Enhanced Multi-frame Images
The New Core Paradigm for DICOM

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Enhanced Multi-Frame

Why – features and benefits

Multi-Frame model

- **Functional Groups**
- **Dimensions and stacks**
- **Concatenations**

Legacy object conversion

Summary

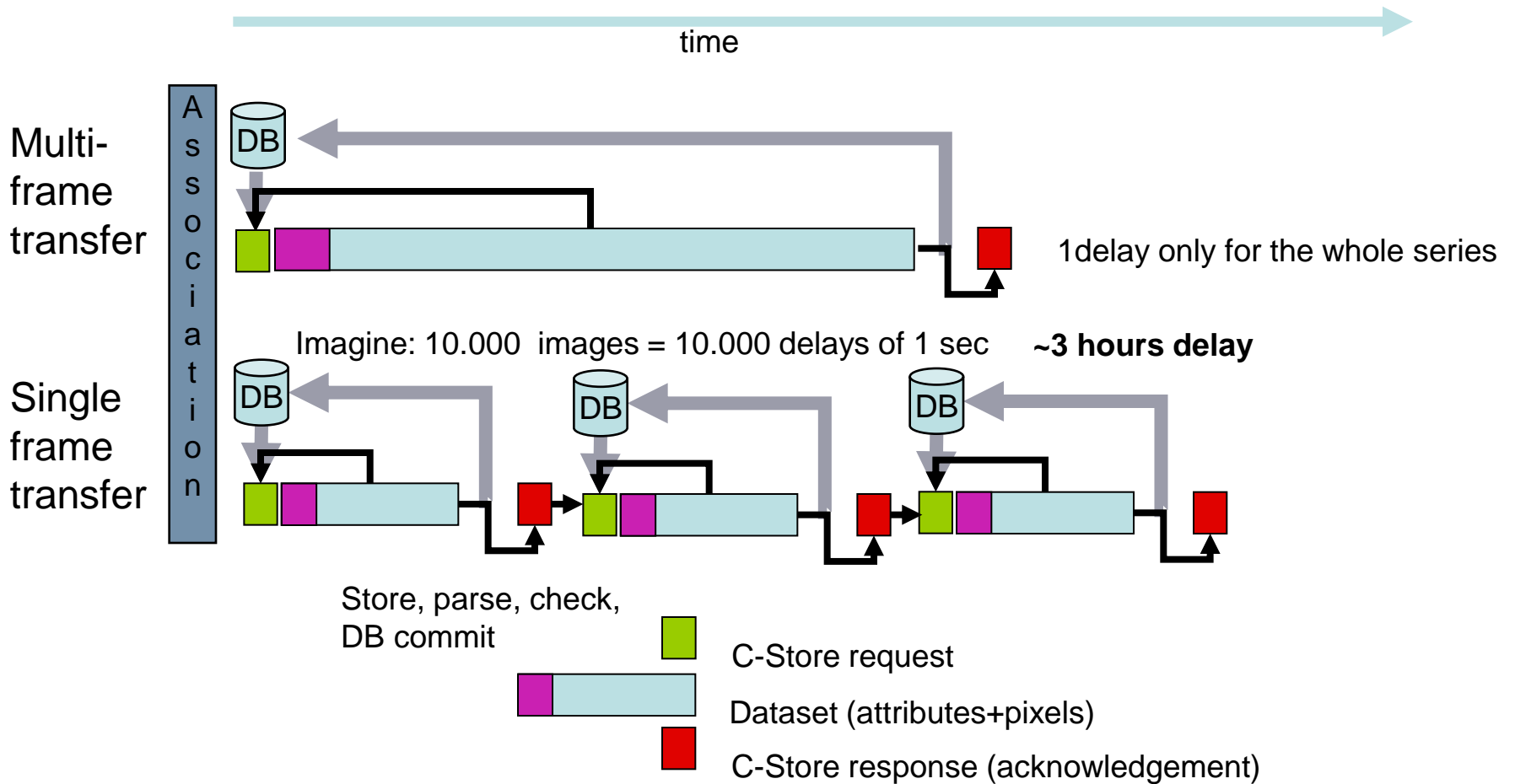# Why a new generation of image objects ?

Imaging is moving from pixels in slices (2-D) to voxels (3-D) and beyond (n-D)

- **Time, space, frequency, tensors, flow …**
- **New dimensions from advanced signal processing constantly evolving**

Data volume is exploding

- **>10,000 frame functional MR images**
- **Huge overhead with 1 frame/object - image headers redundancy, database insertion time, sequential acknowledgement for each transferred object**

Performance – Overhead

Multi-frame transfer — 1delay only for the whole series

Imagine: 10.000 images = 10.000 delays of 1 sec — **~3 hours delay**

Single frame transfer

Store, parse, check, DB commit

- C-Store request
- Dataset (attributes+pixels)
- C-Store response (acknowledgement)

*Slide Courtesy: David A.Clunie

Generalize across modalities and dimensions

Many acquisition dimensions are the same in different modalities

- **Spatial location, time, anatomy, cardiac phase, contrast phase …**

All dimensions can be handled identically algorithmically / mathematically

- **If they are defined in consistent data structures**

**New generation architecture standardizes data approach for all modalities and dimensions**

- **Simplified application logic**

- **Add new dimensions with minimal application change**

Benefits and features

- **Support for latest modality applications** through modern acquisition parameters and context information

- **Better multi-vendor interoperability** through fewer private elements, more mandatory elements, more strict attribute rules

- **Increased clinical app functionality** using consistent data structures and values

- **Consistent display behavior across modalities** using dimension information defined by the creator

- **Improved transfer performance** through fewer objects

Most of all

The Enhanced Multi-frame paradigm is the basic structure used for all new multi-frame IODs

- **Enhanced versions of classic IODs:
CT, MR Image, MR Spectroscopy, PET, US, XA, XRF**

- **New IODs:
3DXR and DBT, Intravascular OCT, Ophthalmic Tomography, Pathology WSI, Segmentation**

One multi-frame object often equivalent to full series
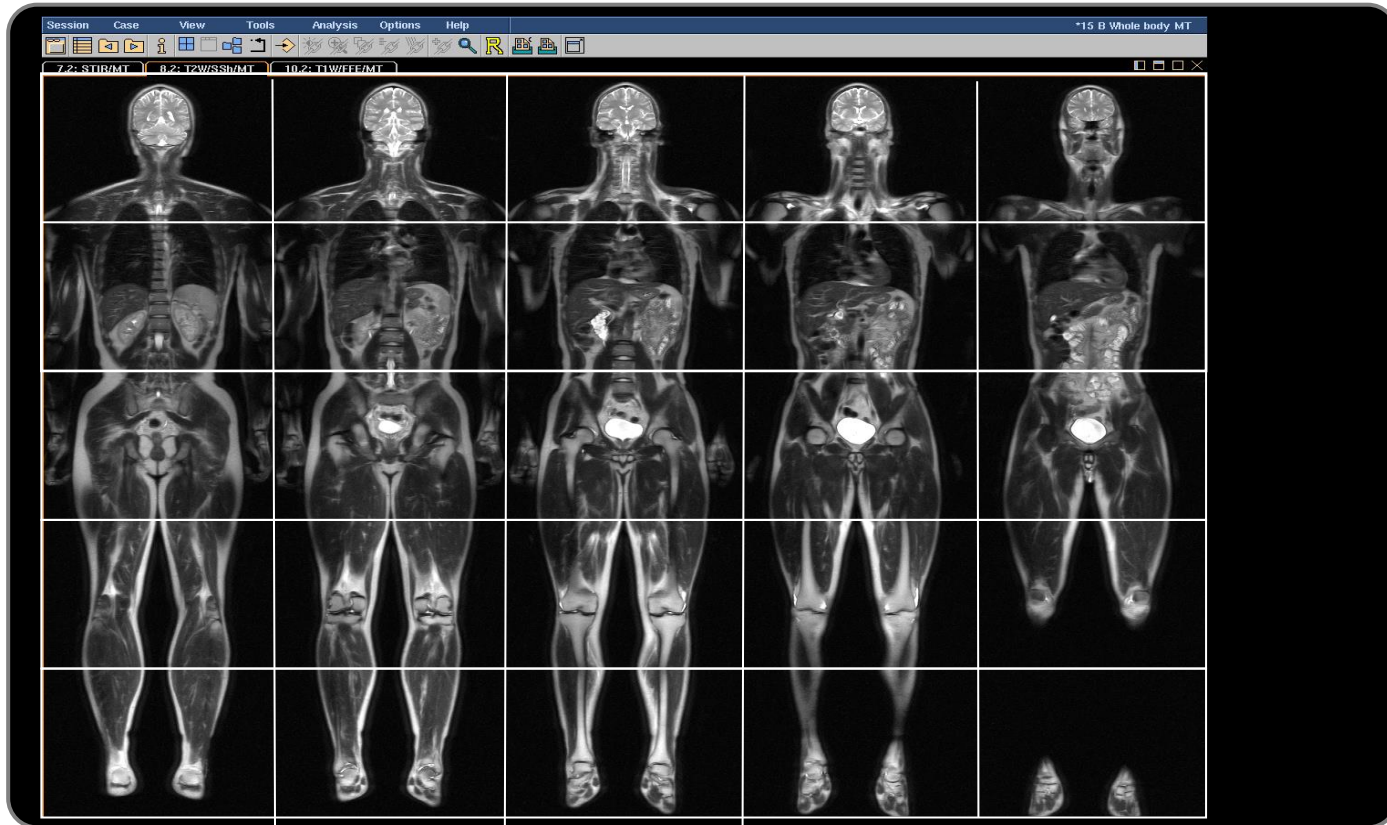
So what's new?
Multi-frame technique

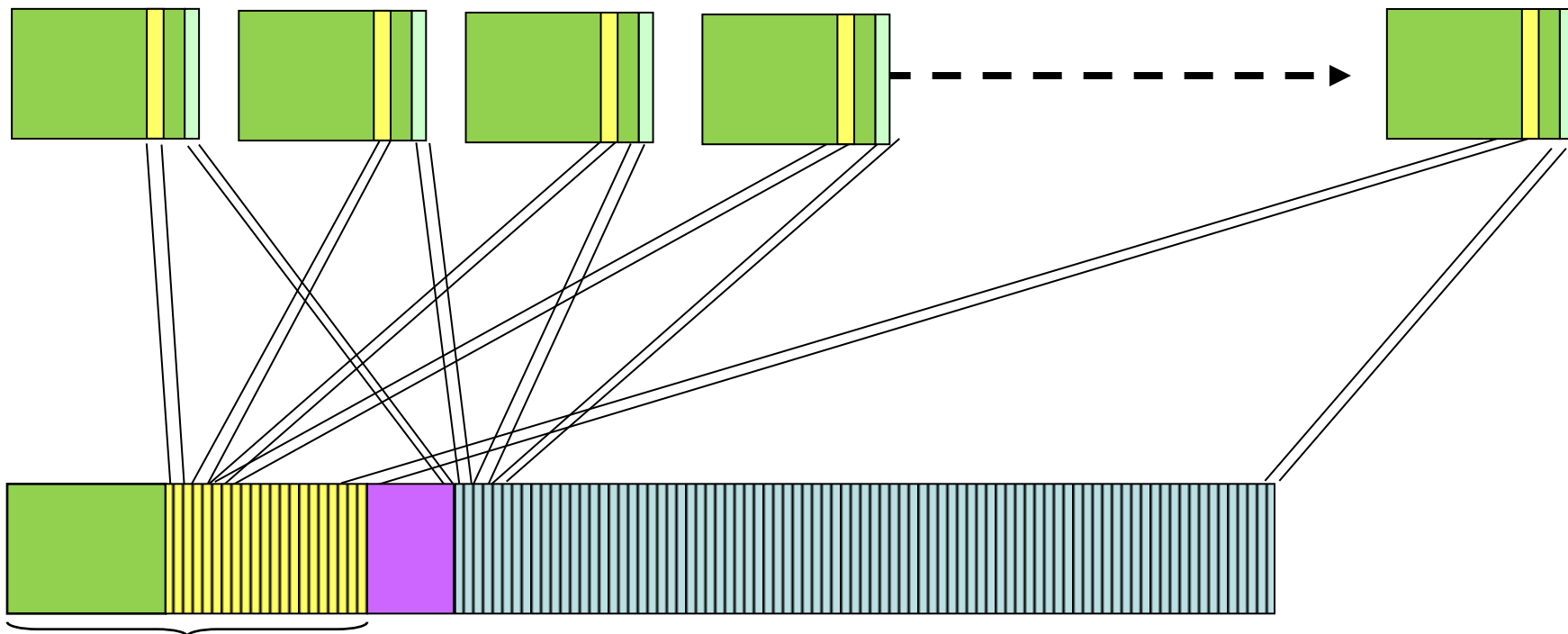**Multi-frame images have been around since DICOM 1993**

- **Distinct attribute for each parameter varying by frame**

- **Inconsistent techniques across IODs**

New approach

- **Functional Groups – Single structure for all parameters varying by frame**

- **Dimension Attributes – Describe navigation (ordering) of multi-frames**

Single-frame to MultiFrame

N Objects, N Headers

N Frames, One Header

| Fixed Header | Per-frame header | Dimension data | Pixel data |

Functional Groups

A Functional Group is a set of Data Elements that are logically related and are likely to vary together on a frame-by frame basis

Each Functional Group is encoded in a Sequence attribute with (usually) 1 Sequence Item

A "mini-Module"

Examples:

- **Plane Position, Plane Orientation, Cardiac Phase, MR Pulse Sequence, Table Dynamics, Frame Content**

Pixel Measures Functional Group

Encapsulating Sequence attribute

Table C.7.6.16-2
PIXEL MEASURES MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Pixel Measures Sequence	(0028,9110)	1	Identifies the physical characteristics of the pixels of this frame. Only a single Item shall be included in this sequence.
>Pixel Spacing	(0028,0030)	1C	Physical distance in the imaging target (patient, specimen, or phantom) between the centers of each pixel, 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. Note: In the case of CT images with an Acquisition Type (0018,9302) of CONSTANT_ANGLE, the pixel spacing is that in a plane normal to the central ray of the diverging X-Ray beam as it passes through the data collection center. Required if Volumetric Properties (0008,9206) is other than DISTORTED or SAMPLED. May be present otherwise.
>Slice Thickness	(0018,0050)	1C	Nominal reconstructed slice thickness (for tomographic imaging) or depth of field (for optical non-tomographic imaging), in mm. See C.7.6.16.2.3.1 for further explanation. Note: Depth of field may be an extended depth of field created by focus stacking (see C.8.12.4). Required if Volumetric Properties (0008,9206) is VOLUME or SAMPLED. May be present otherwise.

Functional Groups in images

A Functional Group is included in <u>one of two</u> (but not both) Sequences:

- **Shared Functional Groups Sequence**

    Functional Groups whose elements' values do not change through the object (same for each frame)
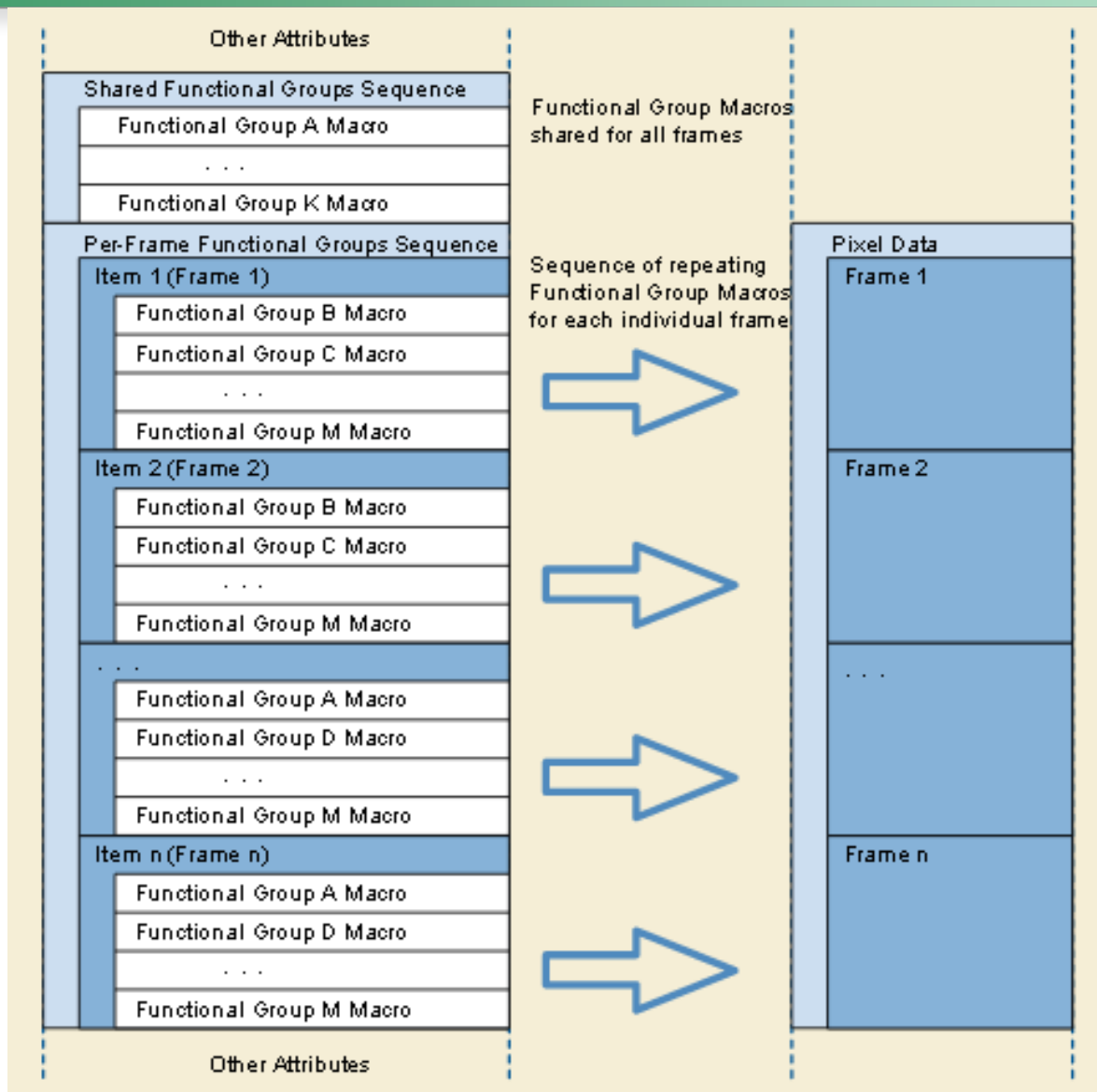
    This Sequence may be zero length

- **Per-Frame Functional Groups Sequence**

    Functional Groups containing elements whose value <u>may</u> change from one frame to another.
    Contains as many items as frames in the image.
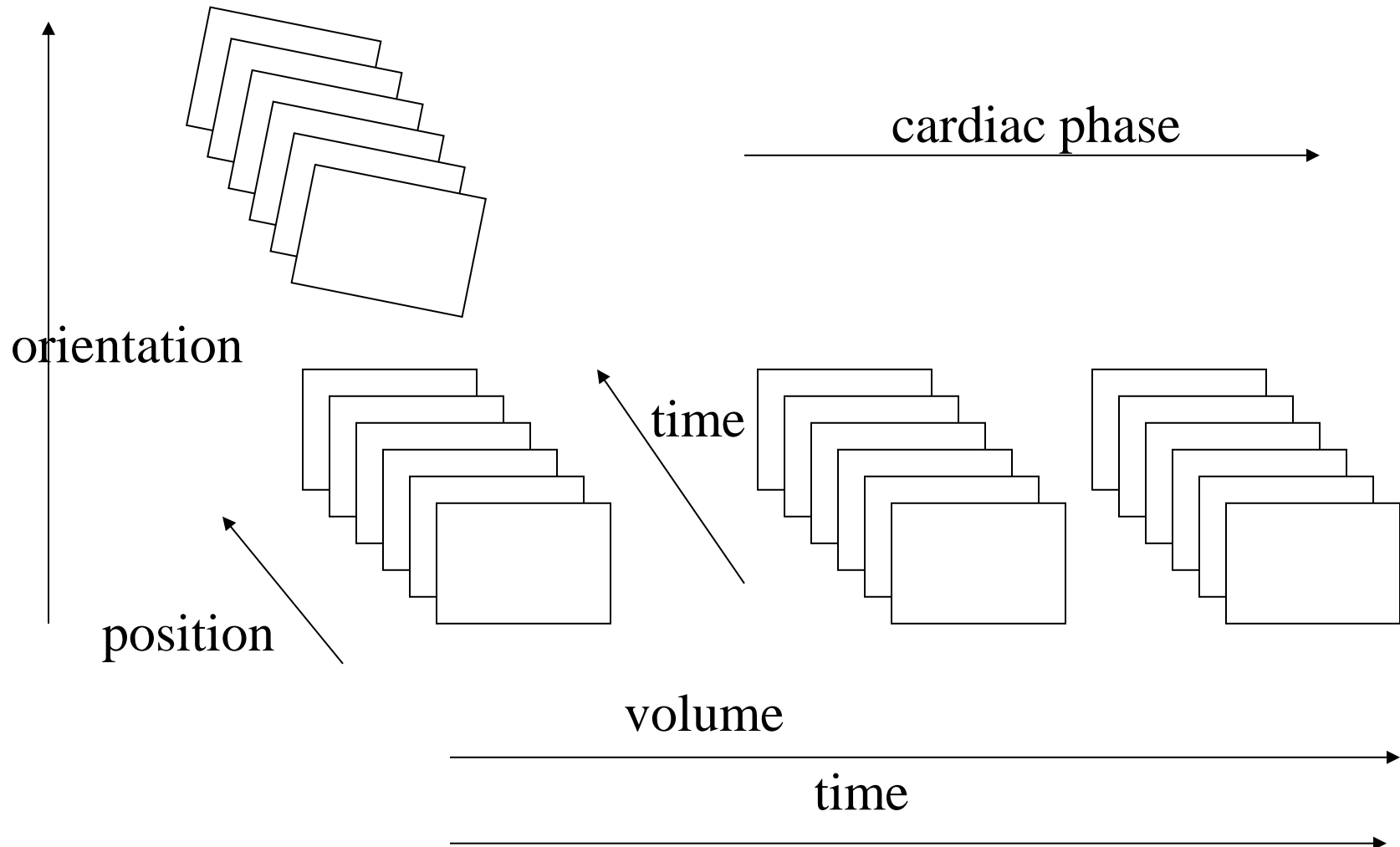
The Frame Information Header

Dimensions and Stacks

Per-frame Functional Groups provide the discrete attributes that vary

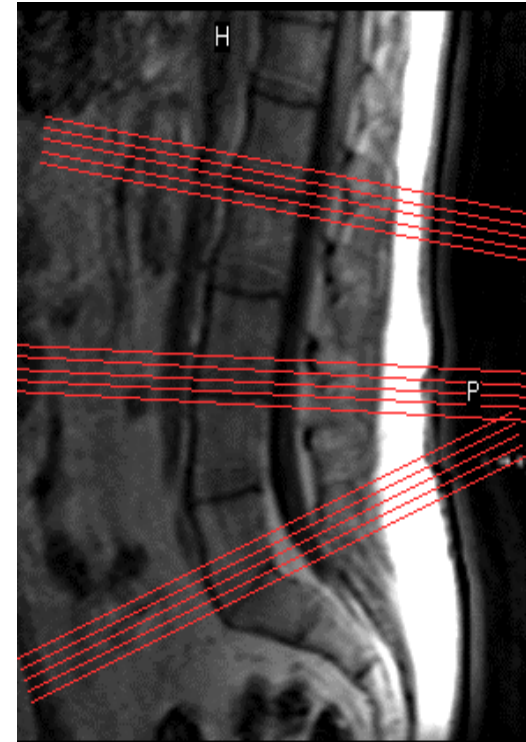**Need to organize those attributes (and their respective frames) into sets meaningful to the user**
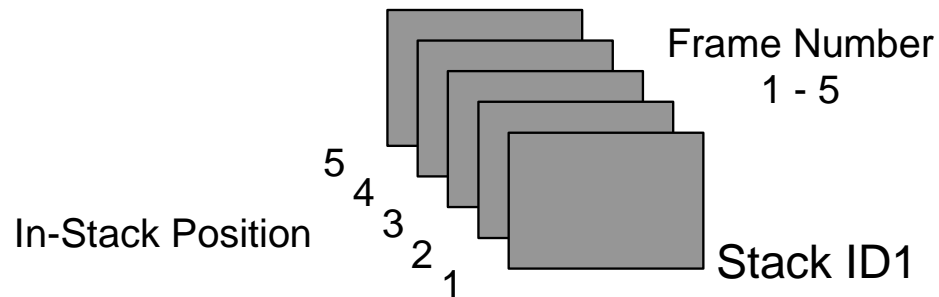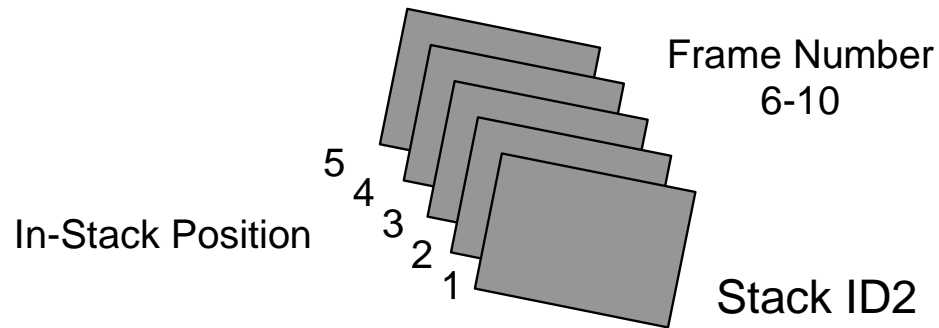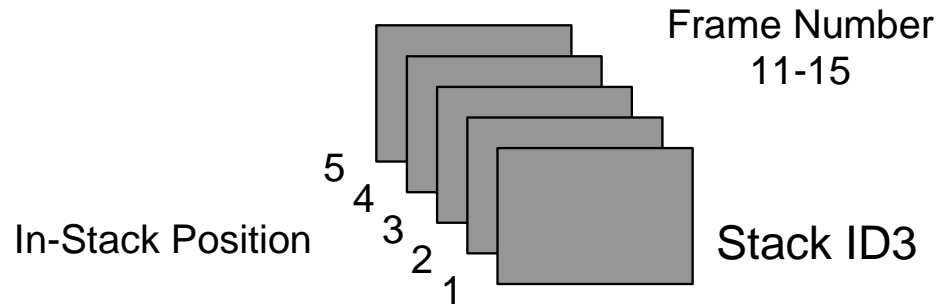
Dimensions organize frames by some Functional Group value that varies in a consistent way

Stacks are groups of frames that have a geometric relationship (e.g., represent a particular anatomic volume); have an "In-stack Position" dimension

Special indexes to handle Stacks

In-Stack Position

5
4
3
2
1

Frame Number 11-15

Stack ID3

In-Stack Position

5
4
3
2
1

Frame Number 6-10

Stack ID2

In-Stack Position

5
4
3
2
1

Frame Number 1 - 5

Stack ID1

Multi-dimensional datasets

Who best knows the important data organizational indexes?

- **Image object creator!**
- **Defines dimensions in** *Dimension Module*

Must the frames be in some specific order within the object?

- **No! Physical Frame order is not relevant; usage / presentation should be driven by the logical order**
- **Each frame has its logical position in Frame Content Functional Group** *Dimension Index Values*
- **Simple apps (e.g., display) simply traverse indexes**

What if multi-frame image gets too big?

Image too big for file system, media, or database storage (4 GB pixels, 640 MB CD, etc.)

File size flexibility through Concatenations

If needed, the content of a multi-frame image may be split into more than one SOP Instance

These SOP instances together form a Concatenation which is a group of SOP Instances within a Series that is uniquely identified by the Concatenation UID (0020,9161)

Concatenations

Legend:
- Fixed Header
- Per-frame header
- Dimension data (not on scale)
- Pixel data (not on scale)
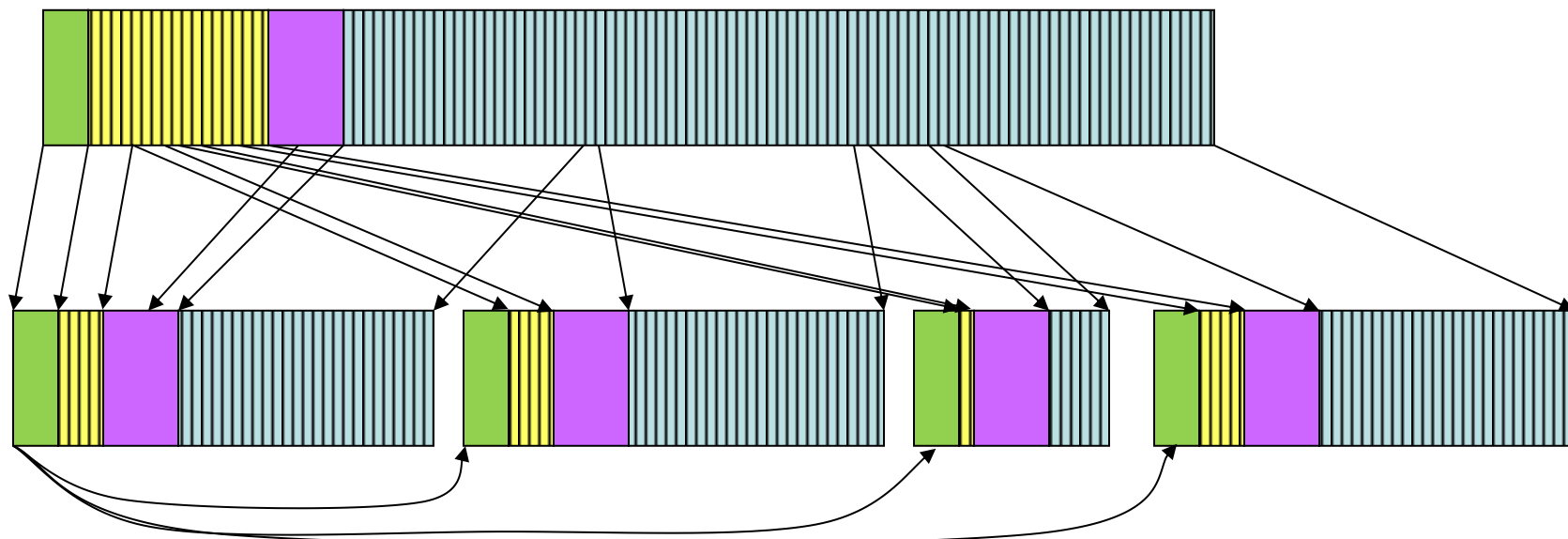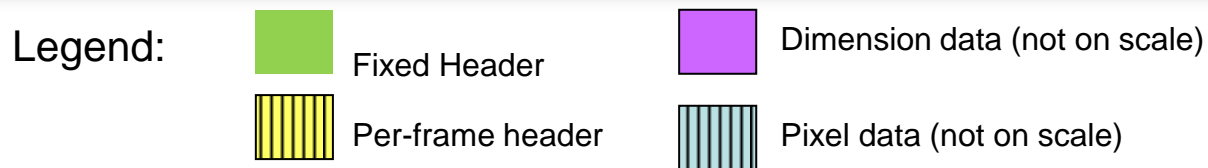
An object may be split up into two or more SOP Instances, using the same concatenation UID

Concatenations are logically a single multi-frame image

In the same series

With the same dimension indexes

Uniquely identified with a Concatenation UID (0020,9161)

"Contained" image objects have the same Instance Number:

Table C.7.6.16-1
Multi-Frame Functional Groups Module attributes extract

Instance Number	(0020,0013)	1	A number that identifies this instance. The value shall be the same for all SOP Instances of a Concatenation, and different for each separate Concatenation and for each SOP Instance not within a Concatenation in a series.

Conversion of legacy images

Why conversion?

- **Enormous archive of classic objects**

- **Supports the transition from classic to enhanced multi-frame environment**

- **Leverage most of the benefits**
  - **Transfer time reduction**
  - **Ready for advanced apps**

IODs (with relaxed constraints)

- **Legacy Converted Enhanced CT, MR, PET**

Conversion workflow

Heterogeneous environment with conversion from single to multi-frame objects

Summary
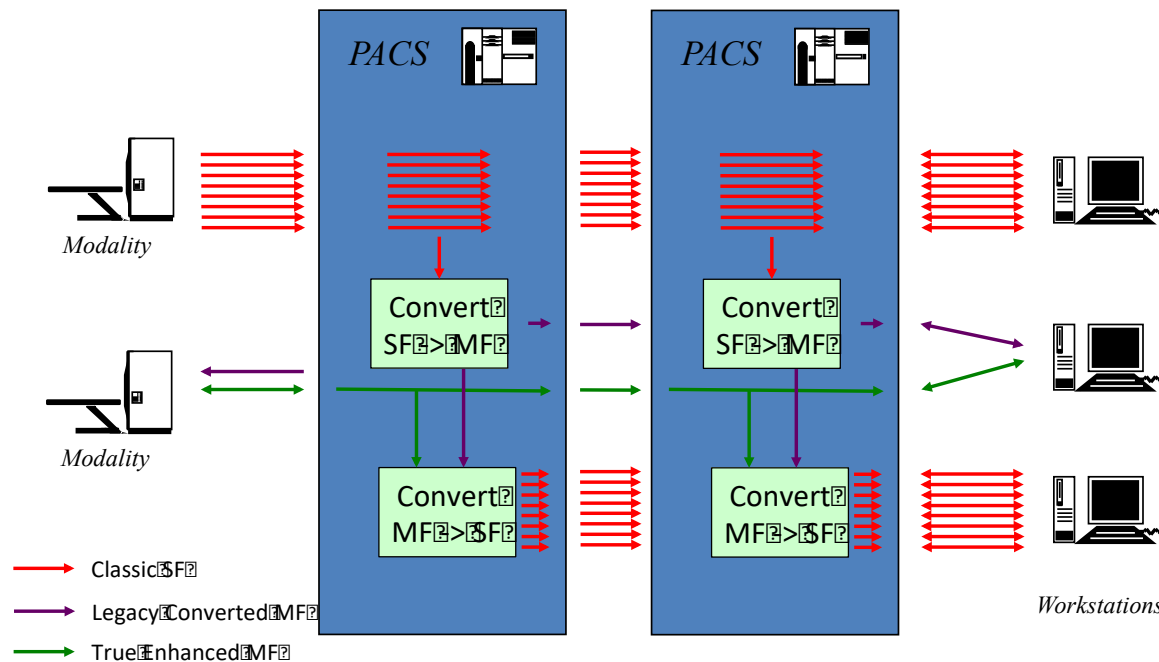
Enhanced Multi-frame is the new core paradigm for DICOM image objects

Critical to support:

- **Improved performance on large data sets**

- **Evolving acquisition techniques**

- **Advanced application architectures that support n-dimensional imaging of all modalities**

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Thank you for your attention !