specifies modifiers for a Protocol Context Content Item. One or more items may be included in this sequence. See Section C.4.10.1.
>>>Include 'Content Item Macro' Table 10-2			No Baseline Template is defined.
Performed Protocol Type	(0040,0261)	1C	Type of protocol performed. Enumerated Values: STAGED NON_STAGED Required if Performed Protocol Code Sequence (0040,0260) is present.

C.8.X.2 Ultrasound Frame of Reference Module

Table C.8.X.2-1 specifies the attributes of the Ultrasound Frame Of Reference Module. See C.8.X.2.1 for an overview of the Ultrasound Frame Of Reference Module.

Table C.8.X.2-1
ULTRASOUND FRAME OF REFERENCE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Volume Frame of Reference UID	(0020,9312)	1	Uniquely identifies this Volume Frame of Reference.
Ultrasound Acquisition Geometry	(0020,9307)	1	Characteristic of the ultrasound acquisition geometry. Defined Terms: APEX = there exists an apex of the scan lines from which the volume data was acquired.
Apex Position	(0020,9308)	1C	Position of the apex (or phase center) of the acquisition geometry, encoded as x_A, y_A, and z_A in mm units in the Volume Frame of Reference. The apex (x_A, y_A, z_A) may be located in the volume or exterior to it. Required if value of Ultrasound Acquisition Geometry (0020,9307) is APEX.
Volume to Transducer Mapping Matrix	(0020,9309)	1	A 4x4 homogeneous transformation matrix that maps the Volume Frame of Reference coordinate system (X_V, Y_V, Z_V) to the Transducer Frame of Reference coordinate system (X_X,Y_X, Z_X). Matrix elements shall be listed in row-major order. See Section

Attribute Name	Tag	Type	Attribute Description
			C.8.X.2.1 for details.
Patient Frame of Reference Source	(0020,930C)	1C	Indicates how the supplied Image Position (Patient) (0020,0032) and Image Orientation (Patient) (0020,0037) values are obtained. Enumerated Values: TABLE A positioning device, such as a gantry, was used to generate these values. ESTIMATED Estimated patient position / orientation (eg, estimated by the user), or if reliable information is not available. REGISTRATION Acquisition has been spatially registered to a prior image set. Required if either Image Position (Patient) (0020,0032) or Image Orientation (Patient) (0020,0037) is present.
Table Frame of Reference UID	(0020,9313)	1C	Uniquely identifies this Table Frame of Reference. Required if Patient Frame of Reference Source (0020,930C) is TABLE.
Volume to Table Mapping Matrix	(0020,930A)	1C	A 4x4 homogeneous transformation matrix that maps the Volume Frame of Reference coordinate system (X_V,Y_V, Z_V) to the Table Frame of Reference coordinate system (X_T,Y_T, Z_T). Matrix elements shall be listed in row-major order. See Section C.8.X.2.2 for details. Required if Patient Frame of Reference Source (0020,930C) is TABLE.

C.8.X.2.1 Ultrasound Frame of Reference Module Overview

The Ultrasound Frame of Reference Module is used to relate the image planes to a frame of reference appropriate for the ultrasound modality, most notably a volume-based frame of reference. There are many different transducer scan acquisition geometries used in 3D ultrasound imaging. Regardless of the acquisition geometry, after acquisition of the initial scan images comprising the volume, the ultrasound (US) scanner will assemble (reformat) the data into a proper Cartesian volume with the assumption that the data are related through a Right-Hand Coordinate System (RHCS). x-positions are defined in mm with positive values increasing towards the right. y-positions are defined in mm with positive values in the direction of increasing image depth. z-positions are defined in mm with positive values in the direction as defined in a right-hand coordinate system.

A Cartesian volume will consist of a series of 1 to n parallel planes. The image planes comprising the Cartesian volume are typically oriented during creation of the volume so that the best image quality is in the XY plane. Table C.8.X.2-1 specifies the attributes of the Ultrasound Frame of Reference Module. There are three levels of detail for the Ultrasound Frame of Reference: Volume, Transducer and Table.

C.8.X.2.1.1 Volume Frame of Reference

The Volume Frame of Reference is a Right-hand Coordinate System consisting of a Volume Origin at the location (0,0,0) and mutually orthogonal X_V, Y_V, and Z_V axes in a Right-Hand Coordinate System. The particular IOD using the Volume Frame of Reference may constrain the alignment of frames with respect to the axes of the Volume Frame of Reference. For example, Figure C.8.X.2-1 illustrates the use of the Volume Frame of Reference with frames whose rows are parallel to the X_V axis and columns are parallel to the Y_V axis and whose origins lie on the Z_V axis.

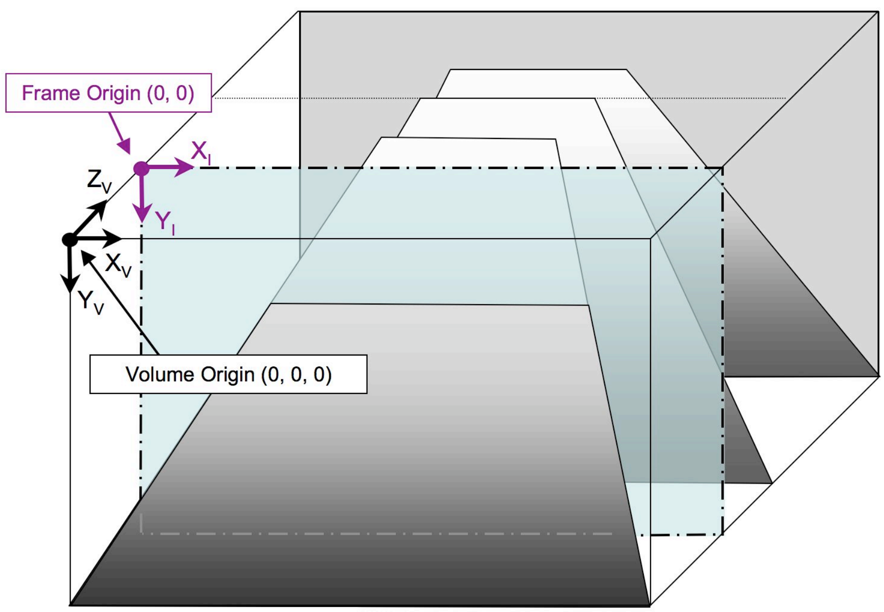

Figure C.8.X.2-1: Volume Frame of Reference

C.8.X.2.1.2 Transducer Frame of Reference

The Transducer Frame of Reference is a Right-hand Coordinate System consisting X_X, Y_X, and Z_X axes originating at a reference “Transducer Origin” defined as the geometric center of the transducer face.

The orientation of the Transducer Frame of Reference relative to the Volume Origin is such that the Y_X axis is normal to the transducer face and the “direction reference” (*i.e.* transducer tactile marker or zero reference) is aligned with the positive X_X axis. A transformation is specified between the Volume Frame of Reference and the Transducer Frame of Reference to define the position of the transducer relative to the volume. This transformation is specified by the Volume to Transducer Mapping Matrix (0020,9309).

The Transducer Frame of Reference recognizes two types of scan geometry: 1) a scan geometry with a real apex such as would be the case for a pyramid, toroid or rotational volume acquisition, or 2) a scan geometry for which there is no specific apex. The point (x_A, y_A, z_A) is the apex (or phase center) of the acquisition volume geometry in the Volume Frame of Reference. The apex (x_A, y_A, z_A) may be located in the volume or exterior to it.

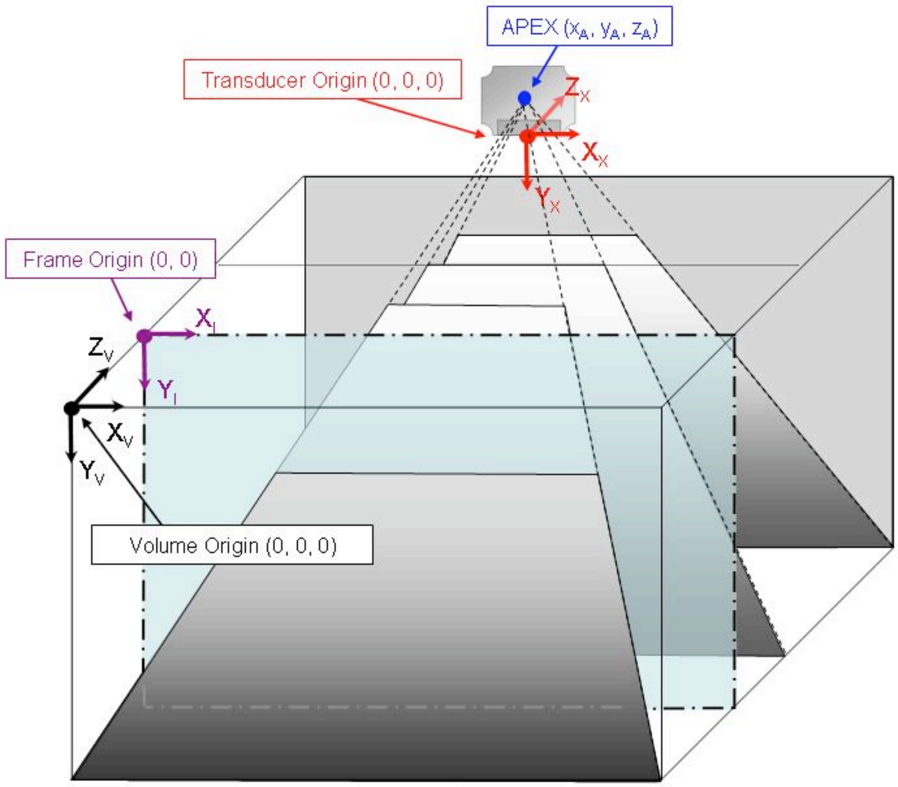

Figure C.8.X.2-2: Transducer Frame of Reference

C.8.X.2.1.3 Table Frame of Reference

There also may exist a fixed equipment reference called the Table Frame of Reference, a Right-hand Coordinate System consisting of X_T, Y_T, and Z_T axes originating at a reference “Table Origin”. See Figure C.8.X.2-3.

> Note: In this context the Table Frame of Reference refers to a fixed coordinate system in space that may be provided by a variety of source devices such as coordinates from a magnetic position sensor, LED sensor array, a physical scanner gantry, or similar device.

A transformation may be specified between the Volume Frame of Reference and the Table Frame of Reference to define the position and orientation of the volume relative to this external frame of reference. This transformation is specified by the Volume to Table Mapping Matrix (0020,930A).

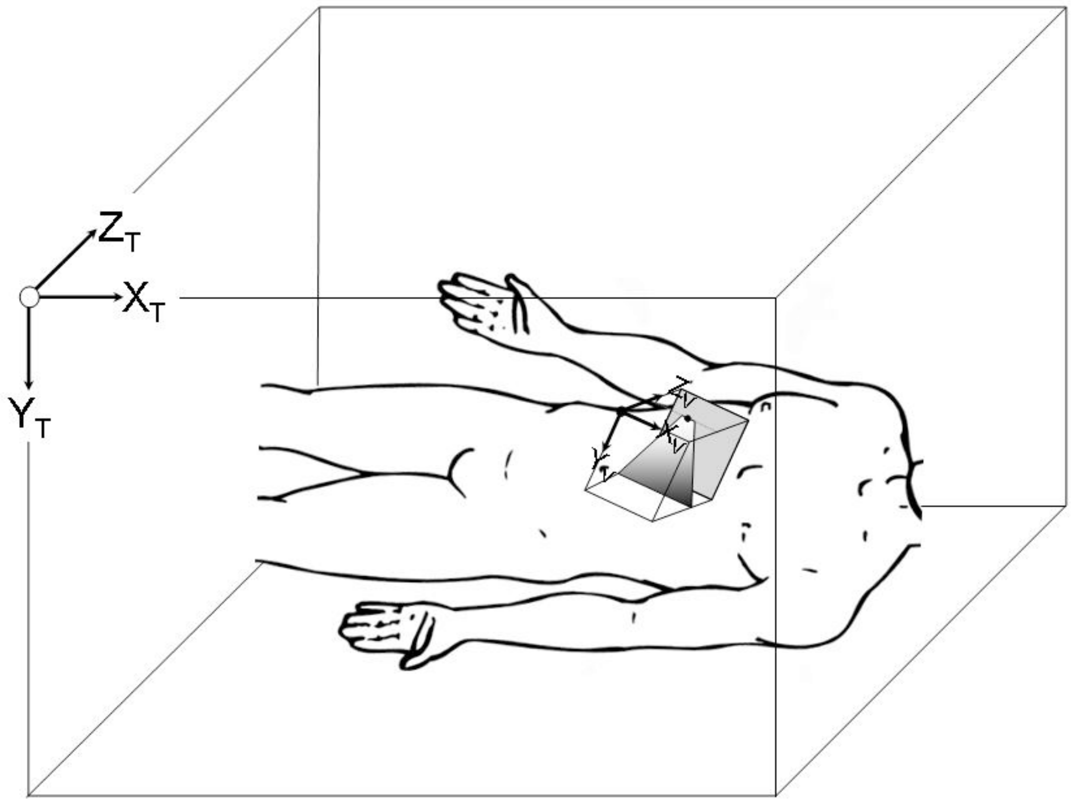

Figure C.8.X.2-3: Table Frame of Reference

C.8.X.2.2 Ultrasound Frame of Reference Module Attributes

C.8.X.2.2.1 Volume to Transducer Mapping Matrix

The Volume to Transducer Mapping Matrix (0020,9309) is used to describe the relationship between the Transducer Frame of Reference coordinate system and the Volume Frame of Reference coordinate system.

The Volume to Transducer Mapping Matrix ($[M_{TV}]=[P]*[Q]$) describes how to transform a point (X_V, Y_V, Z_V) in the Volume coordinate system into (X_X, Y_X, Z_X) in the Transducer coordinate system according to the equation below.

$$\begin{bmatrix} X_X \\ Y_X \\ Z_X \\ 1 \end{bmatrix} = \begin{bmatrix} P_{XX} & P_{YX} & P_{ZX} & Q_X \\ P_{XY} & P_{YY} & P_{ZY} & Q_Y \\ P_{XZ} & P_{YZ} & P_{ZZ} & Q_Z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_V \\ Y_V \\ Z_V \\ 1 \end{bmatrix}$$

Where:

$X_V Y_V Z_V$ The voxel location (in mm) in the Volume Frame of Reference
$X_X Y_X Z_X$ The voxel location (in mm) in the Transducer Frame of Reference
P_{ij},P_{ij},P_{ij} A 3x3 matrix of direction cosine values as measured to the Transducer origin from the volume origin.
Q_x,Q_y,Q_z The translation values (in mm) describe the location in mm of the Transducer Frame of Reference (X_X,Y_X, Z_X) origin from the Volume Reference Origin (X_V,Y_V, Z_V)measured in millimeters along the Volume axes i.e. to the transducer origin from the volume origin.

C.8.X.2.2.2 Volume to Table Mapping Matrix

The Volume to Table Mapping Matrix (0020,930A) is used to describe the relationship between the Volume Frame of Reference coordinate system and a modality specific equipment coordinate system. This mapping can be used only with systems that have a well-defined equipment coordinate system.

The Volume to Table Mapping Matrix ([M_{VG}]=[R]*[S]) describes how to transform a point ($X_V Y_V Z_V$) in the Volume coordinate system into (X_T, Y_T, Z_T) in the Table coordinate system according to the equation below.

$$\begin{bmatrix} X_T \\ Y_T \\ Z_T \\ 1 \end{bmatrix} = \begin{bmatrix} R_{XX} & R_{YX} & R_{ZX} & S_X \\ R_{XY} & R_{YY} & R_{ZY} & S_Y \\ R_{XZ} & R_{YZ} & R_{ZZ} & S_Z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_V \\ Y_V \\ Z_V \\ 1 \end{bmatrix}$$

Where:

$X_V Y_V Z_V$ The voxel location (in mm) in the Volume Frame of Reference
$X_T Y_T Z_T$ The voxel location (in mm) in the Table Frame of Reference
R_{ij},R_{ij},R_{ij} A 3x3 matrix of direction cosine values as measured to the gantry origin from the volume origin.
S_x,S_y,S_z The translation values (in mm) describe the location in mm of the Table Frame of Reference (X_T, Y_T, Z_T) origin from the Volume Reference Origin (X_V,Y_V, Z_V)measured in millimeters along the table axes I.e. to the table origin from the volume origin.

Note: The Mapping Matrices are rigid transformations that involve only translations and rotations. Mathematically, the matrix is orthonormal and describes six degrees of freedom: three translations, and three rotations.

C.8.X.3 Enhanced US Image Module

Table C.8.X.3-1 specifies the Attributes that describe the Enhanced US Image Module. As described in Section A.1.2.6, the Attributes in this Module apply to the first frame of a multi-frame image; any or all of this information may be overridden by Attributes in Per-frame Functional Groups.

Table C.8.X.3-1
ENHANCED US IMAGE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Image identification characteristics. See C.8.X.3.2 for specialization.
Samples Per Pixel	(0028,0002)	1	Number of samples per pixel in this image. Enumerated value: 1

Photometric Interpretation	(0028,0004)	1	Specifies the intended interpretation of the pixel data. Enumerated value: MONOCHROME2
Bits Allocated	(0028,0100)	1	Number of bits allocated for each pixel sample. Enumerated values: 8, 16
Bits Stored	(0028,0101)	1	Number of bits stored for each pixel sample. Enumerated values: 8, 16
High Bit	(0028,0102)	1	Most significant bit for pixel sample data. Enumerated values: 7, 15
Pixel Representation	(0028,0103)	1	Data representation of pixel samples. The constrained enumerated value implies the VR of all Palette Color Lookup Table Descriptors be US (and not SS). Enumerated value: 0000H = unsigned integer See C.8.X.3.1 for specialization.
Dimension Organization Type	(0020,9311)	1	Dimension organization of the instance. Enumerated Values: 3D 3D_TEMPORAL See C.8.X.3.3 for details.
Acquisition Datetime	(0008,002A)	1	The date and time that the acquisition of data that resulted in this image started.
Acquisition Duration	(0018,9073)	1	Duration of the image acquisition in ms.
Pixel Spacing	(0028,0030)	1	Physical distance in the patient between the centers of adjacent pixels, specified by a numeric pair - adjacent row spacing (delimiter) adjacent column spacing, in mm. See 10.7.1.3 for further explanation of the value order.

Position Measuring Device Used	(0018,980C)	1C	Indicates the position measuring device used in the acquisition of the image, which implies the degree of precision of the Pixel Spacing (0028,0030) and Spacing Between Slices (0018,0088) values. Enumerated Values: RIGID The image was acquired with a position measuring device. FREEHAND The image was acquired without a position measuring device. Required if Volumetric Properties (0008,9206) is VOLUME and Volume Based Calculation Technique (0008,9207) is NONE. May be present otherwise.
Lossy Image Compression	(0028,2110)	1C	Specifies whether an Image has undergone lossy compression. Enumerated Values: 00 Image has NOT been subjected to lossy compression. 01 Image has been subjected to lossy compression. See C.7.6.1.1.5 Required if Lossy Compression has been performed on the Image.
Lossy Image Compression Ratio	(0028,2112)	1C	See C.7.6.1.1.5 for further explanation. Required if Lossy Image Compression (0028,2110) equals 01.

Lossy Image Compression Method	(0028,2114)	1C	A label for the lossy compression method(s) that have been applied to this image. See C.7.6.1.1.5 for further explanation. May be multi valued if successive lossy compression steps have been applied; the value order shall correspond to the values of Lossy Image Compression Ratio (0028,2112). Note: For historical reasons, the lossy compression method may also be described in Derivation Description (0008,2111). Required if Lossy Image Compression (0028,2110) equals 01.
Presentation LUT Shape	(2050,0020)	1	Specifies an identity transformation for the Presentation LUT, such that the output of all grayscale transformations defined in the IOD containing this Module are defined to be P-Values. Enumerated Values: IDENTITY - output is in P-Values.
Rescale Intercept	(0028,1052)	1	The value b in relationship between stored values (SV) and the output units. Output units = m*SV + b. Enumerated value 0
Rescale Slope	(0028,1053)	1	m in the equation specified by Rescale Intercept (0028,1052). Enumerated value 1
Source Image Sequence	(0008,2112)	1C	A Sequence that identifies the set of Image SOP Class/Instance pairs of the Images that were used to derive this Image. Zero or more Items may be included in this Sequence. See C.7.6.1.1.4 for further explanation. Required if Image Type (0008,0008) Value 1 is DERIVED.
>Include 'Image SOP Instance Reference Macro' Table 10-3			
>Purpose of Reference Code Sequence	(0040,A170)	1	Describes the purpose for which the reference is made. Only a single item shall be permitted in this sequence.
>>Include 'Code Sequence Macro' Table 8.8-1			Defined Context ID is 7202

Referenced Image Sequence	(0008,1140)	3	A sequence that references other images significantly related to this image. (e.g., an image containing spatially related frames) One or more Items may be included in this sequence.
>Include 'Image SOP Instance Reference Macro' Table 10-3			
>Purpose of Reference Code Sequence	(0040,A170)	1	Describes the purpose for which the reference is made. Only a single item shall be permitted in this sequence.
>>Include 'Code Sequence Macro' Table 8.8-1			Defined Context ID is 7201
Referenced Raw Data Sequence	(0008,9121)	3	A sequence that identifies the set of Raw Data SOP Class/Instance pairs of the raw data that were used to derive this Image. One or more Items may be included in this Sequence.
>Include ''Hierarchical SOP Instance Reference Macro' Table C.17-3			
Referenced Instance Sequence	(0008,114A)	1C	A sequence which provides reference to a set of non-image SOP Class/Instance pairs significantly related to this Image, including waveforms that may or may not be temporally synchronized with this image. One or more Items may be included in this sequence. Required if waveforms are acquired in conjunction with image acquisition. May be present otherwise.
>Include 'SOP Instance Reference Macro' Table 10-11			
>Purpose of Reference Code Sequence	(0040,A170)	1	Code describing the purpose of the reference to the Instance(s). Only a single Item shall be permitted in this sequence.
>>Include 'Code Sequence Macro' Table 8.8-1			Defined Context ID is 7004 for referenced waveforms.
Number of Stages	(0008,2124)	1C	Number of stages in this protocol. Required if Performed Protocol Type (0040,0261) is present with value STAGED.
Stage Number	(0008,2122)	1C	A number that identifies the Stage. Stage Number starts at one. Required if Performed Protocol Type (0040,0261) is present with value STAGED.

Stage Code Sequence	(0040,000A)	1C	Sequence describing the performed Ultrasound Protocol Stage. Only a single item shall be present in this sequence. Required if Performed Protocol Type (0040,0261) is present with value STAGED.
>Include 'Code Sequence Macro' Table 8.8-1			Baseline Context ID is 12002
View Code Sequence	(0054,0220)	1	Sequence that describes the view of the patient anatomy in this image. Only a single Item shall be permitted in this Sequence. See Section C.8.5.6.1.19.
>Include 'Code Sequence Macro' Table 8.8-1		See Section C.8.5.6.1.19 for Context Group ID's	
>View Modifier Code Sequence	(0054,0222)	3	Sequence that provides modifiers for the view of the patient anatomy. One or more Items may be included in this Sequence. See Section C.8.5.6.1.19.
>>Include 'Code Sequence Macro' Table 8.8-1		See Section C.8.5.6.1.19 for Context Group ID's	
Event Timer Sequence	(0008,2133)	3	Sequence of time intervals of significance to this image. Each item describes one time interval either beginning or ending at Acquisition Datetime (0008,002A). One or more Items may be included in this Sequence.
>Event Time Offset	(0008,2134)	1	Signed value of the time between Acquisition Datetime (0008,002A) and the event, in milliseconds. Positive values indicate the event occurs after Acquisition Datetime (0008,002A).
>Event Code Sequence	(0008,2135)	1	Type of event. Only a single item shall be present in this sequence.
>Include 'Code Sequence Macro' Table 8.8-1			Defined Context ID is 12031
>Event Timer Name(s)	(0008,2132)	3	Name that identifies the event timer. May be used in addition to Event Time Code Sequence to offer site-specific user-readable event time names. Only a single value shall be permitted.
Include 'General Anatomy Mandatory Macro' Table 10-5			No Context IDs are specified.

Burned In Annotation	(0028,0301)	1	Indicates whether or not image contains sufficient burned in annotation to identify the patient and date the image was acquired. Enumerated Value: NO
Icon Image Sequence	(0088,0200)	3	This icon image is representative of the image.
>Include 'Image Pixel Macro' Table C.7-11b			See C.7.6.1.1.6 for further explanation.
Transducer Data	(0018,5010)	3	Manufacturer defined code or description
Transducer Scan Pattern Code Sequence	(0018,9809)	1	The scan pattern the transducer is capable of. Only a single item shall be permitted in this sequence. See C.8.X.3.4 for further explanation.
>Include 'Code Sequence Macro' Table 8.8-1			Defined Context ID is 12032.
Transducer Geometry Code Sequence	(0018,980D)	1	Geometric structure of the transducer. Only a single item shall be permitted in this sequence. See C.8.X.3.4 for further explanation.
>Include 'Code Sequence Macro' Table 8.8-1			Defined Context ID is 12033.
Transducer Beam Steering Code Sequence	(0018,980E)	1	Technique used by the transducer for beam steering. One or more items shall be permitted in this sequence. If more than one item is present, the order is significant from plane-forming technique to volume-forming technique. See C.8.X.3.4 for further explanation.
>Include 'Code Sequence Macro' Table 8.8-1			Defined Context ID is 12034.
Transducer Application Code Sequence	(0018,980F)	1	The primary clinical application of the transducer. Only a single Item shall be permitted in this sequence. See C.8.X.3.4 for further explanation.
>Include 'Code Sequence Macro' Table 8.8-1			Defined Context ID is 12035.
Preprocessing Function	(0018,5020)	3	Manufacturer defined description of processing of echo information. Data may include code or description of gain (initial, overall, TGC, dynamic range, etc.), pre-processing, post-processing, Doppler processing parameters, e.g. cutoff filters, etc., as used in generating a given image.
Mechanical Index	(0018,5022)	1	See C.8.5.6.1.8 for Description.

Bone Thermal Index	(0018,5024)	1	See C.8.5.6.1.8 for Description.
Cranial Thermal Index	(0018,5026)	1	See C.8.5.6.1.8 for Description.
Soft Tissue Thermal Index	(0018,5027)	1	See C.8.5.6.1.8 for Description.
Depth(s) of Focus	(0018,9801)	1	The depth or depths from the transducer face, of the manufacturer defined beam focus points used for the image, in mm.
Depth of Scan Field	(0018,5050)	1	The depth, in mm, from the transducer face to the deepest point included in the image– the field of view.

C.8.X.3.1 Pixel Representation

Pixel Representation (0028,0103) is specified to be Type 1 with the constraint that VR for all the pixel data will always be unsigned (US) and not signed (SS).

Enumerated Value: 0000H = unsigned integer

Note: The real-world values that are inherently signed (example: Flow Velocity, Tissue Velocity, Variance …) are represented as unsigned, unitless pixel values and may be mapped to signed real-world quantities via the Real World Value Mapping Macro.

C.8.X.3.2 Image Type

Image Type (0008,0008) is specified to be Type 1 with the following constraints:

Value 1 shall have a value of ORIGINAL or DERIVED

Value 2 shall have a value of PRIMARY

Value 3 (Image Flavor) and Value 4 are not used

C.8.X.3.3 Dimension Organization Type

Dimension Organization Type (0020,9311) specifies the general structure of the image. The concept of “multi-frame dimensions” as specified by the Dimension Index Sequence (0020,9222) and per-frame Dimension Index Values (0020,9157) shall be used to specify the relationships of frames within that general structure.

If Dimension Organization Type (0020,9311) has values of 3D or 3D_TEMPORAL, then the Dimension Index Sequence (0020,9222) shall have exactly three items, with the dimension values described in Table C.8.X.3.3-1.

Table C.8.X.3.3-1
DIMENSION DEFINITION FOR US ACQUISITION 3D IMAGES

Item	Attribute	Tag	Value
Dimension Index Sequence		(0020,9222)	
1st	>Dimension Index Pointer	(0020,9165)	Tag of attribute specifying temporal position of frames
	>Functional Group Pointer	(0020,9167)	Tag of sequence containing above attribute
	…		

2nd	>Dimension Index Pointer	(0020,9165)	(0020,9301) Image Position (Volume)
	>Functional Group Pointer	(0020,9167)	(0020,930E) Plane Position (Volume) Sequence
	…		
3rd	>Dimension Index Pointer	(0020,9165)	(0018,9808) Data Type
	>Functional Group Pointer	(0020,9167)	(0018,9807) Image Data Type Sequence
	…		

The Dimension Index Values (0020,9157) corresponding to these dimension variables positively associate frames with different Data Type values at the same spatial and temporal position. Figure C.8.X.3.3-1 illustrates the use of Dimensions to associate frames with temporal, spatial, and Data Type dimensions.

These Dimension values shall be used even if there is only one possible value for a Dimension.

> Note: For example, if Dimension Organization Type (0020,9311) has the value 3D, the temporal position dimension is present and the dimension index of the temporal attribute is the same in every frame of the image. Similarly, if the Data Type attribute is in the Shared Functional Group and all frames in the object are of Data Type TISSUE_INTENSITY, the Data Type dimension is present and the dimension index of the Data Type dimension is the same in every frame of the image.

Each plane in the volume consists of one or more frames each with a distinct value of Data Type (0018,9808). The planes in the cartesian volume shall have equal inter-plane spacing, accomplished through values of Image Position (Volume) (0020,9301).

Each frame comprising a volume shall have the same value of the temporal dimension attribute. Any appropriate physiological event temporal attribute may be used to specify the temporal position. If there is no specific physiological event to which the temporal position of frames is referenced, then Temporal Position Time Offset (0020,930D) in the Temporal Position Sequence (0020,9310) may be used as the temporal dimension attribute. If all frames are at the same temporal position, any temporal attribute may be referenced.

> Note: For example, the attribute specifying temporal position of frames may be any appropriate temporal attribute, such as Nominal Cardiac Trigger Delay Time (0020,9153) or Nominal Percentage of Cardiac Phase (0020,9241) in the Cardiac Synchronization Sequence (0018,9118) if the temporal position of frames is referenced to the cardiac R-wave, or Nominal Respiratory Trigger Delay Time (0020,9255) or Nominal Percentage of Respiratory Phase (0020,9245) in the Respiratory Synchonization Sequence (0020,9253) if the temporal position of frames is referenced to the latest inspiration maximum.

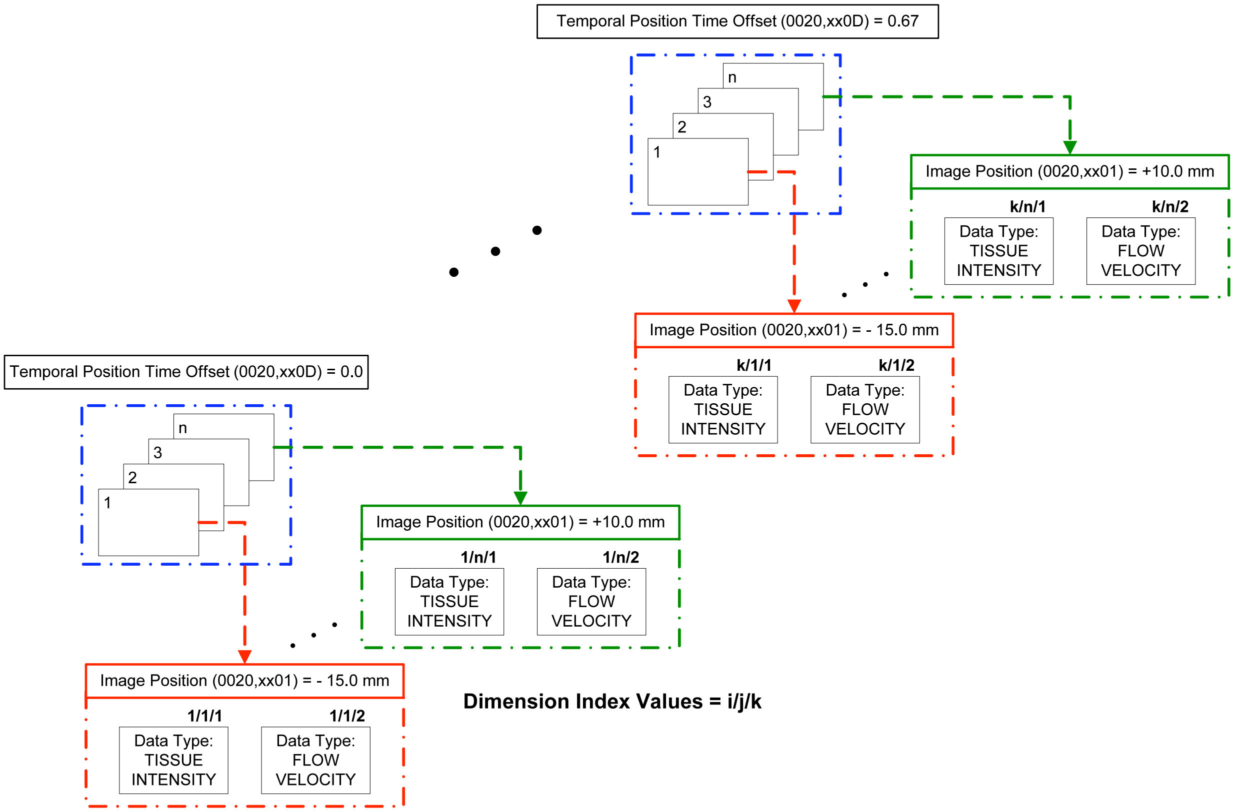

Figure C.8.X.3.3-1 Dimension Organization Type Frame Relationships

C.8.X.3.4 Transducer Description

The following elements together describe the type of transducer used to acquire the image. These are characteristics of the transducer itself rather than its specific use in the acquisition of this image. In other words, these attribute values are determined from the construction and design of the transducer and a given transducer generally has the same values of these attributes in every image it is used to create.

- Transducer Scan Pattern Code Sequence (0018,9809)
  The shape of the acoustic scan field the transducer is capable of.
- Transducer Geometry Code Sequence (0018,980D)
  The physical scan aperture from which acoustic pulses are emitted and received.
- Transducer Beam Steering Code Sequence (0018,980E)
  The method used to steer acoustic beam.
- Transducer Application Code Sequence (0018,980F)
  The placement on the subject for which the transducer is designed.

Each probe model has a unique set of values of these attributes. For example, these sample probes have the following characteristics which are encoded in the attributes above:

Table C.8.X.3.4-1
SAMPLE TRANSDUCER CHARACTERISTICS

Model	Scan Pattern	Geometry	Beam Steering	Application
Pedoff CW	Line	NonImaging	Fixed direction	External
Phased array sector probe	Plane	Sector	Phased	External
Steerable TEE	Plane	Sector	Phased, Mechanical	Transesophogeal
Curved Linear Abdominal	Plane	Curved Linear	Phased	External
Endovaginal	Plane	Curved Linear	Phased	Endovaginal
Mechanical 3D	Volume	Sector	Phased, Mechanical	External
Phased 3D	Volume	Sector	Phased	External
Endovaginal 3D	Volume	Curved Linear	Phased, Mechanical	Endovaginal

C.8.X.4 IVUS Image Module

Table C.8.X.4-1 specifies the Attributes of an IVUS Module.

Table C.8.X.4-1
IVUS IMAGE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
IVUS Acquisition	(0018,3100)	1	Defined Terms: MOTOR_PULLBACK MANUAL_PULLBACK SELECTIVE GATED_PULLBACK See C.8.5.6.1.21
IVUS Pullback Rate	(0018,3101)	1C	Required if IVUS Acquisition (0018,3100) value is MOTOR_PULLBACK. Specified in units of mm/sec. See C.8.5.6.1.22
IVUS Gated Rate	(0018,3102)	1C	Required if IVUS Acquisition (0018,3100) value is GATED_PULLBACK. Specified in units of mm/beat. See C.8.5.6.1.23

IVUS Pullback Start Frame Number	(0018,3103)	1C	Required if IVUS Acquisition (0018,3100) value is MOTOR_PULLBACK or GATED_PULLBACK. See C.8.5.6.1.24
IVUS Pullback Stop Frame Number	(0018,3104)	1C	Required if IVUS Acquisition (0018,3100) value is MOTOR_PULLBACK or GATED_PULLBACK. See C.8.5.6.1.25

C.8.X.5 Excluded Intervals Module

The Excluded Intervals Module indicates those periods within the Acquisition Duration (0018,9073) during which no volume acquisition takes place. It provides information not available at the frame level or image level, since individual frames of the volume may have been built-up over a time period within which some intervals were excluded from acquisition. Further, it provides information that is not specific to associated waveform objects since the fact that volume acquisition was excluded during these intervals is a characteristic of the volume, not the associated waveform(s). Table C.8.X.5-1 specifies the attributes of the Excluded Intervals Module.

Note: For example, if the imaging device performing a gated volume acquisition excludes volume data acquired during an ectopic beat, the Excluded Intervals attributes would be used to mark this interval in an associated physio waveform display.

Table C.8.X.5-1
EXCLUDED INTERVALS MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Excluded Intervals Sequence	(0018,9803)	1C	List of excluded intervals. Required if one or more intervals was excluded. One or more items shall be included in this sequence.
>Exclusion Start Datetime	(0018,9804)	1	Time-point of the exclusion start in the same Synchronization Frame of Reference as Acquisition Datetime (0008,002A).
>Exclusion Duration	(0018,9805)	1	Duration of the exclusion in ms.

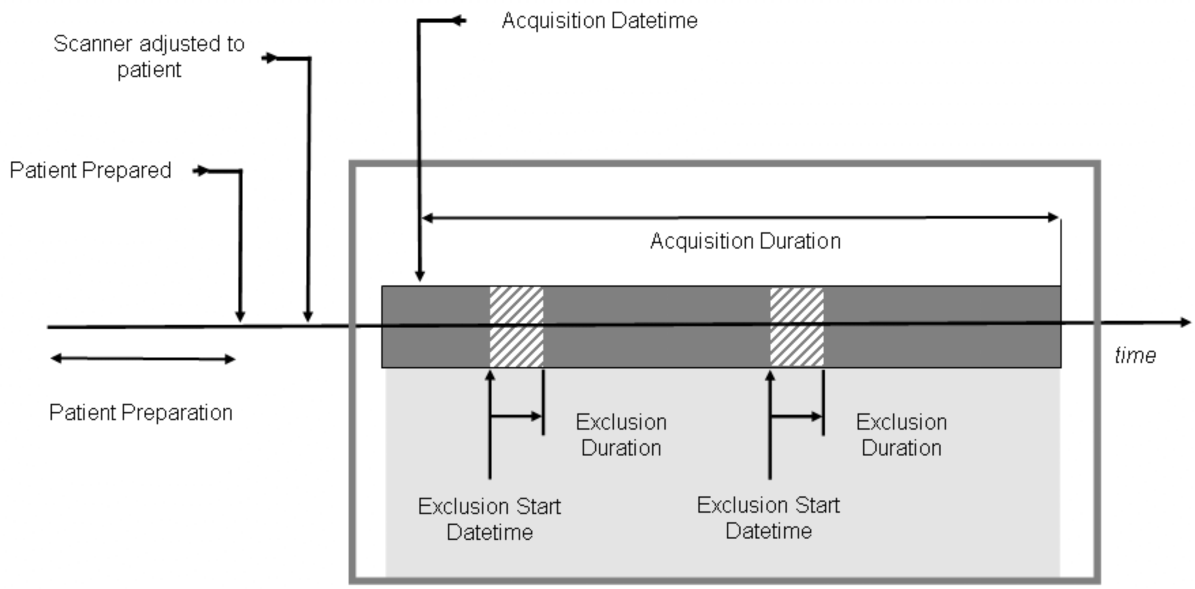

Figure C.7.6.16-2: Relationship of Timing Related Attributes

C.8.X.6 Enhanced US Volume Functional Group Macros

The following sections contain Functional Group macros specific to the Enhanced US Volume IOD.

Note: The attribute descriptions in the Functional Group Macros are written as if they were applicable to a single frame (i.e., the macro is part of the Per-frame Functional Groups Sequence). If an attribute is applicable to all frames (i.e. the macro is part of the Shared Functional Groups Sequence) the phrase "this frame" in the attribute description shall be interpreted to mean " for all frames".

C.8.X.6.1 US Image Description Macro

Table C.8.X.6.1-1 specifies the attributes of the US Image Description Functional Group Macro.

Table C.8.X.6.1-1
US IMAGE DESCRIPTION MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
US Image Description Sequence	(0018,9806)	1	A sequence that describes a general description of this image or frame. Only a single Item shall be permitted in this sequence.

>Frame Type	(0008,9007)	1	Type of Frame. A multi-valued attribute analogous to the Image Type (0008,0008). Enumerated Values and Defined Terms are the same as those for the four values of the Image Type (0008,0008) attribute, except that the value MIXED is not allowed. See section C.8.X.3.2.
>Volumetric Properties	(0008,9206)	1	Indication if geometric manipulations are possible with frames in the SOP Instance. See C.8.16.2.1.2 for a description and Enumerated Values.
>Volume Based Calculation Technique	(0008,9207)	1	Method used for volume calculations with frames in the SOP Instance. See C.8.16.2.1.3 for a description and Defined Terms.

If Volumetric Properties (0008,9206) is VOLUME and Volume Based Calculation Technique (0008,9207) is NONE, all frames in the frame set shall be spaced the same Z-distance from adjacent frames (i.e., spacing between slices is constant).

Change to existing Ultrasound Image and Ultrasound Multi-frame Image IODs

Item #11: Modification to section C.8.5 Ultrasound Modules

C.8.5.6.1.1 Image Type

…

Value 4 is constructed as a modality bit map to allow for a description of multi-modality displays. In using this bit map, the sum of the values of the various modalities will unambiguously determine the constituent modalities.

0001 = 2D Imaging	0002 = M-Mode	0004 = CW Doppler
0008 = PW Doppler	0010 = Color Doppler	0020 = Color M-Mode
0040 = 3D rendering	0100 = Color Power Mode	0200 = Tissue Characterization
0400 = Spatially-related frames		

Note: See Section A.X.1 for the relationship between a 3D volume set and the 3D Rendering, 3D MPR View, and Spatially-related frames image types. In the case of "3D Rendering", Derivation Code Sequence (0008,9215) should be used to describe the specific type of 3D rendering (volume rendering, surface rendering, multiplanar reformatting, etc.).

Changes to NEMA Standards Publication PS 3.4-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 4: Service Class Specifications

Item #12: Add SOP Classes to Table B.5-1

B.5 Standard SOP Classes

Table B.5-1
Standard SOP Classes

SOP Class	SOP Class UID	IOD Specification (defined in PS 3.3)
Enhanced US Volume Storage	1.2.840.10008.5.1.4.1.1.6.2	Enhanced US Volume
Arterial Pulse Waveform Storage	1.2.840.10008.5.1.4.1.1.9.5.1	Arterial Pulse Waveform
Respiratory Waveform Storage	1.2.840.10008.5.1.4.1.1.9.6.1	Respiratory Waveform
General Audio Waveform Storage	1.2.840.10008.5.1.4.1.1.9.4.2	General Audio Waveform

Item #13: Add SOP Classes to Table I.4-1

I.4 MEDIA Storage sop Classes

Table I.4-1
Media Storage Standard SOP Classes

SOP Class	SOP Class UID	IOD Specification
Enhanced US Volume Storage	1.2.840.10008.5.1.4.1.1.6.2	Enhanced US Volume
Arterial Pulse Waveform Storage	1.2.840.10008.5.1.4.1.1.9.5.1	Arterial Pulse Waveform
Respiratory Waveform Storage	1.2.840.10008.5.1.4.1.1.9.6.1	Respiratory Waveform
General Audio Waveform Storage	1.2.840.10008.5.1.4.1.1.9.4.2	General Audio Waveform

Changes to NEMA Standards Publication PS 3.16-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 5: Data Structures and Encoding

Item #14: Add Transfer Syntax Specifications for new OW attributes

Annex A Transfer Syntax Specifications - (Normative)

A.1 DICOM IMPLICIT VR LITTLE ENDIAN TRANSFER SYNTAX

...

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

- For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Little Endian as specified in Section 7.3.
- For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:
  - ...
  - Data Elements (0028,1201), (0028,1202), (0028,1203)**, (0028,1204)** Red, Green, Blue**, Alpha** Palette Lookup Table Data have the Value Representation OW and shall be encoded in Little Endian.

    Note: Previous versions of the Standard either did not specify the encoding of ~~these~~ Data Elements **(0028,1201), (0028,1202), (0028,1203)** in this Part, but specified a VR of US or SS in PS 3.6 (1993), or specified OW in this Part but a VR of US, SS or OW in PS 3.6 (1996). The actual encoding of the values and their byte order would be identical in each case.
  - Data Elements (0028,1101), (0028,1102),(0028,1103) Red, Green, Blue Palette Lookup Table Descriptor have the Value Representation SS or US (depending on rules specified in the IOD in PS 3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
  - Data Elements (0028,1221),(0028,1222),(0028,1223) Segmented Red, Green, Blue Palette Color Lookup table Data have the Value Representation OW and shall be encoded in Little Endian.
  - Data Element (0028,3006) Lookup Table Data has the Value Representation US, SS or OW and shall be encoded in Little Endian.

    Note: Previous versions of the Standard did not specify the encoding of these Data Elements in this Part, but specified a VR of US or SS in PS 3.6 (1998). A VR of OW has been added to support explicit VR transfer syntaxes. The actual encoding of the values and their byte order would be identical in each case.
  - Data Element (0028,3002) Lookup Table Descriptor has the Value Representation SS or US (depending on rules specified in the IOD in PS 3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
  - **Data Element (0028,1408) Blending Lookup Table Data has the Value Representation OW and shall be encoded in Little Endian.**

...

A.2 DICOM LITTLE ENDIAN TRANSFER SYNTAX (EXPLICIT VR)

...

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

– For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Little Endian as specified in Section 7.3.

– For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:

  – ...

  – Data Elements (0028,1201), (0028,1202), (0028,1203)**, (0028,1204)** Red, Green, Blue**, Alpha** Palette Lookup Table Data have the Value Representation OW and shall be encoded in Little Endian.

    Note: Previous versions of the Standard either did not specify the encoding of ~~these~~ Data Elements **(0028,1201), (0028,1202), (0028,1203)** in this Part, but specified a VR of US or SS in PS 3.6 (1993), or specified OW in this Part but a VR of US, SS or OW in PS 3.6 (1996). The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different. However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits.

  – Data Elements (0028,1101), (0028,1102),(0028,1103) Red, Green, Blue Palette Lookup Table Descriptor have the Value Representation SS or US (depending on rules specified in the IOD in PS 3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.

  – Data Elements (0028,1221), (0028,1222), (0028,1223) Segmented Red, Green, Blue Palette Color Lookup table Data have the Value Representation OW and shall be encoded in Little Endian.

  – Data Element (0028,3006) Lookup Table Data has the Value Representation US, SS or OW and shall be encoded in Little Endian.

    Note: Previous versions of the Standard did not specify the encoding of these Data Elements in this Part, but specified a VR of US or SS in PS 3.6 (1998). However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits. Hence a VR of OW has been added. The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different.

  – Data Element (0028,3002) Lookup Table Descriptor has the Value Representation SS or US (depending on rules specified in the IOD in PS 3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.

  – **Data Element (0028,1408) Blending Lookup Table Data has the Value Representation OW and shall be encoded in Little Endian.**

...

A.3 DICOM BIG ENDIAN TRANSFER SYNTAX (EXPLICIT VR)

...

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

– For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Big Endian as specified in Section 7.3.

- For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:
  - ...
  - Data Elements (0028,1201), (0028,1202), (0028,1203)**, (0028,1204)** Red, Green, Blue**, Alpha** Palette Lookup Table Data have the Value Representation OW and shall be encoded in Big Endian.

    Note: Previous versions of the Standard either did not specify the encoding of ~~these~~ Data Elements **(0028,1201), (0028,1202), (0028,1203)** in this Part, but specified a VR of US or SS in PS 3.6 (1993), or specified OW in this Part but a VR of US, SS or OW in PS 3.6 (1996). The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different. However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits.
  - Data Elements (0028,1101), (0028,1102),(0028,1103) Red, Green, Blue Palette Lookup Table Descriptor have the Value Representation SS or US (depending on rules specified in the IOD in PS 3.3), and shall be encoded in Big Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
  - Data Elements (0028,1221), (0028,1222), (0028,1223) Segmented Red, Green, Blue Palette Color Lookup table Data have the Value Representation OW and shall be encoded in Big Endian.
  - Data Element (0028,3006) Lookup Table Data has the Value Representation US, SS or OW and shall be encoded in Big Endian.

    Note: Previous versions of the Standard did not specify the encoding of these Data Elements in this Part, but specified a VR of US or SS in PS 3.6 (1998). However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits. Hence a VR of OW has been added. The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different.
  - Data Element (0028,3002) Lookup Table Descriptor has the Value Representation SS or US (depending on rules specified in the IOD in PS 3.3), and shall be encoded in Big Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
  - **Data Element (0028,1408) Blending Lookup Table Data has the Value Representation OW and shall be encoded in Big Endian.**

...

A.4 TRANSFER SYNTAXES FOR ENCAPSULATION OF ENCODED PIXEL DATA

...

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

- For all Value Representations defined in this part of the DICOM Standard, except for the Value Representations OB and OW, the encoding shall be in Little Endian as specified in Section 7.3.
- For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:
  - ...
  - Data Elements (0028,1201), (0028,1202), (0028,1203)**, (0028,1204)** Red, Green, Blue**, Alpha** Palette Lookup Table Data have the Value Representation OW and shall be encoded in Little Endian.

Note: Previous versions of the Standard either did not specify the encoding of ~~these~~ Data Elements **(0028,1201), (0028,1202), (0028,1203)** in this Part, but specified a VR of US or SS in PS 3.6 (1993), or specified OW in this Part but a VR of US, SS or OW in PS 3.6 (1996). The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different. However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits.

- Data Elements (0028,1101), (0028,1102),(0028,1103) Red, Green, Blue Palette Lookup Table Descriptor have the Value Representation SS or US (depending on rules specified in the IOD in PS 3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
- Data Elements (0028,1221), (0028,1222), (0028,1223) Segmented Red, Green, Blue Palette Color Lookup table Data have the Value Representation OW and shall be encoded in Little Endian.
- Data Element (0028,3006) Lookup Table Data has the Value Representation US, SS or OW and shall be encoded in Little Endian.

Note: Previous versions of the Standard did not specify the encoding of these Data Elements in this Part, but specified a VR of US or SS in PS 3.6 (1998). However, an explicit VR of US or SS cannot be used to encode a table of 2^{16} elements, since the Value Length is restricted to 16 bits. Hence a VR of OW has been added. The actual encoding of the values and their byte order would be identical in each case, though the explicitly encoded VR field would be different.

- Data Element (0028,3002) Lookup Table Descriptor has the Value Representation SS or US (depending on rules specified in the IOD in PS 3.3), and shall be encoded in Little Endian. The first and third values are always interpreted as unsigned, regardless of the Value Representation.
- **Data Element (0028,1408) Blending Lookup Table Data has the Value Representation OW and shall be encoded in Little Endian.**

…

Changes to NEMA Standards Publication PS 3.6-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

Item #15: Add the following rows to PS3.6 Section 6

Tag	Name	VR	VM	RET
(0008,2133)	Event Timer Sequence	SQ	1	
(0008,2134)	Event Time Offset	FD	1	
(0008,2135)	Event Code Sequence	SQ	1	

Tag	Name	VR	VM	RET
(0018,9801)	Depth(s) of Focus	FD	1-n	
(0018,9803)	Excluded Intervals Sequence	SQ	1	
(0018,9804)	Exclusion Start Datetime	DT	1	
(0018,9805)	Exclusion Duration	FD	1	
(0018,9806)	US Image Description Sequence	SQ	1	
(0018,9807)	Image Data Type Sequence	SQ	1	
(0018,9808)	Data Type	CS	1	
(0018,9809)	Transducer Scan Pattern Code Sequence	SQ	1	
(0018,980B)	Aliased Data Type	CS	1	
(0018,980C)	Position Measuring Device Used	CS	1	
(0018,980D)	Transducer Geometry Code Sequence	SQ	1	
(0018,980E)	Transducer Beam Steering Code Sequence	SQ	1	
(0018,980F)	Transducer Application Code Sequence	SQ	1	

Tag	Name	VR	VM	RET
(0020,9301)	Image Position (Volume)	FD	3	
(0020,9302)	Image Orientation (Volume)	FD	6	
(0020,9307)	Ultrasound Acquisition Geometry	CS	1	
(0020,9308)	Apex Position	FD	3	
(0020,9309)	Volume to Transducer Mapping Matrix	FD	16	
(0020,930A)	Volume to Table Mapping Matrix	FD	16	
(0020,930C)	Patient Frame of Reference Source	CS	1	
(0020,930D)	Temporal Position Time Offset	FD	1	
(0020,930E)	Plane Position (Volume) Sequence	SQ	1	
(0020,930F)	Plane Orientation (Volume) Sequence	SQ	1	
(0020,9310)	Temporal Position Sequence	SQ	1	
(0020,9311)	Dimension Organization Type	CS	1	

Tag	Name	VR	VM	RET
(0020,9312)	Volume Frame of Reference UID	UI	1	
(0020,9313)	Table Frame of Reference UID	UI	1	

Tag	Name	VR	VM	RET
(0028,1104)	Alpha Palette Color Lookup Table Descriptor	US	3	
(0028,1204)	Alpha Palette Color Lookup Table Data	OW	1	
(0028,1401)	Data Frame Assignment Sequence	SQ	1	
(0028,1402)	Data Path Assignment	CS	1	
(0028,1403)	Bits Mapped to Color Lookup Table	US	1	
(0028,1404)	Blending LUT 1 Sequence	SQ	1	
(0028,1405)	Blending LUT 1 Transfer Function	CS	1	
(0028,1406)	Blending Weight Constant	FD	1	
(0028,1407)	Blending Lookup Table Descriptor	US	3	
(0028,1408)	Blending Lookup Table Data	OW	1	
(0028,140B)	Enhanced Palette Color Lookup Table Sequence	SQ	1	
(0028,140C)	Blending LUT 2 Sequence	SQ	1	
(0028,140D)	Blending LUT 2 Transfer Function	CS	1	
(0028,140E)	Data Path ID	CS	1	
(0028,140F)	RGB LUT Transfer Function	CS	1	
(0028,1410)	Alpha LUT Transfer Function	CS	1	

Tag	Name	VR	VM	RET
(0040,0261)	Performed Protocol Type	CS	1	

Item #16: Add the following rows to PS3.6 Annex A Table A-1

UID Value	UID Name	UID Type	Part
1.2.840.10008.5.1.4.1.1.6.2	Enhanced US Volume Storage	SOP Class	PS 3.4
1.2.840.10008.5.1.4.1.1.9.5.1	Arterial Pulse Waveform Storage	SOP Class	PS 3.4
1.2.840.10008.5.1.4.1.1.9.6.1	Respiratory Waveform Storage	SOP Class	PS 3.4

1.2.840.10008.5.1.4.1.1.9.4.2	General Audio Waveform	SOP Class	PS 3.4

Item #17: Add Context Groups and Controlled Terminology in PS3.6 Annex A Table A-3

Table A-3
CONTEXT GROUP UID VALUES

Context UID	Context Identifier	Context Group Name
...		
1.2.840.10008.6.1.803	3004	Arterial Pulse Waveform
1.2.840.10008.6.1.804	3005	Respiration Waveform
1.2.840.10008.6.1.806	12030	Ultrasound Contrast/Bolus Agents
1.2.840.10008.6.1.807	12031	Protocol Interval Events
1.2.840.10008.6.1.808	12032	Transducer Scan Pattern
1.2.840.10008.6.1.809	12033	Ultrasound Transducer Geometry
1.2.840.10008.6.1.810	12034	Ultrasound Transducer Beam Steering
1.2.840.10008.6.1.811	12035	Ultrasound Transducer Application

Changes to NEMA Standards Publication PS 3.15-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 15: Security and System Management Profiles

Item #18: Add to Sections C2 and C3

C.2 Creator RSA Digital Signature Profile

…

a. the SOP Class and Instance UIDs
b. the SOP Creation Date and Time, if present
c. the Study and Series Instance UIDs
d. any attributes of the General Equipment module that are present
e. any attributes of the Overlay Plane, Curve or Graphic Annotation modules that are present
f. any attributes of the General Image and Image Pixel modules that are present
g. any attributes of the SR Document General and SR Document Content modules that are present
h. any attributes of the Waveform and Waveform Annotation modules that are present
i. any attributes of the Multi-frame Functional Groups module that are present
j. any attributes of the Enhanced MR Image module that are present
k. any attributes of the MR Spectroscopy modules that are present
l. any attributes of the Raw Data module that are present
m. any attributes of the Enhanced CT Image module that are present
n. any attributes of the Enhanced XA/XRF Image module that are present
?. any attributes of the Enhanced US Image module that are present

C.3 Authorization RSA Digital Signature Profile

…

a. the SOP Class and Instance UIDs
b. the Study and Series Instance UIDs
c. any attributes whose Values are verifiable by the technician or physician (e.g., their Values are displayed to the technician or physician)
d. any attributes of the Overlay Plane, Curve or Graphic Annotation modules that are present
e. any attributes of the General Image and Image Pixel modules that are present
f. any attributes of the SR Document General and SR Document Content modules that are present
g. any attributes of the Waveform and Waveform Annotation modules that are present
h. any attributes of the Multi-frame Functional Groups module that are present
i. any attributes of the Enhanced MR Image module that are present
j. any attributes of the MR Spectroscopy modules that are present
k. any attributes of the Raw Data module that are present
l. any attributes of the Enhanced CT Image module that are present
m. any attributes of the Enhanced XA/XRF Image module that are present
?. any attributes of the Enhanced US Image module that are present

Changes to NEMA Standards Publication PS 3.16-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 16: Content Mapping Resource

Item #19: Add Context Groups and Controlled Terminology in PS3.16 Annex B and Annex D

Annex B DCMR Context Groups (Normative)

This Annex specifies the content of Context Groups required by DICOM IODs.

CID 3004 Arterial Pulse Waveform

Context ID 3004
Arterial Pulse Waveform

Type: Extensible Version: 20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	109116	Arterial Pulse Waveform

CID 3005 Respiration Waveform

Context ID 3005
Respiration Waveform

Type: Extensible Version: 20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	109117	Respiration Waveform

CID 7004 Waveform Purposes of Reference

Context ID 7004
Waveform Purposes of Reference
Type: Extensible Version: ~~20080123~~20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
…		
DCM	**121306**	**Simultaneous Arterial Pulse Waveform**
DCM	**121307**	**Simultaneous Phonocardiographic Waveform**

CID 12030 Ultrasound Contrast/Bolus Agents

Context ID 12030
Ultrasound Contrast/Bolus Agents
Type: Extensible Version: 20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104) See Controlled Terminology descriptions in Annex D for manufacturer references.
DCM	125901	CARDIOsphere
NDC	11994-*011-04	Definity
DCM	125902	Echovist
DCM	125903	Imagify
DCM	125904	Levovist
NDC	00019-2707-03	Optison
DCM	125905	Sonazoid
DCM	125906	SonoVue
DCM	125907	Targestar-B
DCM	125908	Targestar-P

Note: The generic formulation is not used for Code Meaning (0008,0104) because for ultrasonic contrast agents the physical properties of the agent are more significant than chemical formula in determining its acoustic properties.

CID 12031 Protocol Interval Events

Context ID 12031
Protocol Interval Events
Type: Extensible Version: 20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	125233	Start of drug dose administration
DCM	125234	Start of contrast agent administration
DCM	125235	Destruction of microbubbles
DCM	125236	Onset of exercise
DCM	125237	Cessation of exercise
DCM	125238	Onset of stimulation
DCM	125239	Cessation of stimulation

CID 12032 Transducer Scan Pattern

Context ID 12032
Transducer Scan Pattern
Type: Extensible Version: 20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	125240	Line scan pattern
DCM	125241	Plane scan pattern
DCM	125242	Volume scan pattern

CID 12033 Ultrasound Transducer Geometry

Context ID 12033
Ultrasound Transducer Geometry
Type: Extensible Version: 20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	125251	Non-imaging Doppler ultrasound transducer geometry
DCM	125252	Linear ultrasound transducer geometry
DCM	125253	Curved linear ultrasound transducer geometry
DCM	125254	Sector ultrasound transducer geometry
DCM	125255	Radial ultrasound transducer geometry
DCM	125256	Ring ultrasound transducer geometry

CID 12034 Ultrasound Transducer Beam Steering

Context ID 12034
Ultrasound Transducer Beam Steering
Type: Extensible Version: 20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	125257	Fixed beam direction
DCM	125258	Mechanical beam steering
DCM	125259	Phased beam steering

CID 12035 Ultrasound Transducer Application

Context ID 12035
Ultrasound Transducer Application
Type: Extensible Version: 20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	125261	External Transducer
DCM	125262	Transesophageal Transducer
DCM	125263	Endovaginal Transducer
DCM	125264	Endorectal Transducer
DCM	125265	Intravascular Transducer

CID 7201 Referenced Image Purposes of Reference

Context ID 7201
Referenced Image Purposes of Reference
Type: Extensible Version: ~~20020904~~20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
…		
DCM	**121346**	**Acquisition frames corresponding to volume**
DCM	**121347**	**Volume corresponding to spatially-related acquisition frames**
DCM	**121348**	**Temporal Predecessor**
DCM	**121349**	**Temporal Successor**

CID 7203 Image Derivation

Context ID 7203
Image Derivation
Type: Extensible Version: ~~20050822~~20090409

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
…		
DCM	**113091**	**Spatially-related frames extracted from the volume**
DCM	**113092**	**Temporally-related frames extracted from the set of volumes**

Annex 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.

DICOM Code Definitions (Coding Scheme Designator “DCM” Coding Scheme Version “01”)

Code Value	Code Meaning	Definition	Notes
109116	Arterial Pulse Waveform	A digitized signal from the patient arterial system collected through pulse oximetry or other means	
109117	Respiration Waveform	A digitized signal from the patient respiratory system representing respiration	
113091	Spatially-related frames extracted from the volume	Spatially-related frames in this image are representative frames from the referenced 3D volume dataset	
113092	Temporally-related frames extracted from the set of volumes	Temporally-related frames in this image are representative frames from the referenced 3D volume dataset	
121306	Simultaneous Arterial Pulse Waveform	Atrerial pulse waveform obtained simultaneously with acquisition of a referencing image	
121307	Simultaneous Phonocardiographic Waveform	Phonocardiographic waveform obtained simultaneously with acquisition of a referencing image	
121346	Acquisition frames corresponding to volume	The referenced image is the source of spatially-related frames from which the referencing 3D volume dataset was derived	
121347	Volume corresponding to spatially-related acquisition frames	3D Volume containing the spatially-related frames in the referencing instance	
121348	Temporal Predecessor	Instance acquired prior to the referencing instance in a set of consecutively acquired instances	

121349	Temporal Successor	Instance acquired subsequent to the referencing instance in a set of consecutively acquired instances	
125233	Start of drug dose administration	Onset of administration of dose of a drug	
125234	Start of contrast agent administration	Onset of contrast agent administration	
125235	Destruction of microbubbles	Destruction of ultrasonic contrast microbubbles by a high-energy ultrasound pulse	
125236	Onset of exercise	Instant at which exercise begins	
125237	Cessation of exercise	Instant at which exercise ends	
125238	Onset of stimulation	Instant at which stimulation begins	
125239	Cessation of stimulation	Instant at which stimulation ends	
125240	Line scan pattern	Ultrasound transducer scan pattern in which information is gathered along a line	
125241	Plane scan pattern	Ultrasound transducer scan pattern in which information is gathered within a plane	
125242	Volume scan pattern	Ultrasound transducer scan pattern in which information is gathered within a volume	
125251	Non-imaging Doppler ultrasound transducer geometry	Ultrasound transducer geometry characterized by a single scan line used for PW or CW Doppler scanning	
125252	Linear ultrasound transducer geometry	Ultrasonic transducer geometry characterized by parallel lines	
125253	Curved linear ultrasound transducer geometry	Ultrasonic transducer geometry characterized by radial lines normal to the outside of a curved surface	
125254	Sector ultrasound transducer geometry	Ultrasonic transducer geometry characterized by lines originating from a common apex	
125255	Radial ultrasound transducer geometry	Ultrasonic transducer geometry characterized by lines eminating radially from a single point	

125256	Ring ultrasound transducer geometry	Ultrasonic transducer geometry characterized by a circular ring of transducer elements	
125257	Fixed beam direction	Ultrasonic steering technique consisting of a single beam normal to the transducer face steered by the orientation of the probe	
125258	Mechanical beam steering	Ultrasonic steering technique consisting of mechanically directing the beam	
125259	Phased beam steering	Ultrasonic steering technique consisting of electronically-steered beams	
125261	External Transducer	Transducer is designed to be placed onto the surface of the subject	
125262	Transesophageal Transducer	Transducer is designed for insertion into the esophagus	
125263	Endovaginal Transducer	Transducer is designed for insertion into the vagina	
125264	Endorectal Transducer	Transducer is designed for insertion into the rectum	
125265	Intravascular Transducer	Transducer is designed for insertion via a catheter	
125901	CARDIOsphere	CARDIOsphereTM ultrasonic contrast agent produced by POINT Biomedical	
125902	Echovist	Echovist® ultrasonic contrast agent produced by Schering AG	
125903	Imagify	ImagifyTM ultrasonic contrast agent produced by Accusphere Inc.	
125904	Levovist	Levovist® ultrasonic contrast agent produced by Schering AG.	
125905	Sonazoid	SonazoidTM ultrasonic contrast agent produced by Daiichi Pharmaceutical / General Electric	
125906	SonoVue	SonoVueTM ultrasonic contrast agent produced by Bracco Diagnostics	

125907	**Targestar-B**	**TargestarTM-B ultrasonic contrast agent produced by Targeson LLC**	
125908	**Targestar-P**	**TargestarTM-P ultrasonic contrast agent produced by Targeson LLC**	

Changes to NEMA Standards Publication PS 3.17-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 17: Explanatory Information

Item #20: Add Annexes to Part 17

Annex X 3D Ultrasound Volumes (Informative)

X.1 Purpose of this Annex

The purpose of this annex is to identify the clinical use cases that drove the development of Enhanced US Volume Object Definition for 3D Ultrasound image storage. They represent the clinical needs that must be addressed by interoperable Ultrasound medical devices and compatible workstations exchanging 3D Ultrasound image data. The use cases listed here are reviewed by representatives of the clinical community and are believed to cover most common applications of 3-D Ultrasound datasets.

X.2 3D Ultrasound Clinical Use Cases

X.2.1 Use Cases

The following use cases consider the situations in which 3D Ultrasound data is produced and used in the clinical setting:

1. An ultrasound scanner generates a *Volume Dataset* consisting of a set of parallel XY planes whose positions are specified relative to each other and/or a transducer frame-of-reference, with each plane containing one or more frames of data of different ultrasound data types. Ultrasound data types include, but are not limited to reflector intensity, Doppler velocity, Doppler power, Doppler variance, etc.
2. An ultrasound scanner generates a *set of temporally related Volume Datasets*, each as described in Case 1. Includes a set of volumes that are acquired sequentially, or acquired asynchronously and reassembled into temporal sequence (such as through the “Spatial-Temporal Image Correlation” (STIC) technique).
3. Any Volume Dataset may be operated upon by an application to create one or more *Multi-Planar Reconstruction (MPR)* views (as in Case 7)
4. Any Volume Dataset may be operated upon by an application to create one or more *Volume Rendered* views (as in Case 8)
5. Make *3D size measurements on a volume* in 3D-space
6. An ultrasound scanner generates 3D image data consisting of one or more *2D frames that may be displayed*, including
   a. A single 2D frame
   b. A temporal loop of 2D frames
   c. A loop of 2D frames at different spatial positions and/or orientations positions relative to one another
   d. A loop of 2D frames at different spatial positions, orientations, and/or times relative to one another
7. An ultrasound scanner generates 3D image data consisting of one or more *MPR Views* that may be displayed as ordinary 2D frames, including
   a. An MPR View
   b. A temporal loop of MPR Views
   c. A loop of MPR Views representing different spatial positions and/or orientations relative to one another

   d. A loop of MPR Views representing different spatial positions, orientations, and/or times relative to one another
   e. A collection of MPR Views related to one another (example: 3 mutually orthogonal MPR Views around the point of intersection)

8. An ultrasound scanner generates 3D image data consisting of one or more *Volume Rendered Views* that may be displayed as ordinary 2D frames, including
   f. An Rendered View
   g. A temporal loop of Rendered Views
   h. A loop of Rendered Views with a varying observer point
   i. A temporal loop of Rendered Views with a varying observer point

   Note: Images in this group are not normally measurable because each pixel in the 2D representation may be comprised of data from many pixels in depth along the viewing ray and does not correspond to any particular point in 3D-space.

9. Allow *successive display* of frames in multi-frame objects in cases 6, 7, and 8.

10. Make *size measurements on 2D frames* in cases 6, 7, and 8.

11. *Separation of different data types* allows for independent display and/or processing of image data (for example, color suppression to expose tissue boundaries, grayscale suppression for vascular flow trees, elastography, etc.)

12. Represent *ECG and other physiological waveforms* synchronized to acquired images.

13. *Two-stage Retrieval*: The clinician initially queries for and retrieves all the images in an exam that are directly viewable as sets of frames. Based on the review of these images (potentially on a legacy review application), the clinician may decide to perform advanced analysis of a subset of the exam images. Volume Datasets corresponding to those images are subsequently retrieved and examined.

14. An ultrasound scanner allows user to specify *qualitative patient orientation* (e.g., Left, Right, Medial, etc.) along with the image data.

15. An ultrasound scanner may maintain a *patient-relative frame of reference* (obtained such as through a gantry device) along with the image data.

16. Fiducial markers that tag *anatomical references* in the image data may be specified along with the image data.

17. *Key Images* of clinical interest are identified and either the entire image, or one or more frames or a volume segmentation within the image must be tagged for later reference.

X.2.2 Hierarchy of Use Cases

This section organizes the list of use cases into a hierarchy. Section X.3 maps items in this hierarcy to specific solutions in the DICOM Standard.

1) Data
   a) 3D Volume Data
      i) Static and Dynamic volume datasets (Cases 1 and 2)
      ii) Suitable for applications that create MPR and Render views (Cases 3 and 4)
      iii) 3D size measurements (Case 5)
   b) 2D representations of 3D volume data (Cases 6, 7, and 8)
      i) Static and Dynamic varieties (Case 9)
      ii) 2D size measurements (Case 10)
   c) Separation of data types (Case 11)

   d) Integrate physiological waveforms with image acquisition (Case 12)

2) Workflow
   a) Permit Two-step review (Case 13)
      i) Review 2D representations first (potentially on legacy viewer)
      ii) On-demand operations on 3D volume dataset
   b) Frame of Reference
      i) Frame-relative
      ii) Probe-relative
      iii) Patient-relative (Cases 14 and 15)
      iv) Anatomical (Fiducials) (Case 16)
   c) Identify Key images (Case 17)

X.3 3D Ultrasound Solutions in DICOM

This section maps the use case hierarchy in Section X.2.2 to specific solutions in the DICOM Standard. As described in items 1a and 1b, there are two different types of data related to 3D image acquisition: the 3D volume dataset itself and 2D images derived from the volume dataset. See Figure X.3-1.

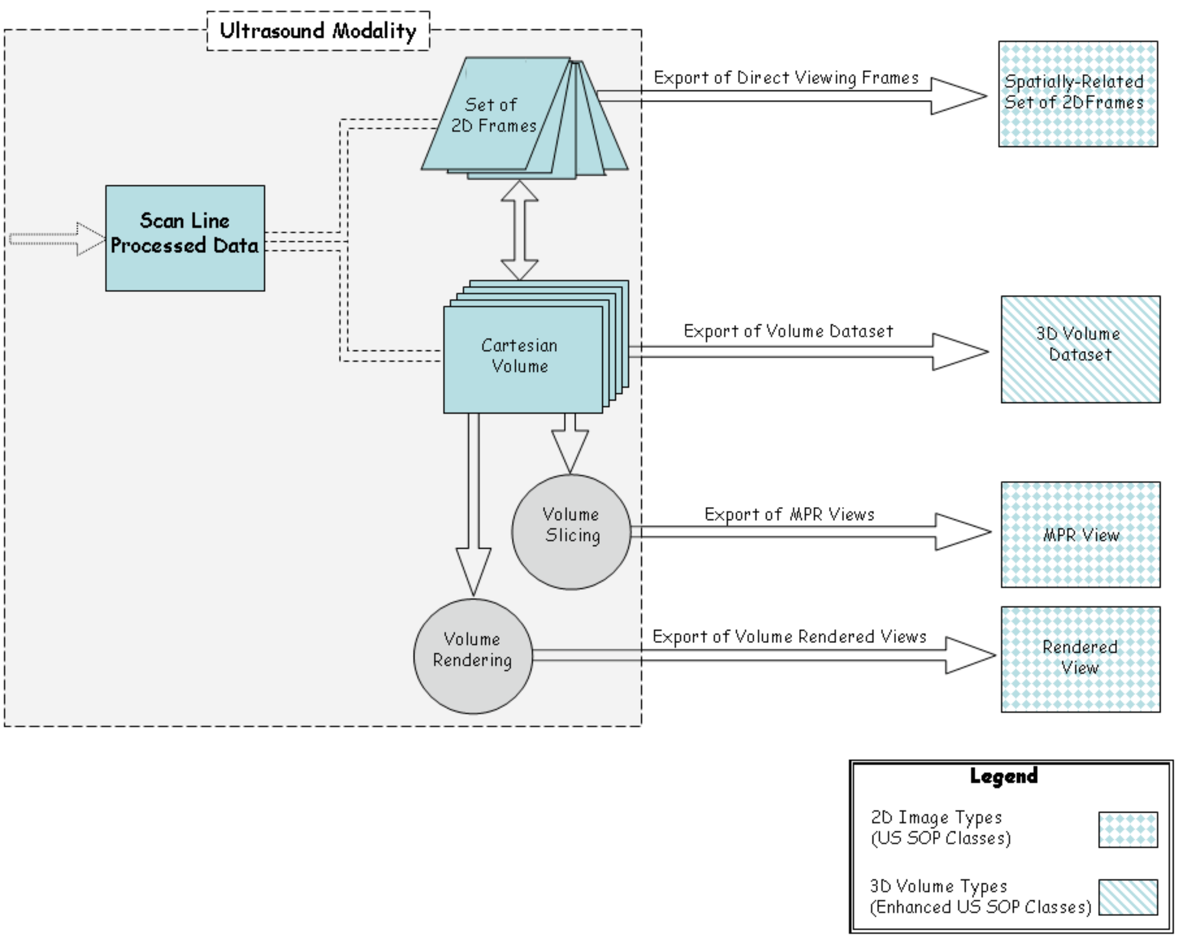

Figure X.3-1: Types of 3D Ultrasound Source and Derived Images

X.3.1 3D Volume Datasets

The 3D volume dataset is conveyed via the Enhanced US Volume SOP Class which represents individual 3D Volume Datasets or collections of temporally-related 3D Volume Datasets using the 'enhanced' multi-frame features used by Enhanced Storage SOP Classes for other modalities, including shared and per-frame functional group sequences and multi-frame dimensions. The 3D Volume Datasets represented by the Enhanced Ultrasound IOD (the striped box in Figure X.3-1) are suitable for Multi-Planar Reconstruction (MPR) and 3D rendering operations. Note that the generation of the Cartesian volume, its relationship to spatially-related 2D frames (whether the volume was created from spatially-related frames, or spatially-related frames extracted from the Cartesian volume), and the algorithms used for MPR or 3D rendering operations are outside the scope of this standard.

Functional Group Macros allow the storage of many parameters describing the acquisition and positioning of the image planes relative to the patient and external frame of references (such as a gantry or probe locating device). These macros may apply to the entire instance (Shared Functional Group) or may vary frame-to-frame (Per-Frame Functional Group).

Multi-frame Dimensions are used to organize the data type, spatial, and temporal variations among frames. Of particular interest is Data Type used as a dimension to relate frames of different data types (like tissue and flow) comprising each plane of an ultrasound image (item 1c in the use case hierarchy). Refer to PS3.3 section C.8.X.3.3 for the use of Dimensions with the Enhanced US Volume SOP Class.

Sets of temporally-related volumes may have been acquired sequentially or acquired asynchronously and reassembled into a temporal sequence, such as through Spatial-Temporal Image Correlation (STIC). Regardless of how the temporal volume sequence was acquired, frames in the resultant volumes are marked with a temporal position value, such as Temporal Position Time Offset (0020,930D) indicating the temporal position of the resultant volumes independent of the time sequence of the acquisition prior to reassembly into volumes.

X.3.2 2D Derived Images

The 2D image types represent collections of frames that are related to or derived from the volume dataset, namely Render Views (projections), separate Multi-Planar Reconstruction (MPR) views, or sets of spatially-related source frames, either parallel or oblique (the cross-hatched images in Figure X.3-1). The Ultrasound Image and Ultrasound Multiframe Image IOD's are used to represent these related or derived 2D images. The US Image Module for the Ultrasound Image Storage and Ultrasound Multi-frame Image Storage SOP Classes have defined terms for "3D Rendering" (render or MPR views) and "Spatially Related Frames" in value 4 of the Image Type (0008,0008) attribute to specify that the object contains these views while maintaining backwards compatibility with Ultrasound review applications for frame-by-frame display, which may be displayed sequentially ("fly-through" or temporal) loop display or as a side-by-side ("light-box") display of spatially-related slices. Also, the optional Source Image Sequence (0008,2112) and Derivation Code Sequence (0008,9215) attributes may be included to more succinctly specify the type of image contained in the instance and the 3D Volume Dataset from which it was derived.

2D Derived image instances should be linked to the source 3D Volume Dataset through established DICOM reference mechanisms. This is necessary to support the "Two-Stage Review" use case. Consider the following examples:

1) In the case of a 3D Volume Dataset created from a set of spatially-related frames within the ultrasound scanner, the Enhanced US Volume instance should include

    a) Referenced Image Sequence (0008,1140) to the source Ultrasound Image and/or Multi-frame Image instances

    b) Referenced Image Purpose of Reference Code Sequence (0040,A170) using (121346, DCM, "Acquisition frames corresponding to volume") and the Ultrasound Image and/or Multi-frame Image instances should include:

c) Referenced Image Sequence (0008,1140) to the 3D Volume Dataset

d) Referenced Image Purpose of Reference Code Sequence (0040,A170) using (121347, DCM, "Volume corresponding to spatially-related acquisition frames")

2) In the case of an Ultrasound Image or Ultrasound Multi-frame Image instance containing one or more of the spatially-related frames derived from a 3D volume dataset, the ultrasound image instance should include:

a) Source Image Sequence (0008,2112) referencing the Enhanced US Volume instance

b) Source Image Sequence, Purpose of Reference Code Sequence (0040,A170) using (121322, DCM, "Source of Image Processing Operation")

c) Derivation Code Sequence (0008,9215) using (113091, DCM, "Spatially-related frames extracted from the volume")

3) In the case of separate MPR or 3D rendered views derived from a 3D Volume Dataset, the image instance(s) should include:

a) Source Image Sequence (0008,2112) referencing the Enhanced US Volume instance

b) Source Image Sequence, Purpose of Reference Code Sequence (0040,A170) using (121322, DCM, "Source of Image Processing Operation")

c) Derivation Code Sequence (0008,9215) using Context ID 7203 code(s) describing the specific derivation operation(s)

X.3.3 Physiological Waveforms associated with 3D Volume Datasets

ECG or other physiological waveforms associated with an Enhanced US Volume (item 1d in the use case hierarchy) are to be conveyed via a one or more companion instances of Waveform IOD's linked bidirectionally to the Enhanced US Volume instance. Physiological waveforms associated with Ultrasound image acquisition may be represented using any of the Waveform IODs, and are linked with the Enhanced US Volume instance and to other simultaneous waveforms through the Referenced Instance Sequence in the image instance and each waveform instance. The Synchronization module and the Acquisition Datetime attribute (0018,1800) are used to synchronize the waveforms with the image and each other.

X.3.4 Workflow Considerations

The use case of two-step review (item 2a in the use case hierarchy) is addressed by the use of separate SOP Classes for 2D and 3D data representations. A review may initially be performed on the Ultrasound Image and Ultrasound Multi-frame image instances created during the study. If additional operations on the 3D volume dataset are desired, the Enhanced US Volume instance referenced in the Source Image Sequence of the derived object may be individually retrieved and operated upon by an appropriate application.

The 3D volume dataset spatially relates individual frames of the image to each other using the Transducer Frame of Reference defined in PS3.3 section C.8.X.2 (items 2b in the use case hierarchy) . This permits alignment of frames with each other in the common situation where a hand-held ultrasound transducer is used without an external frame of reference. However, the Transducer Frame of Reference may in turn be related to an external Frame of Reference through the Transducer Gantry Position and Transducer Gantry Orientation attributes. This would permit the creation of optional Image Position and Orientation values relative to the Patient when this information is available. In addition to these frames of reference, the spatial registration, fiducials, segmentation, and deformation objects available for other Enhanced objects may also be used with the Enhanced US Volume instances.

The Key Object Selection Document SOP Class may be used to identify specific Enhanced US Volume instances of particular interest (item 2d in the use case hierarchy).

Annex Y Enhanced US Data Type Blending Examples (Informative)

Y.1 Enhanced US Volume Use of the Blending and Display Pipeline

This Annex contains a number of examples illustrating Ultrasound's use of the Blending and Display Pipeline. An overview of the examples included is found in Table Y.1-1.

Table Y.1-1 - Enhanced US Data Type BlendingExamples (Informative)

Example	Data Types	Blending RGB Inputs	Mapping	Blending Operation	Blending Weight Inputs
1	TISSUE_INTENSITY	NA	Identity	None	NA
2	TISSUE_INTENSITY	RGB1 = grayscale TISSUE_INTENSITY	Grayscale	Output = RGB1	Weight 1 = 1.0 (constant)
					Weight 2 = 0.0 (constant)
3	TISSUE_INTENSITY	RGB1 = f(TISSUE_INTENSITY)	Colorized	Output = RGB1	Weight 1 = 1.0 (constant)
					Weight 2 = 0.0 (constant)
4	TISSUE_INTENSITY	RGB1 = grayscale TISSUE_INTENSITY	Grayscale	Output = proportional summation of RGB1 and RGB2	Weight 1 = constant
	FLOW_VELOCITY	RGB2 = g(FLOW_VELOCITY)	Colorized		Weight 2 = constant
5	TISSUE_INTENSITY	RGB1 = grayscale TISSUE_INTENSITY	Grayscale	Threshold based on FLOW_VELOCITY	Weight 1 = 1 – Alpha 2
	FLOW_VELOCITY	RGB2 = g(FLOW_VELOCITY)	Colorized		Weight 2 = constant
6	TISSUE_INTENSITY	RGB1 = grayscale TISSUE_INTENSITY	Grayscale	Threshold based on FLOW_VELOCITY (MSB) and FLOW_VARIANCE (LSB) with 2-dimensional color mapping	Weight 1 = 1 - Alpha 2
	FLOW_VELOCITY	RGB2 = g(FLOW_VELOCITY, FLOW_ VARIANCE)	Colorized		Weight 2 = Alpha 2
	FLOW_ VARIANCE		Colorized		
7	TISSUE_INTENSITY	RGB1 = f(TISSUE_INTENSITY)	Colorized	Combination based on all data value inputs with colorized tissue and colorized 2-dimensional color mapping of flow and variance.	Weight 1 = Alpha 1
	FLOW_VELOCITY	RGB2 = g(FLOW_VELOCITY, FLOW_ VARIANCE)	Colorized		Weight 2 = Alpha 2
	FLOW_ VARIANCE		Colorized		

In the examples below, the following attributes are referenced:

Data Type	(0018,9808)
Data Path Assignment	(0028,1402)
Bits Mapped to Color Lookup Table	(0028,1403)
Blending LUT 1 Transfer Function	(0028,1405)
Blending LUT 2 Transfer Function	(0028,140D)
Blending Weight Constant	(0028,1406)
RGB LUT Transfer Function	(0028,140F)
Alpha LUT Transfer Function	(0028,1410)
Red Palette Color Lookup Table Descriptor	(0028,1101)
Red Palette Color Lookup Table Data	(0028,1201)
Green Palette Color Lookup Table Descriptor	(0028,1102)
Green Palette Color Lookup Table Data	(0028,1202)
Blue Palette Color Lookup Table Descriptor	(0028,1103)
Blue Palette Color Lookup Table Data	(0028,1203)
Alpha Palette Color Lookup Table Descriptor	(0028,1104)
Alpha Palette Color Lookup Table Data	(0028,1204)

Example 1 – Grayscale P-values output

Grayscale pass through for 1 data frame using identity Presentation LUT:

Data Type	Data Path Assignment	Usage
TISSUE_INTENSITY	PRIMARY_PVALUES	Grayscale

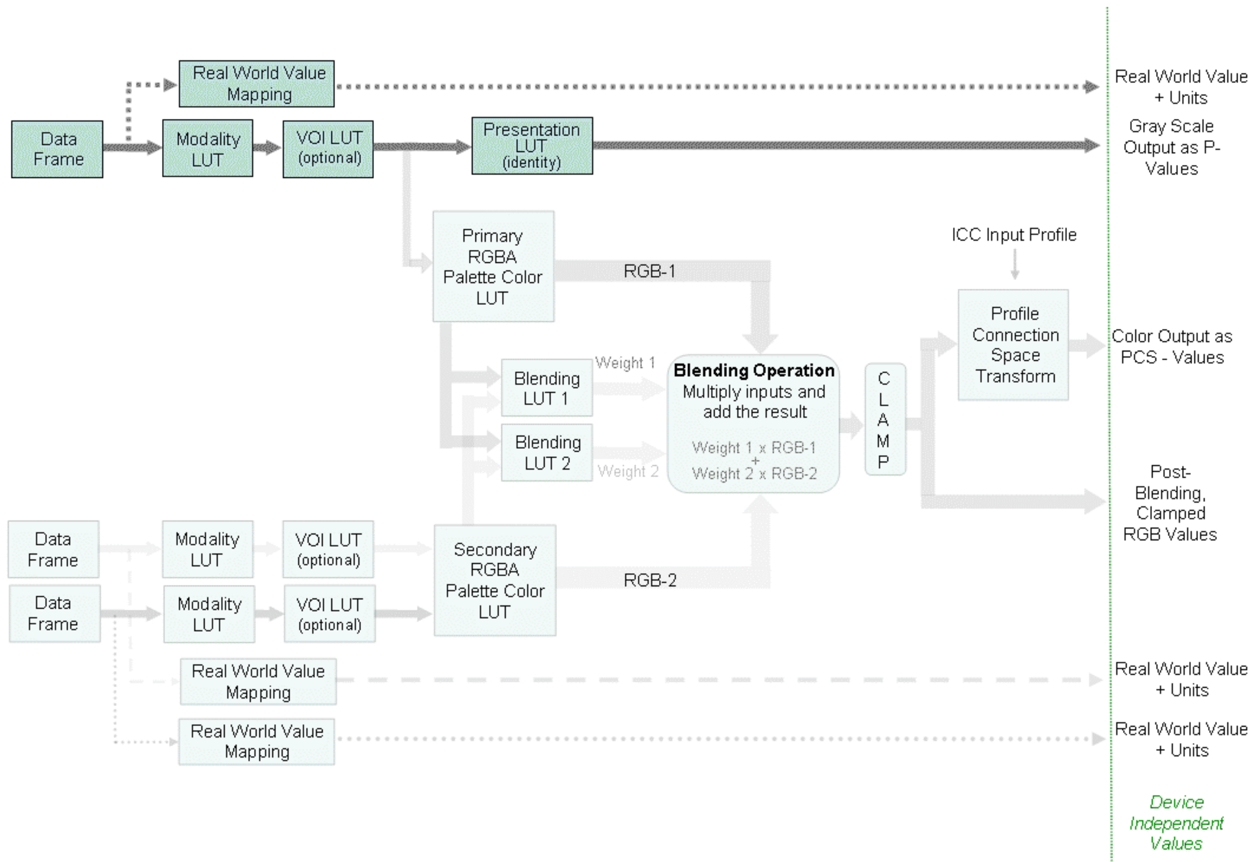

Figure Y.1-1: Example 1

Example 2 – Grayscale-only Color Output

Grayscale mapping only from 1 data frame:
- Weight 1:
  - Blending LUT 1 Transfer Function = CONSTANT
  - Blending Weight Constant = 1.0
- Weight 2:
  - Blending LUT 2 Transfer Function = CONSTANT
  - Blending Weight Constant = 0.0
- Primary Palette Color Lookup Table
  - RGB LUT Transfer Function = EQUAL_RGB
  - Alpha LUT Transfer Function = not significant with these Blending LUT Transfer Function values
- Secondary Palette Color Lookup Table
  - <none>

Note: Compared to Example 1, the perceived contrast of the displayed grayscale image will likely be different as a consequence of the use of PCS-Values as opposed to P-Values unless color management software interpreting the PCS-Values attempts to approximate the Grayscale Standard Display Function. This is true regardless of whether a color or grayscale display is used.

Data Type	Data Path Assignment	Usage
TISSUE_INTENSITY	PRIMARY_SINGLE	Mapped to Grayscale

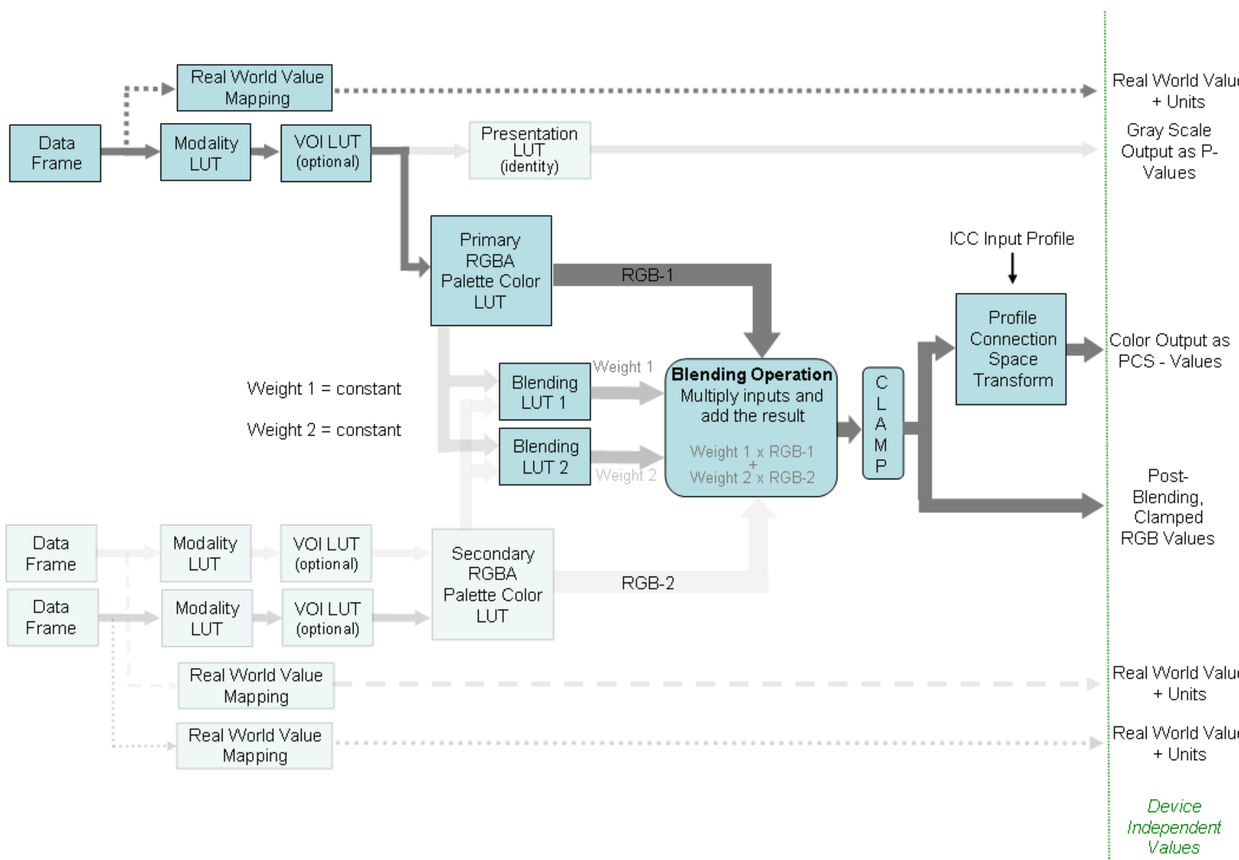

Figure Y.1-2: Example 2

Example 3 – Color Tissue (Pseudo-Color) Mapping

Grayscale mapping only from 1 data frame:

- Weight 1:
  - Blending LUT 1 Transfer Function = CONSTANT
  - Blending Weight Constant = 1.0
- Weight 2:
  - Blending LUT 2 Transfer Function = CONSTANT
  - Blending Weight Constant = 0.0
- Primary Palette Color Lookup Table
  - RGB LUT Transfer Function = TABLE
  - Alpha LUT Transfer Function = not significant with these Blending LUT Transfer Function values
  - Red, Green, and Blue Palette Color Lookup Table Descriptors and Data included
- Secondary Palette Color Lookup Table
  - <none>

Data Type	Data Path Assignment	Usage
TISSUE_INTENSITY	PRIMARY_SINGLE	Mapped through Palette Color Lookup Table

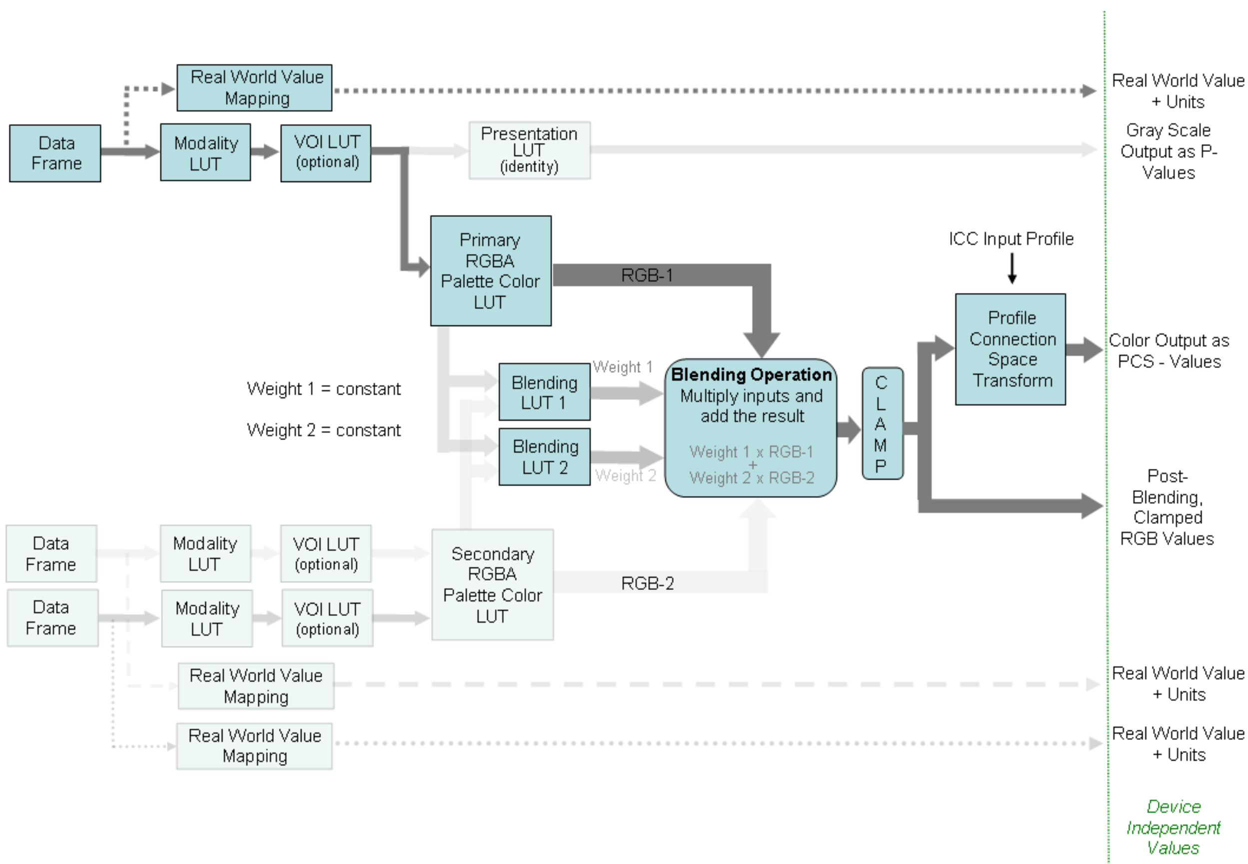

Figure Y.1-3: Example 3

1425

Example 4 – Fixed Proportion Additive Grayscale Tissue and Color Flow

Grayscale mapping from primary data frame and color mapping from secondary data frame:
- Weight 1:
  - Blending LUT 1 Transfer Function = CONSTANT
  - Blending Weight Constant = value between 0.0 and 1.0, inclusive
- Weight 2:
  - Blending LUT 2 Transfer Function = CONSTANT
  - Blending Weight Constant = value between 0.0 and 1.0, inclusive
- Primary Palette Color Lookup Table
  - RGB LUT Transfer Function = EQUAL_RGB
  - Alpha LUT Transfer Function = not significant with these Blending LUT Transfer Function values
- Secondary Palette Color Lookup Table
  - RGB LUT Transfer Function = TABLE
  - Alpha LUT Transfer Function = not significant with these Blending LUT Transfer Function values
  - Red, Green, and Blue Palette Color Lookup Table Descriptors and Data included

Data Type	Data Path Assignment	Usage
TISSUE_INTENSITY	PRIMARY_SINGLE	Mapped to Grayscale
FLOW_VELOCITY	SECONDARY_SINGLE	Mapped through Palette Color Lookup Table

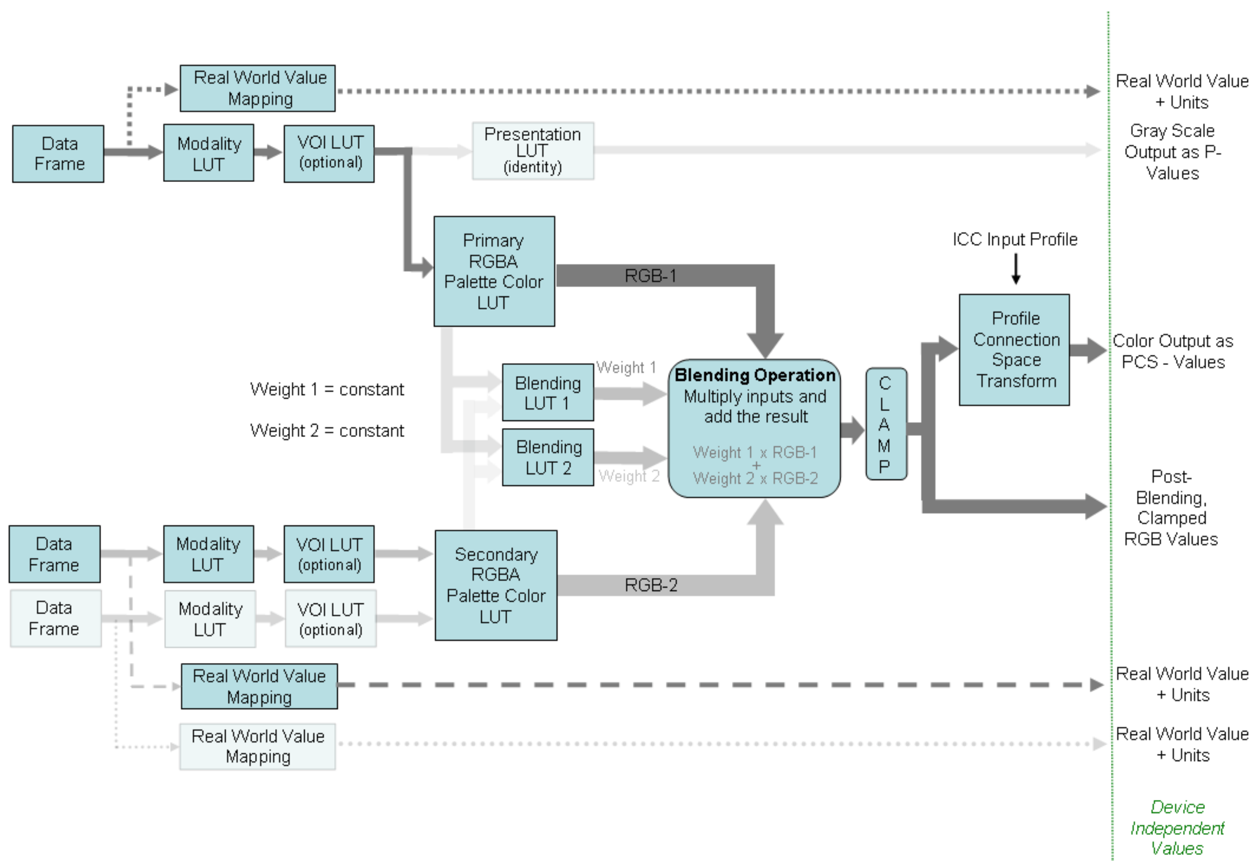

Figure Y.1-4: Example 4

Example 5 – Threshold based on FLOW_VELOCITY

Each output value is either the grayscale tissue intensity value or the colorized flow valocity value based on the magnitude of the flow velocity sample value:

- Weight 1:
  - Blending LUT 1 Transfer Function = ALPHA_2
- Weight 2:
  - Blending LUT 2 Transfer Function = ONE_MINUS
- Primary Palette Color Lookup Table
  - RGB LUT Transfer Function = EQUAL_RGB
  - Alpha LUT Transfer Function = not significant with these Blending LUT Transfer Function values
- Secondary Palette Color Lookup Table
  - RGB LUT Transfer Function = TABLE
  - Alpha LUT Transfer Function = TABLE
  - Red, Green, Blue, and Alpha Palette Color Lookup Table Descriptors and Data included
  - All Alpha Palette Color Lookup Table Data values (normalized) are either 0.0 or 1.0

Data Type	Data Path Assignment	Usage
TISSUE_INTENSITY	PRIMARY_SINGLE	Mapped to Grayscale
FLOW_VELOCITY	SECONDARY_SINGLE	Mapped through Palette Color Lookup Table

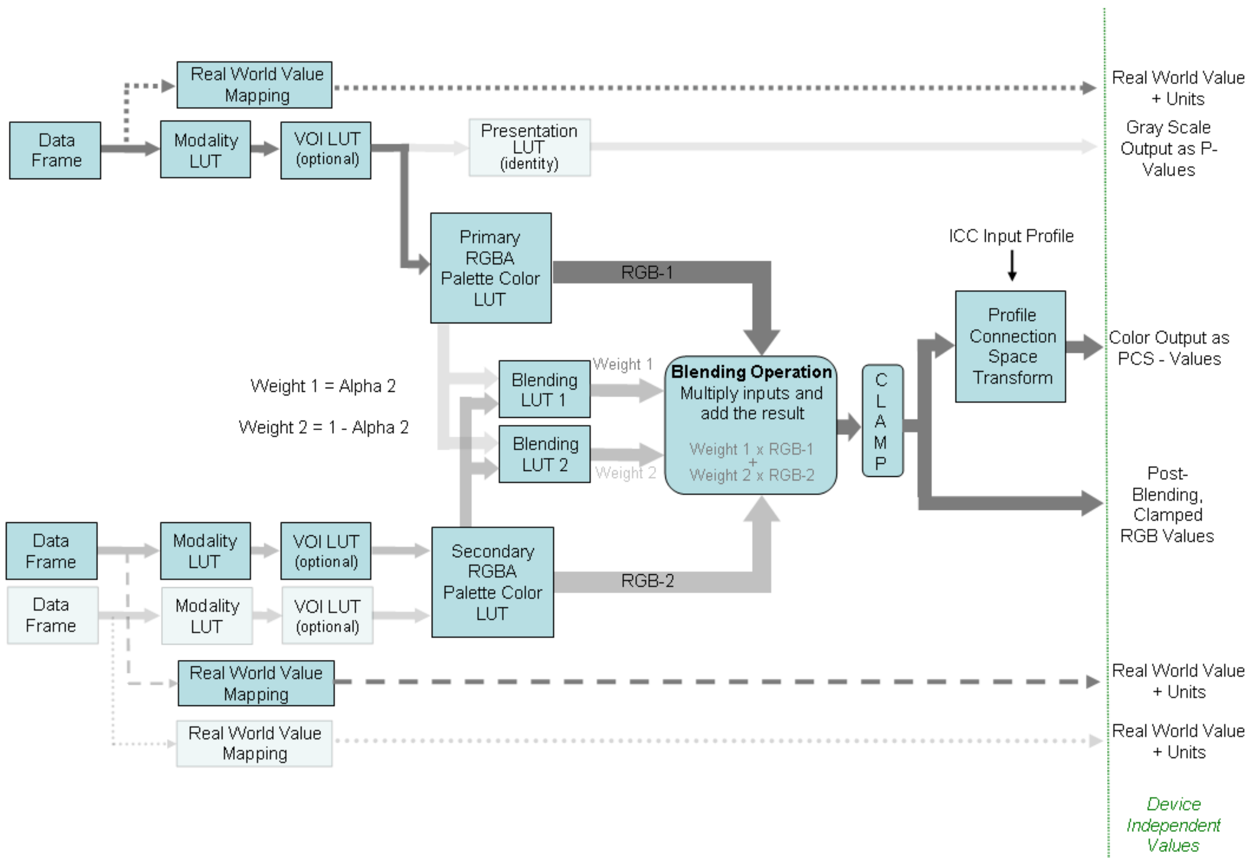

Figure Y.1-5: Example 5

Example 6 – Threshold based on FLOW_VELOCITY and FLOW_VARIANCE w/2D Color Mapping

Each output value is either the grayscale tissue intensity value or a colorized flow/variance value determined by a 2-dimensional Secondary RGB Palette Color Lookup Table, based on flow/variance values. The colorized flow/variance value comes from a 2-dimensional Secondary RGB Palette Color LUT:

- Weight 1:
  - Blending LUT 1 Transfer Function = ALPHA_2
- Weight 2:
  - Blending LUT 2 Transfer Function = ONE_MINUS
- Primary Palette Color Lookup Table
  - RGB LUT Transfer Function = EQUAL_RGB
  - Alpha LUT Transfer Function = not significant with these Blending LUT Transfer Function values
- Secondary Palette Color Lookup Table
  - RGB LUT Transfer Function = TABLE
  - Alpha LUT Transfer Function = TABLE
  - Red, Green, Blue, and Alpha Palette Color Lookup Table Descriptors and Data included
  - All Alpha Palette Color Lookup Table Data values (normalized) are either 0.0 or 1.0

Data Type	Data Path Assignment	Usage
TISSUE_INTENSITY	PRIMARY_SINGLE	Mapped to Grayscale
FLOW_VELOCITY	SECONDARY_HIGH	MSB's of index to Palette Color LUT
FLOW_VARIANCE	SECONDARY_LOW	LSB's of index to Palette Color LUT

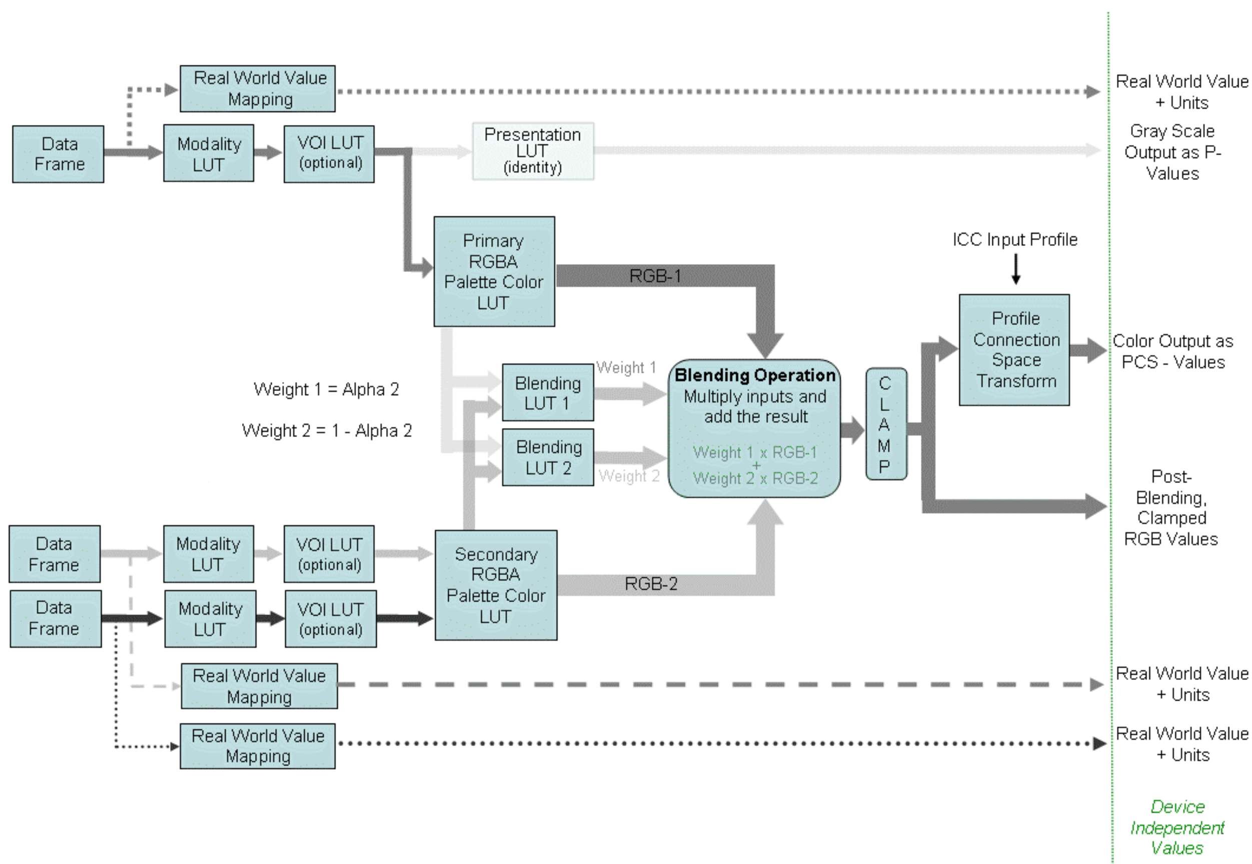

Figure Y.1-6: Example 6

Example 7 – Color Tissue / Velocity / Variance Mapping – Blending Considers Both Data Paths

Each output value is a combination of colorized tissue intensity and a colorized flow/variance value determined by a 2-dimensional Secondary RGB Palette Color Lookup Table using the upper 5 bits of the FLOW_VELOCITY value and upper 3 bits of the FLOW_VARIANCE value to allow the use of 256-value Secondary Palette Color Lookup Tables. The blending proportion is based on values from both data paths. If the sum of the two RGB values exceeds 1.0, the value is clamped to 1.0. The colorized flow/variance value comes from a 2-dimensional Secondary RGB Palette Color LUT:

Weight 1:
    Blending LUT 1 Transfer Function = ALPHA_1

Weight 2:
    Blending LUT 2 Transfer Function = ALPHA_2

Primary Palette Color Lookup Table
    RGB LUT Transfer Function = TABLE
    Alpha LUT Transfer Function = TABLE
    Red, Green, Blue, and Alpha Palette Color Lookup Table Descriptors and Data included

Secondary Palette Color Lookup Table
    RGB LUT Transfer Function = TABLE
    Alpha LUT Transfer Function = TABLE
    Red, Green, Blue, and Alpha Palette Color Lookup Table Descriptors and Data included

Data Type	Data Path Assignment	Bits Mapped To Color Lookup Table	Usage
TISSUE_INTENSITY	PRIMARY_SINGLE	8	Mapped through Palette Color Lookup Table
FLOW_VELOCITY	SECONDARY_HIGH	5	MSB's of index to Palette Color LUT
FLOW_VARIANCE	SECONDARY_LOW	3	LSB's of index to Palette Color LUT

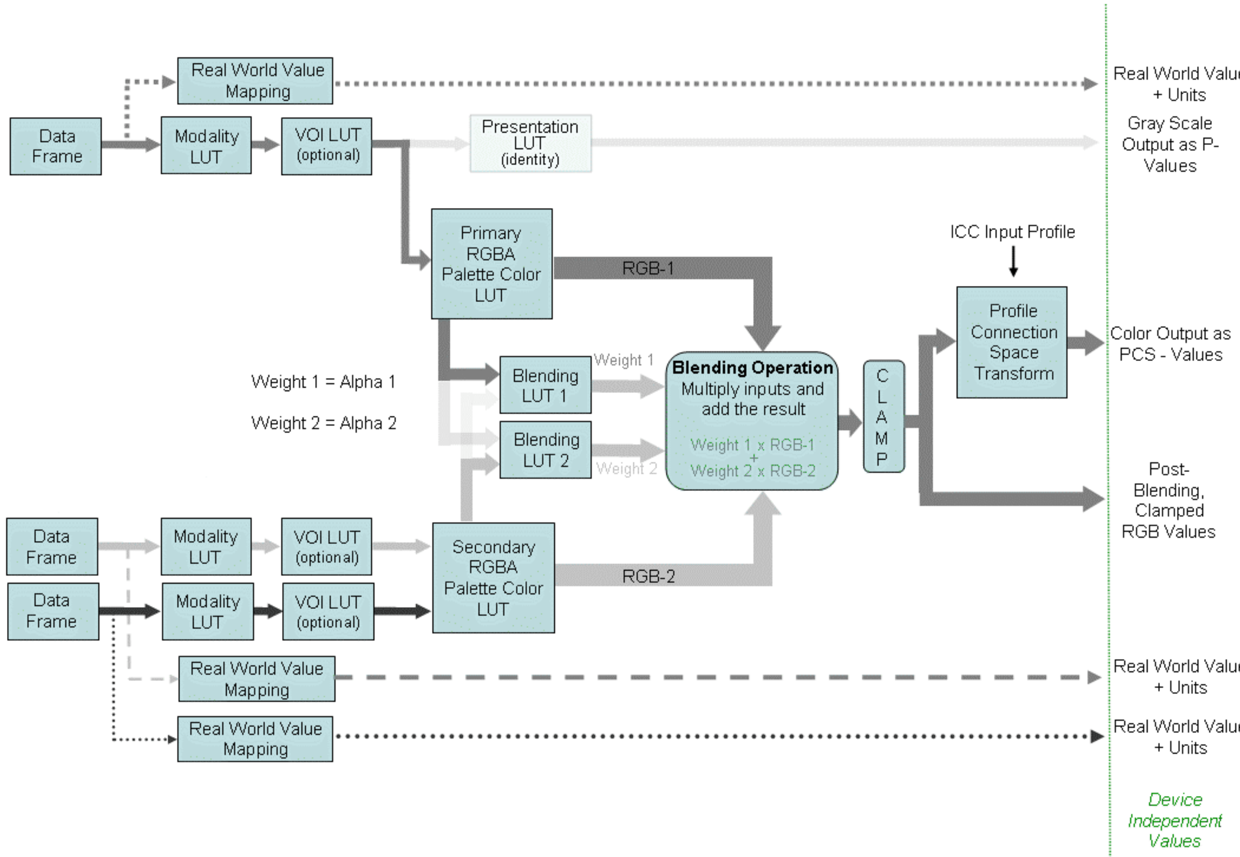

Figure Y.1-7: Example 7

INDEX