New Enhanced Multi-frame DICOM CT and MR Objects to Enhance Performance and Image Processing on PACS and Workstations

SCAR 2004 Hot Topics - 22 May 2004

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Greater Expectations

- Previously, users content with viewing + annotations
- Increasingly advanced applications
  - Hanging protocols, MPR, 3D, virtual colonoscopy
  - Perfusion, diffusion, functional MR, spectroscopy
  - Cardiac cine, CT and MR fluoroscopy
  - Lung CAD
- Such applications are often vendor-specific
  - Performed on console or same vendor's workstation
  - Depend on private attributes
- Want advanced application interoperability
- Support in multi-vendor PACS workstations
- Distributing "screen saves" on PACS insufficient

Why are new objects needed ?

- CT and MR objects more than 10 years old
  - Technology on which they are based probably more than 15 years old
- Pre-date many technological advances
  - Helical CT & fast spin echo pulse sequences
- Explosion in data set size -> performance ?
  - Multi-detector CT and functional MR
- Expectations beyond simple viewing
  - Hanging protocols & advanced applications

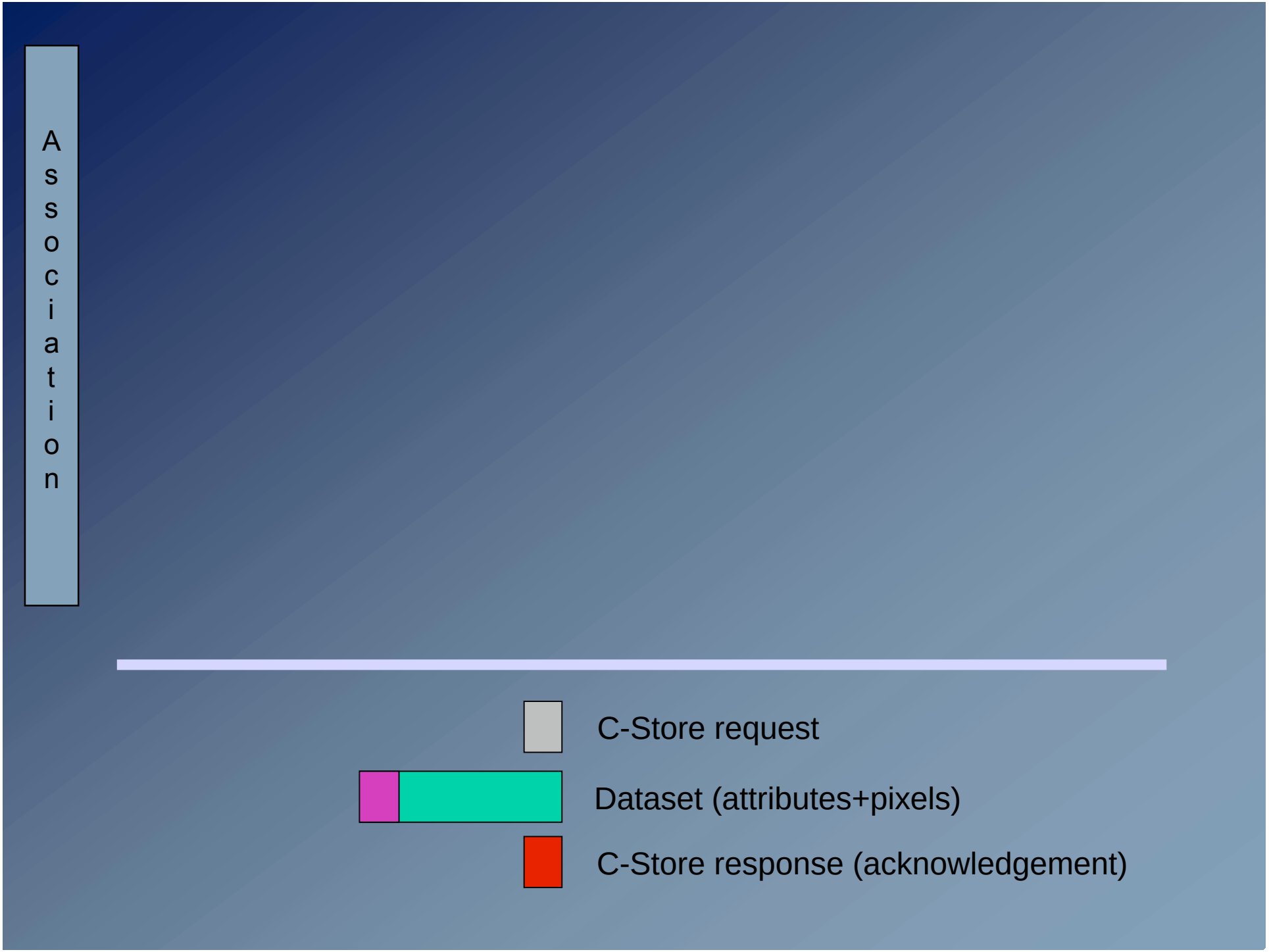
New Multi-frame CT & MT

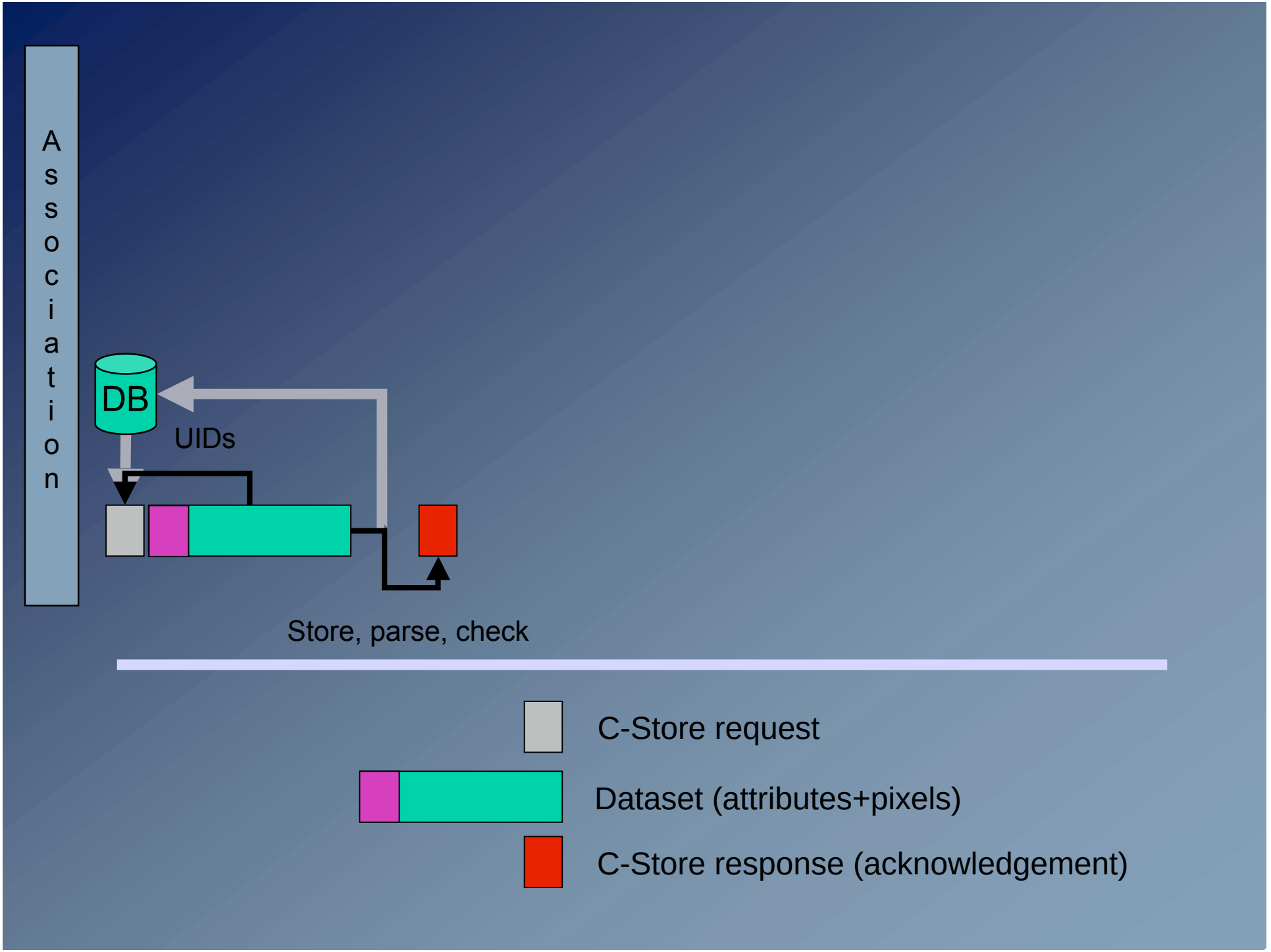
- Potential performance gain during transfer & loading
- Easier access to organized multi-slice data
- Preservation of intended semantics of acquisition (e.g. a volume set, a cine run)
- More extensive, up-to-date acquisition parameters
- Additional features for special acquisition and analysis types
  - color values, e.g. for functional data overlaid on structure
  - real world value mapping, e.g. ADC, velocity
- Specialized data interchange, and central archiving
  - Spectroscopy and raw data

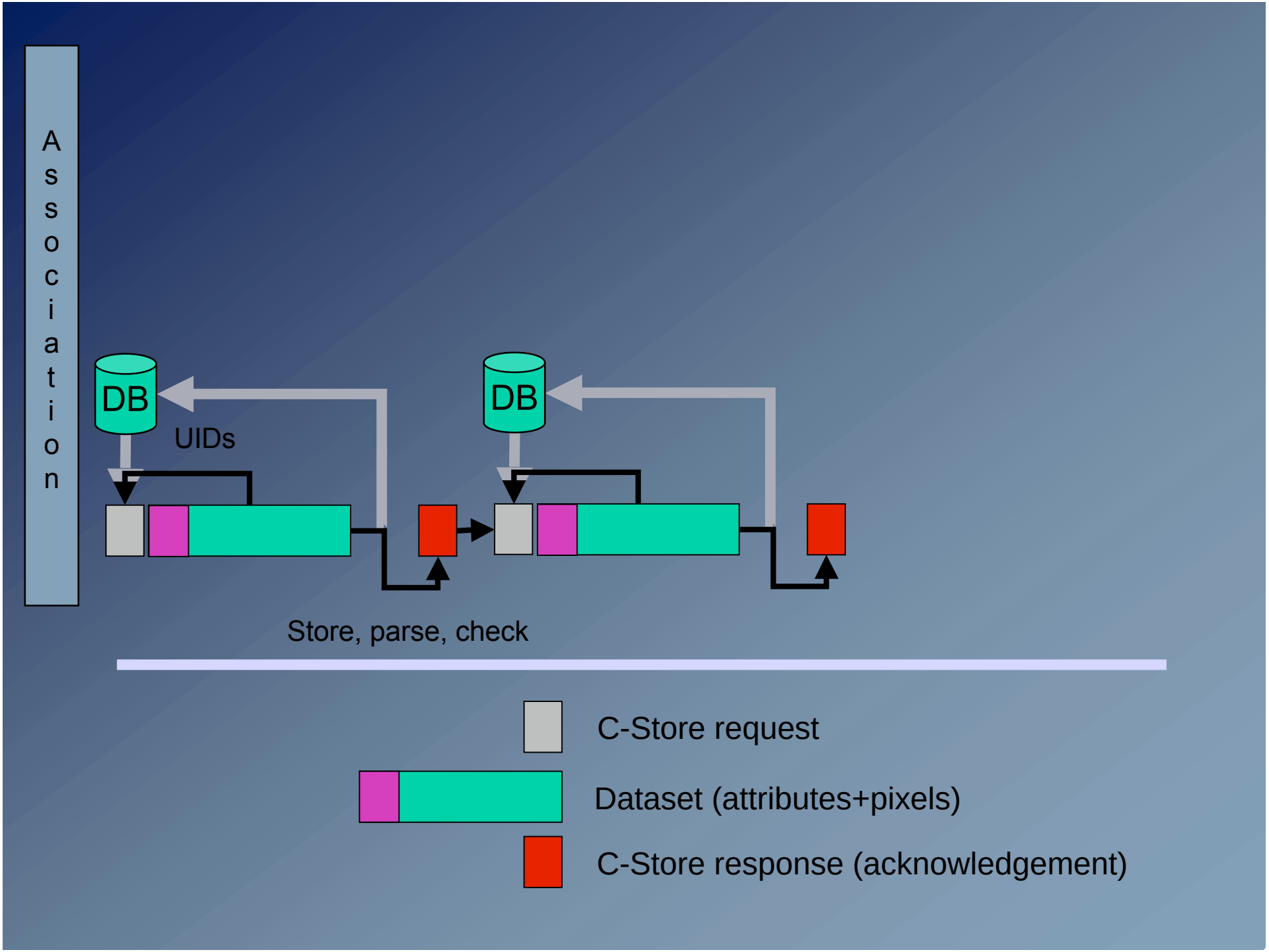
Performance Opportunities

- New multi-frame object does not change
  - TCP connection establishment
  - Association establishment
- Common header information is not repeated
  - But reduction is negligible compared to pixel data size
- Reduced latency (delay) between storage requests
- Creates opportunity for inter-slice (3D) compression

- Extremely implementation-dependent


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


Association
DB
UIDs
Store, parse, check
C-Store request
Dataset (attributes+pixels)
C-Store response (acknowledgement)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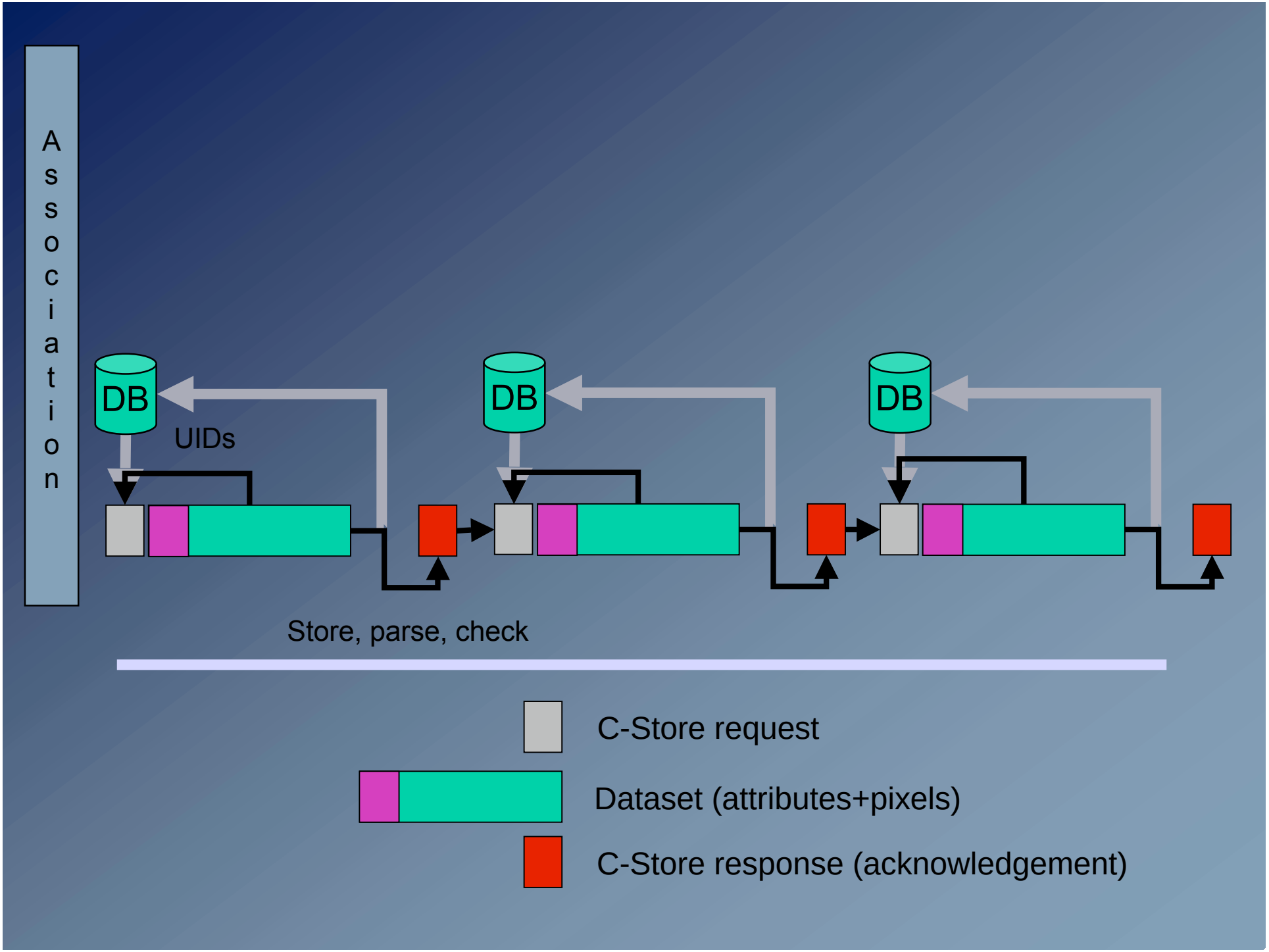
Association
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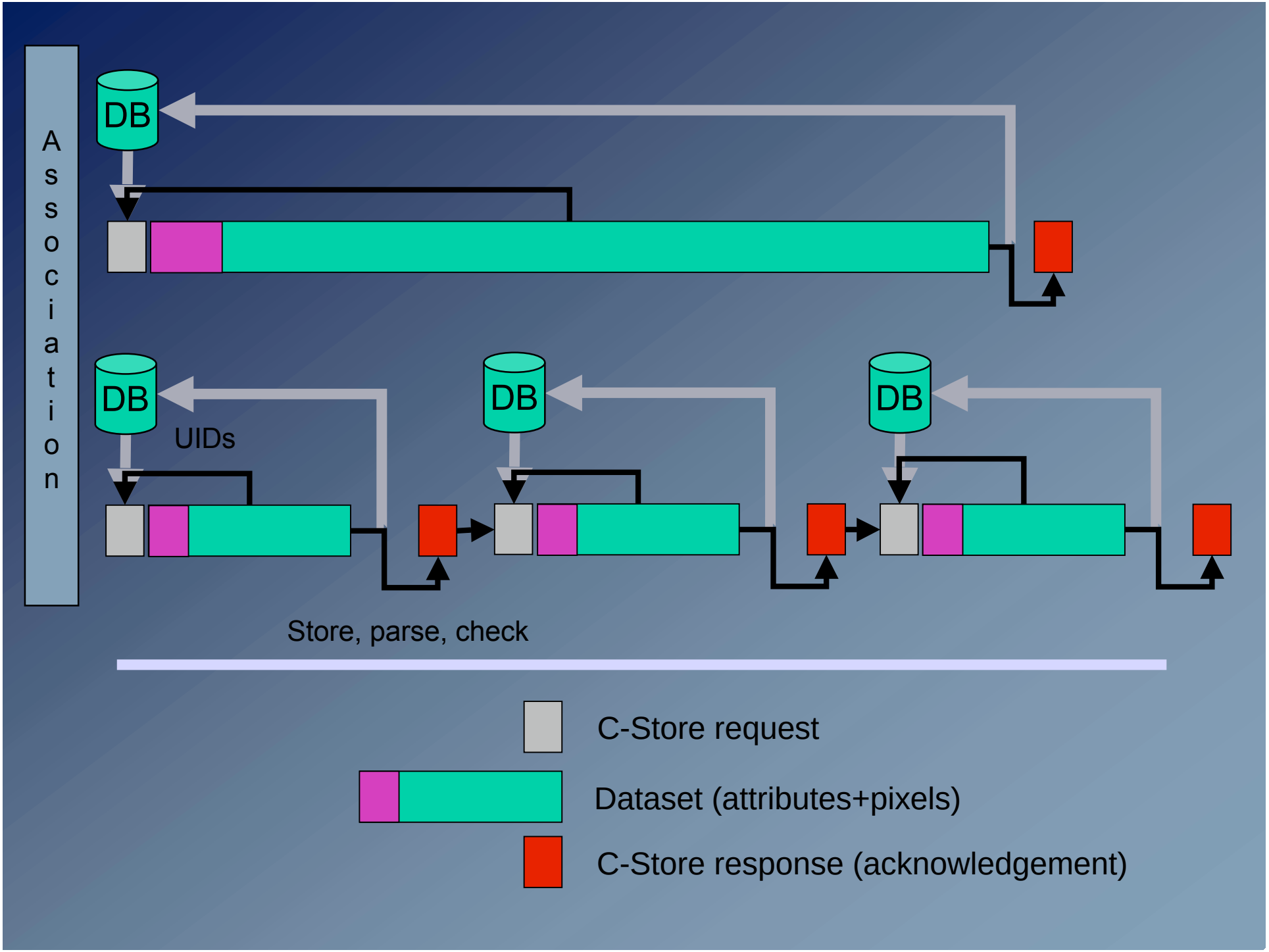
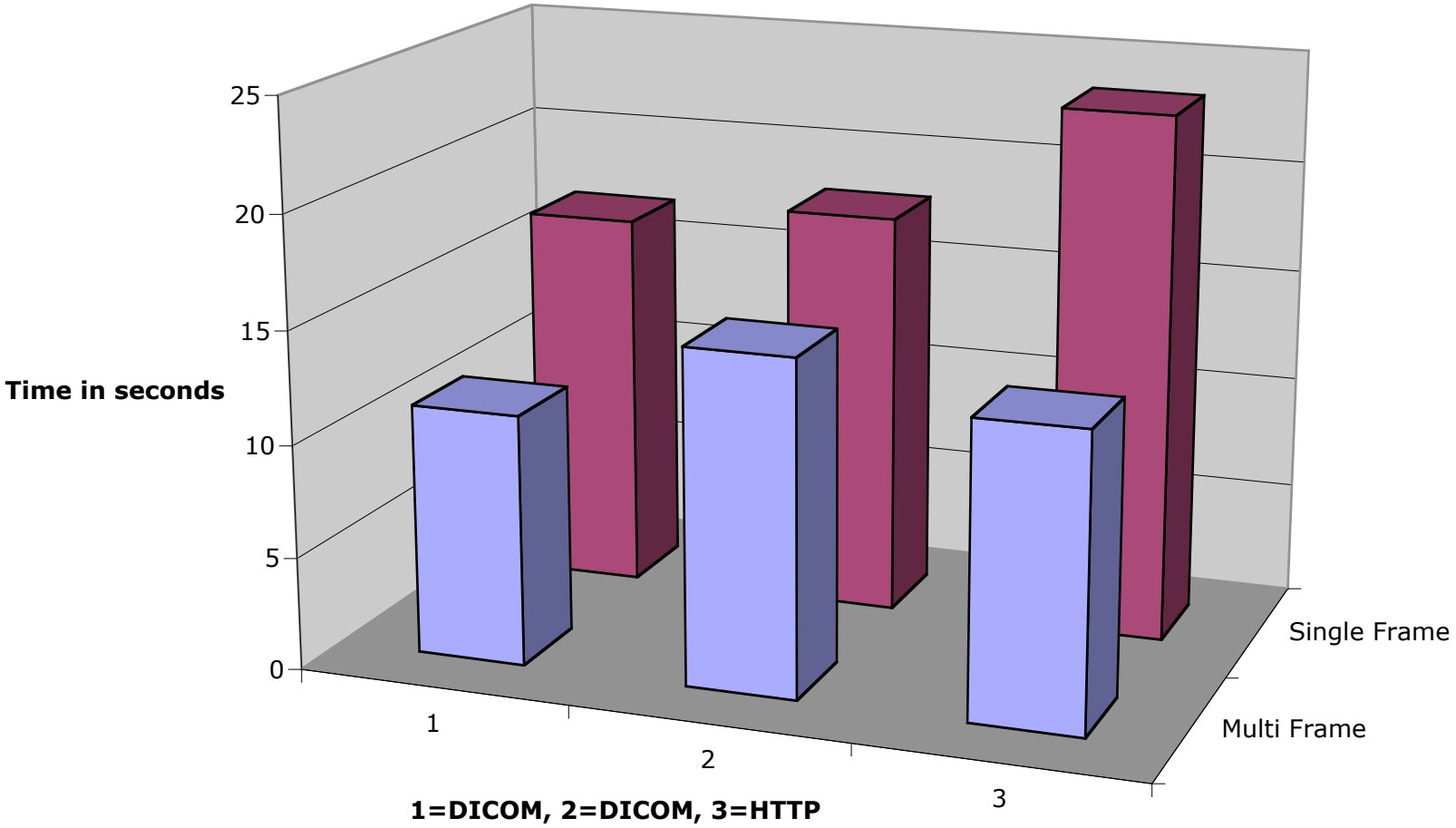
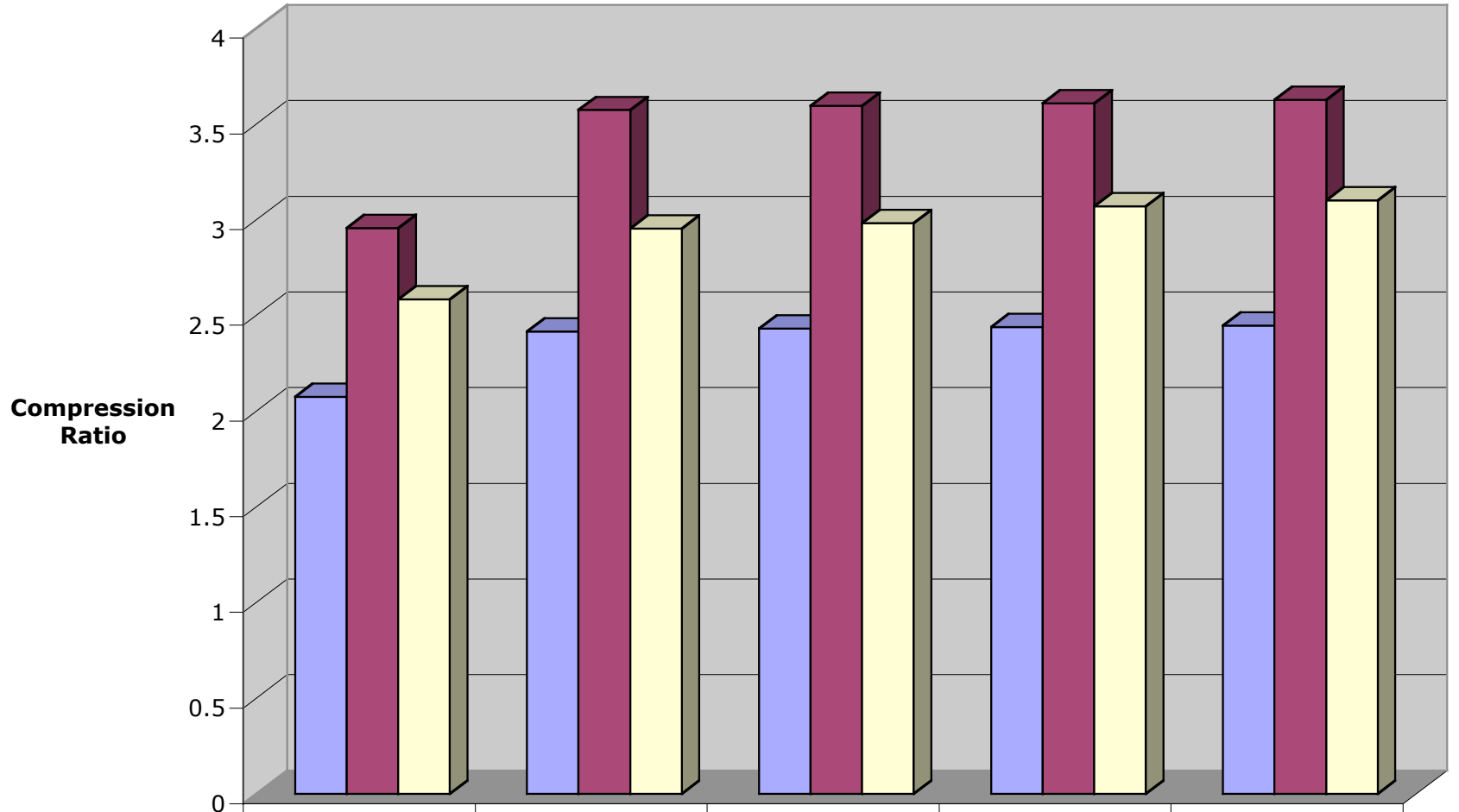

Association
DB
DB
UIDs
DB
DB
Store, parse, check
C-Store request
Dataset (attributes+pixels)
C-Store response (acknowledgement)

CTA - 548x512x512 (275MB) File read/transfer/save (GB Ethernet)



	1	2	3
Multi Frame	11.14111111	14.86703704	13.07333333
Single Frame	16.905	17.97	23.42666667

Lossless JPEG 2000 Compression (Alexis Tzannes, Aware, 2003)



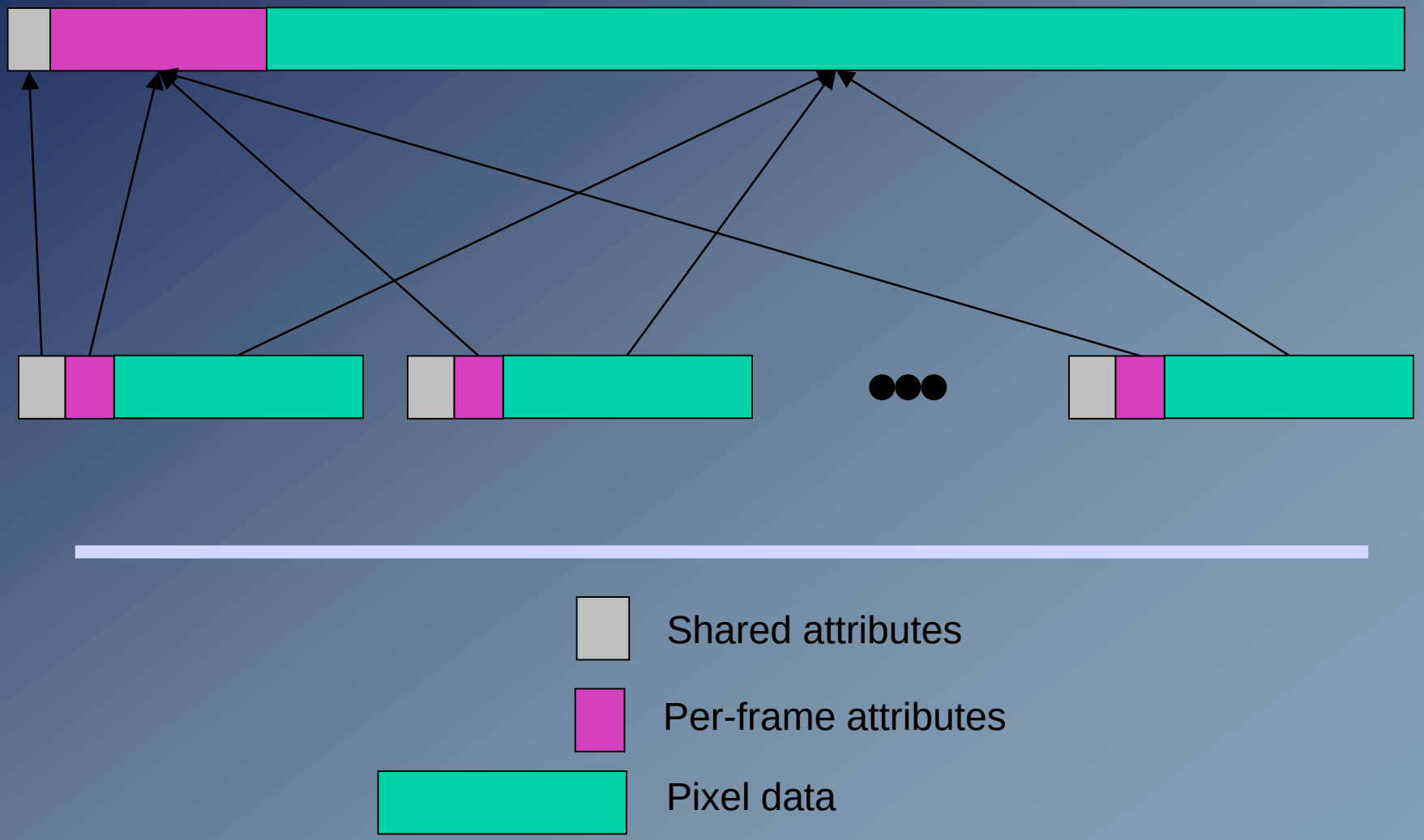
	single	20	40	80	all
127x256x8 7.9MB	2.073490814	2.415902141	2.430769231	2.438271605	2.445820433
449x512x16 224MB	2.955145119	3.572567783	3.595505618	3.607085346	3.624595469
620x512x16 310MB	2.583333333	2.952380952	2.980769231	3.069306931	3.1

Slices in 3rd dimension

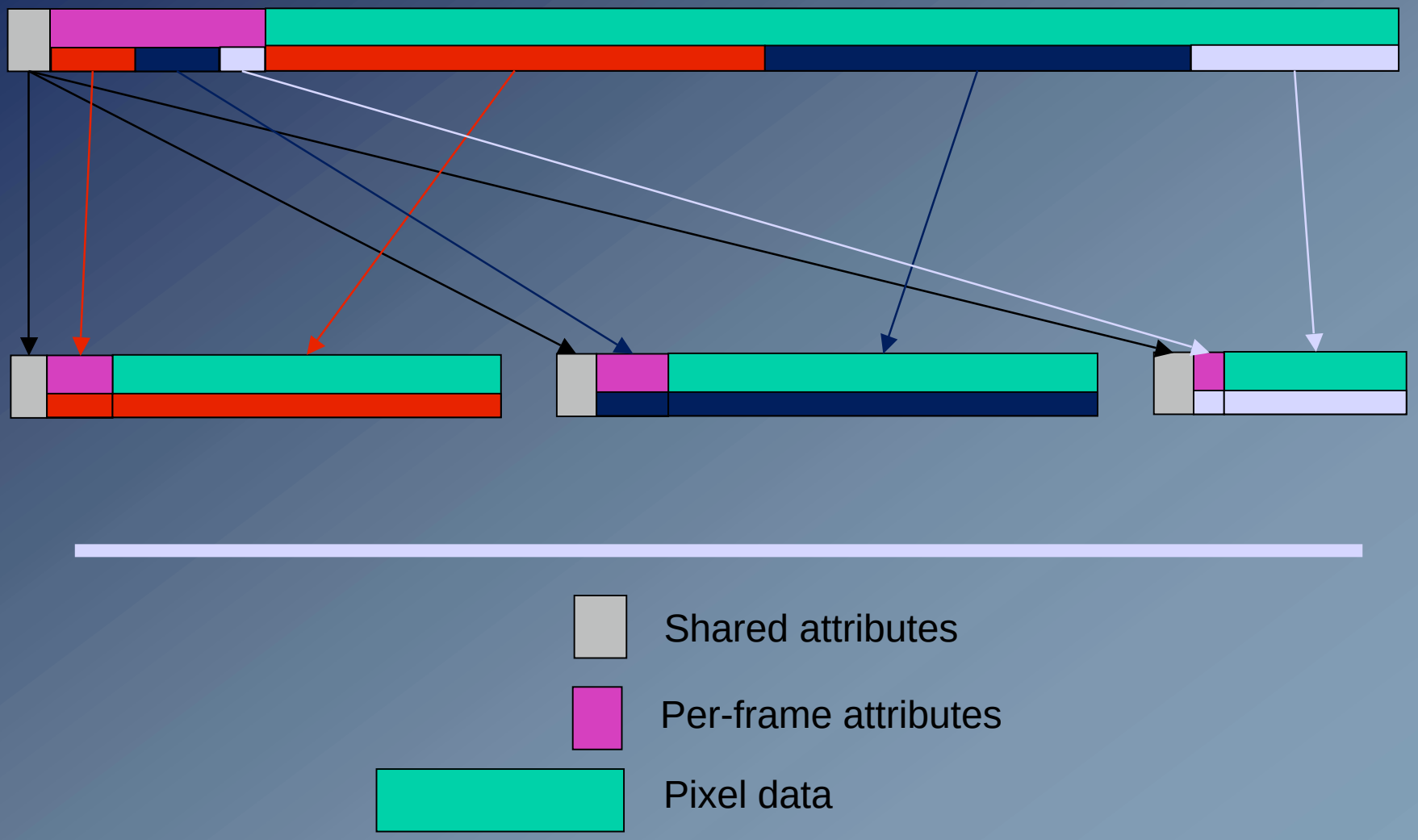
Organizational Features

- Multi-frame pixel data
- Comprehensive, mandatory, coded attributes
- Shared and per-frame functional groups
  - Compact & makes explicit what doesn't change
- Dimensions
  - *a priori* hints as to how the frames are organized
- Stacks
- Temporal positions
- Concatenations
  - Reasonable size chunks, viewing in batches as acquired

Multi-frame Functional Groups



Concatenations



Robust Application Support

- More technique-specific attributes
  - Majority of them mandatory for original images
- More technique-specific terms
  - Categorizing acquisition types
  - Describing acquisition parameters
- Less dependence on private attributes
- Better organization of data

Technique Attributes & Terms

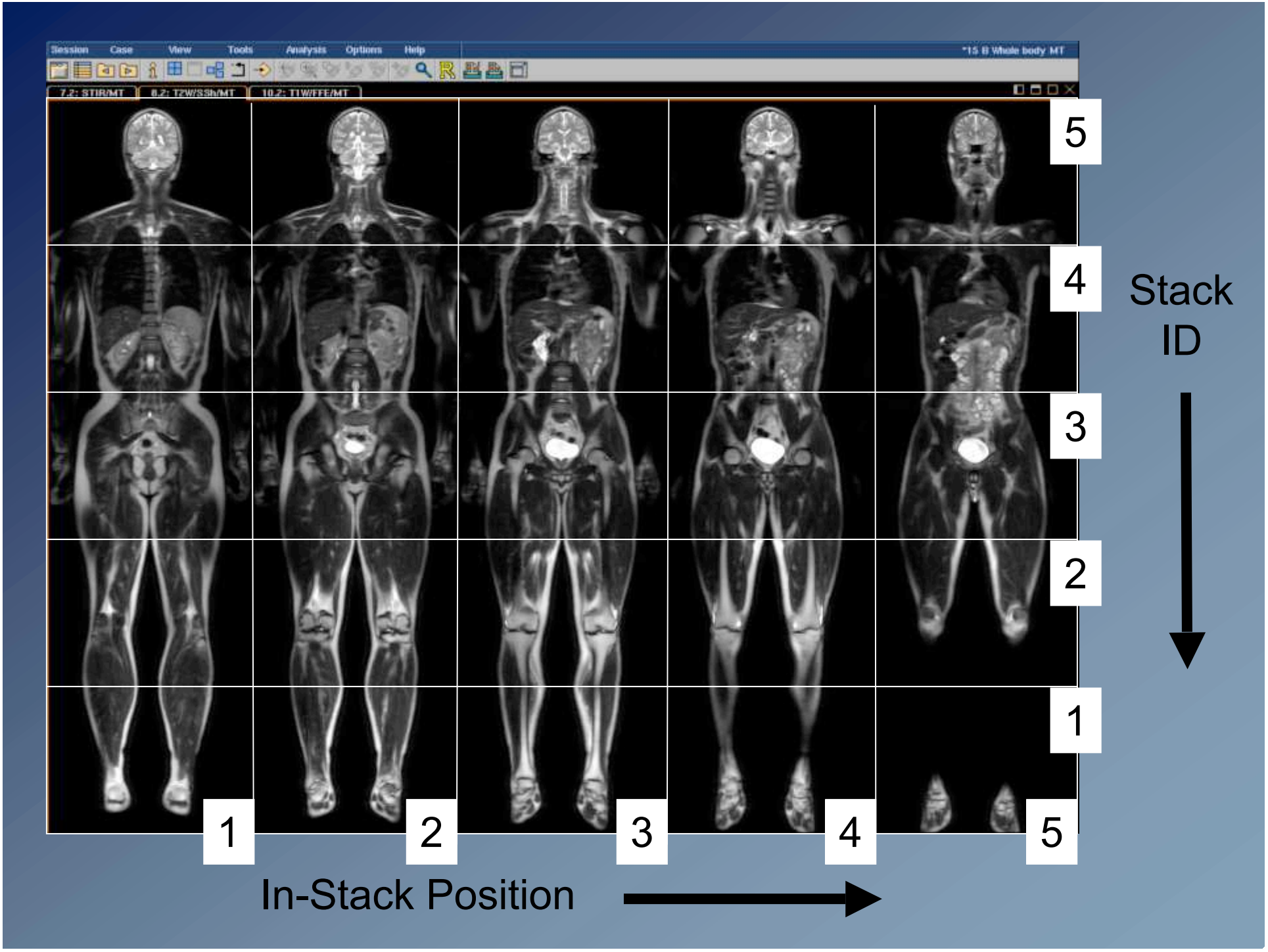
	CT		MR	
SOP Class	Original	Enhanced	Original	Enhanced
Attributes (Mandatory)	18 (0)	41 (39)	44 (2)	103 (94)
Terms (Enumerated)	4 (2)	86 (18)	38 (9)	228 (47)

CT Image Type Value 3

- Original SOP Class
  - AXIAL or LOCALIZER
- Enhanced SOP Class
  - Common to CT and MR
    - ANGIO, FLUOROSCOPY, LOCALIZER, MOTION, PERFUSION, PRE_CONTRAST, POST_CONTRAST, REST, STRESS, VOLUME
  - CT-specific
    - ATTENUATION, CARDIAC, CARDIAC_GATED, REFERENCE

Organization of Data

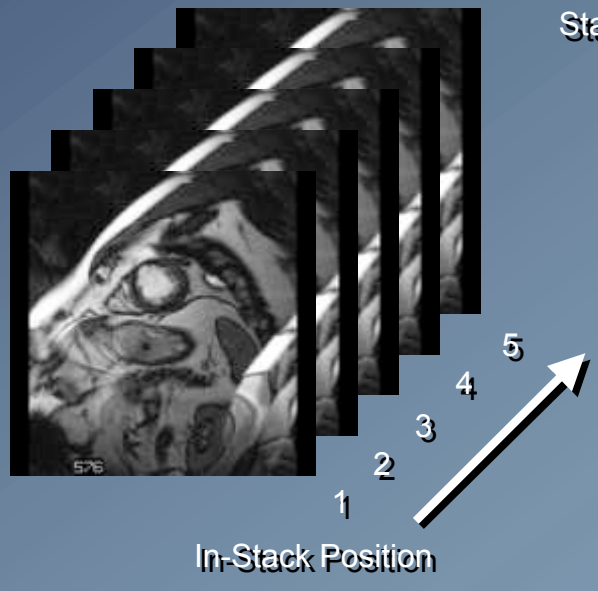
- Shared and Per-frame Functional Groups
  - Each functional group contains attributes that likely vary as a group, e.g. Pixel Measures, Plane Orientation, Velocity Encoding, etc.
- Dimensions
  - Specify intended order of traversal, such as space, then time (e.g., for cardiac cine loops)
- Stacks
  - Groups of spatially-related slices, repeatable
- Temporal Position Index


Session
Case
View
Tools
Analysis
Options
Help
*15 B Whole body MT
7.2: STIR/MT
8.2: T2W/SSh/MT
10.2: T1W/FFE/MT
5
4
3
2
1
Stack ID
1
2
3
4
5
In-Stack Position

Dimensions

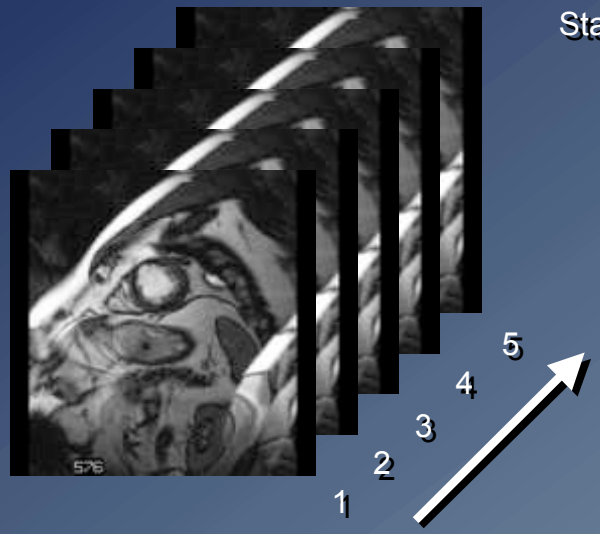
Start with a dimension of space.

A set of contiguous slices through the heart.



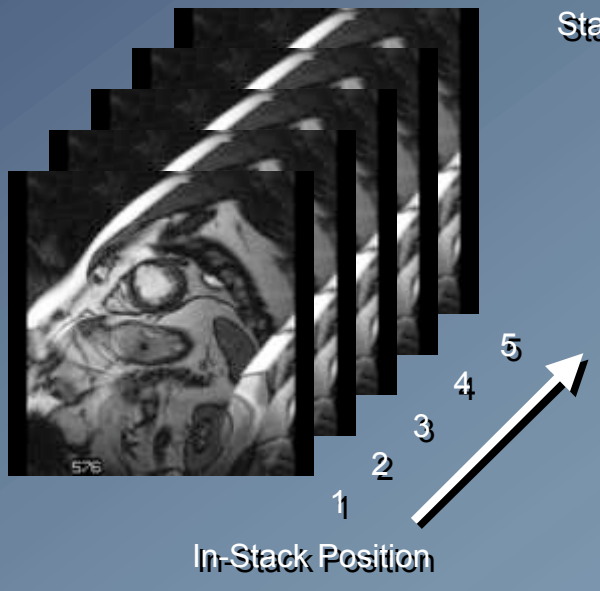
Trigger Delay Time

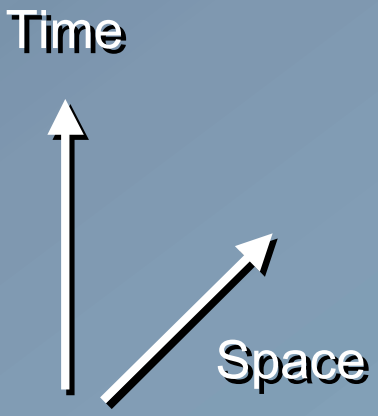
Temporal Position Index

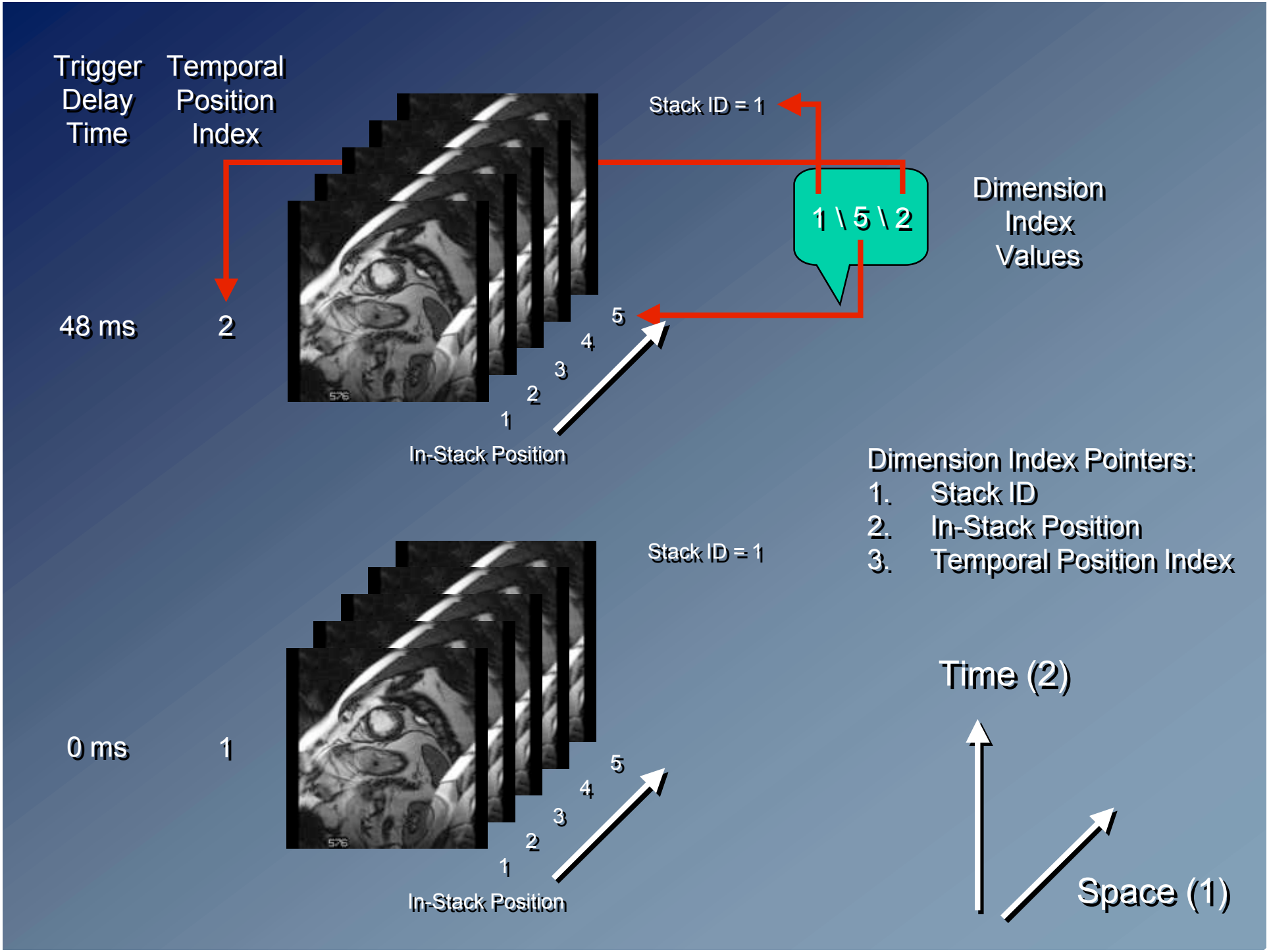


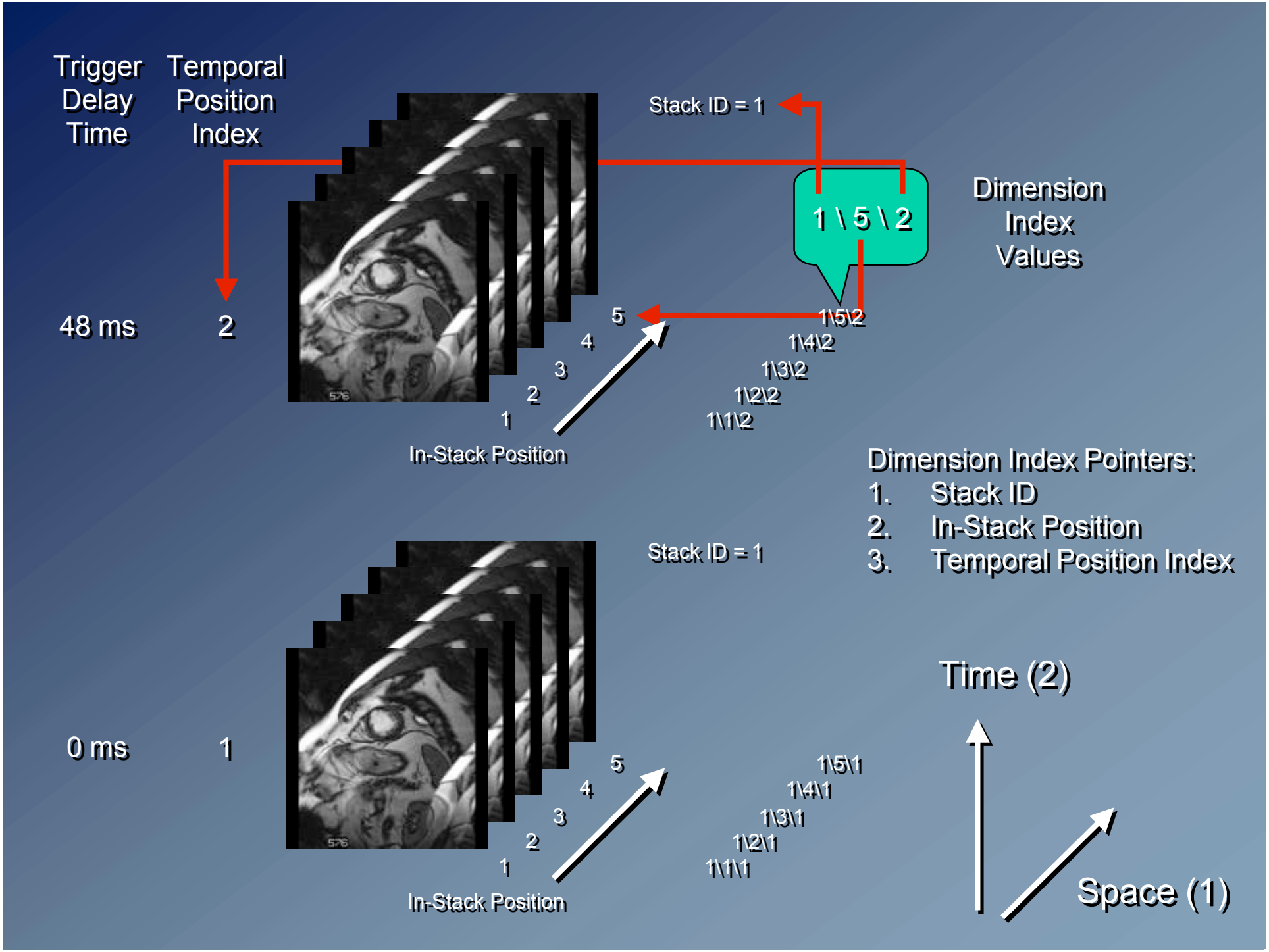
Add dimension of time (delay time from R-wave).

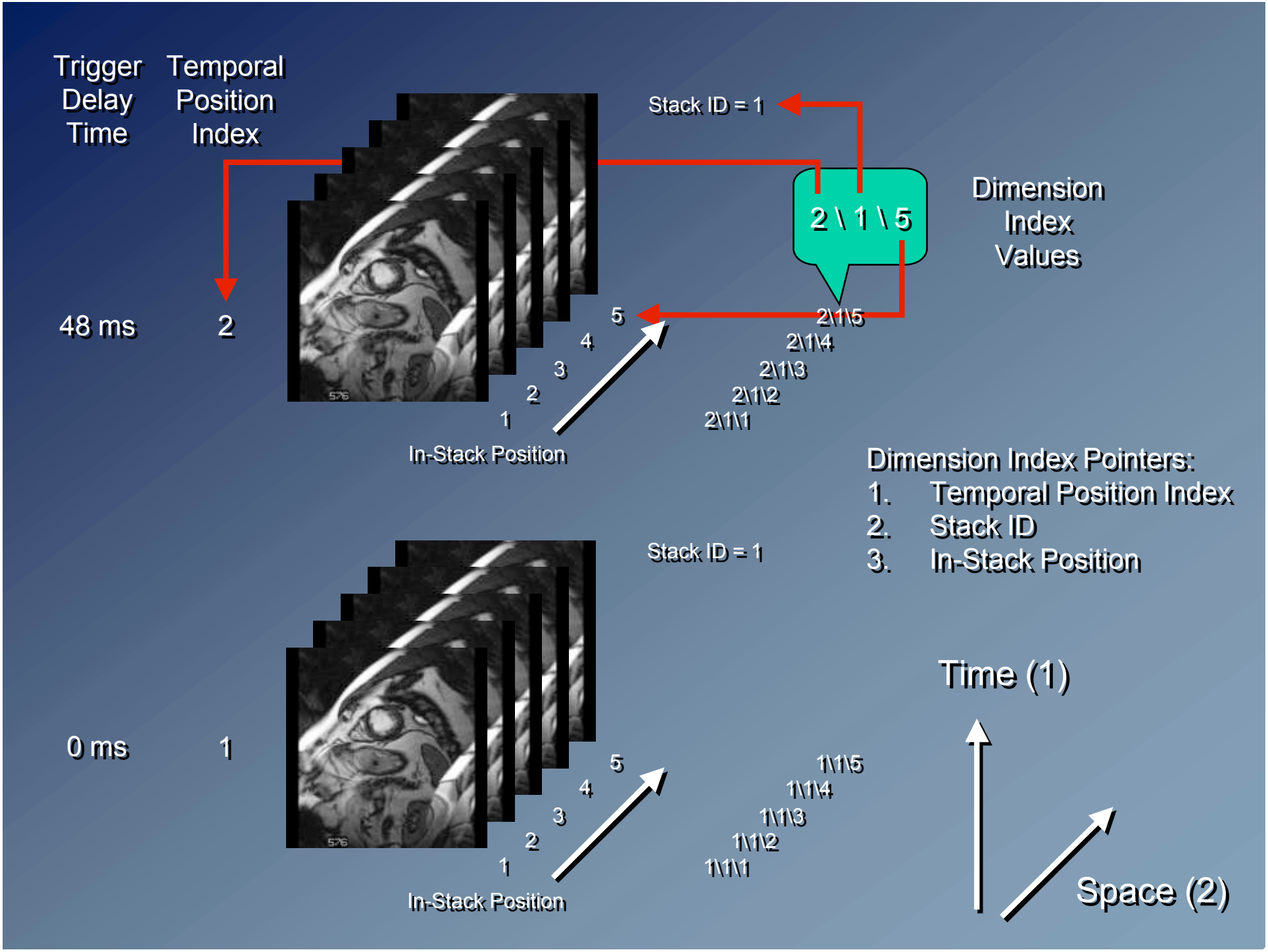
Sets of contiguous slices throughout cardiac cycle.

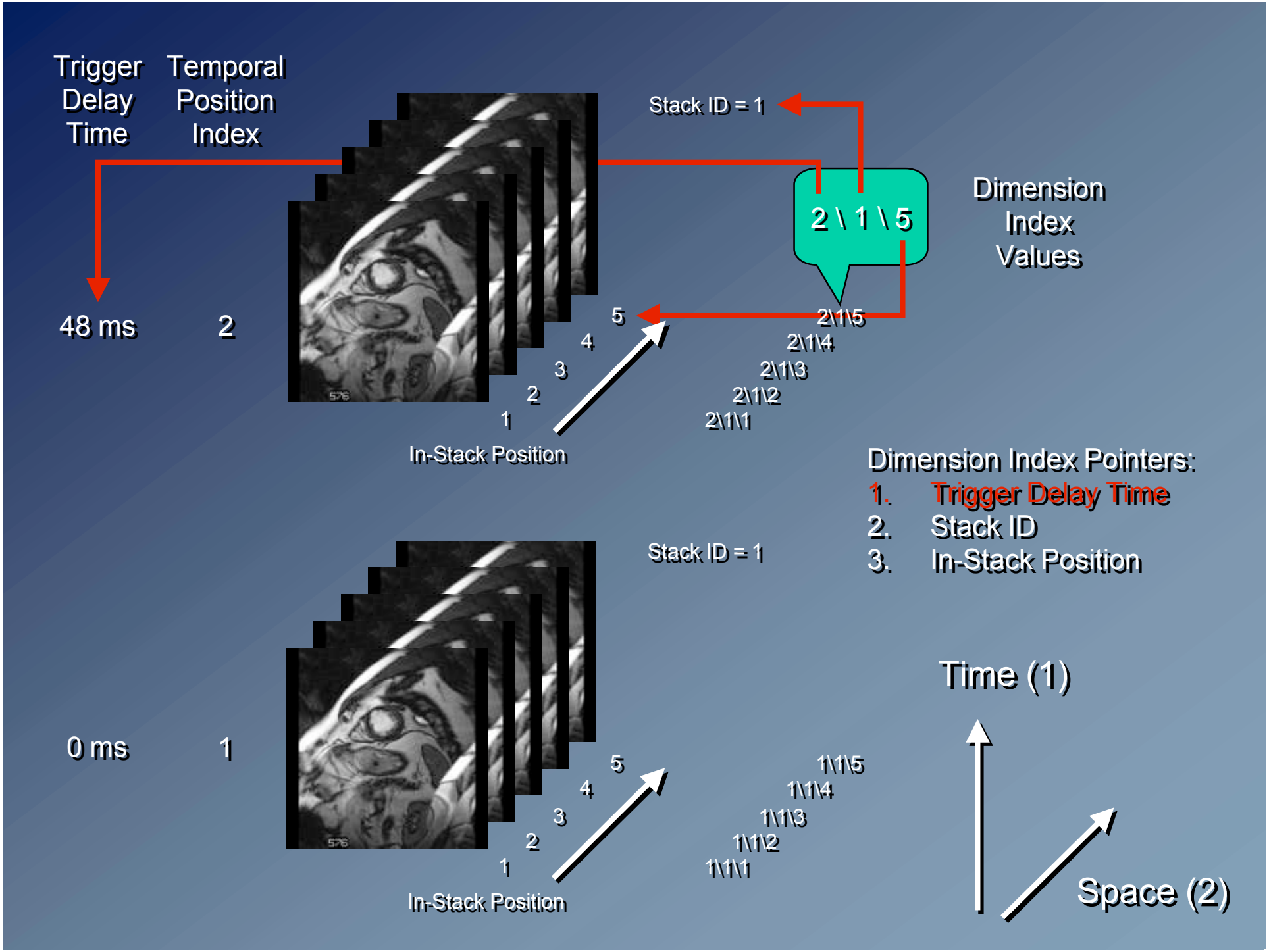





Trigger Delay Time
Temporal Position Index
Stack ID = 1
1 \ 5 \ 2
Dimension Index Values
48 ms
2
5
4
3
2
1
In-Stack Position
Dimension Index Pointers:
1. Stack ID
2. In-Stack Position
3. Temporal Position Index
Stack ID = 1
0 ms
1
5
4
3
2
1
In-Stack Position
Time (2)
Space (1)


Trigger Delay Time
Temporal Position Index
Stack ID = 1
1 \ 5 \ 2
Dimension Index Values
48 ms
2
5
4
3
2
1
In-Stack Position
1\5\2
1\4\2
1\3\2
1\2\2
1\1\2
Dimension Index Pointers:
1. Stack ID
2. In-Stack Position
3. Temporal Position Index
Stack ID = 1
0 ms
1
5
4
3
2
1
In-Stack Position
1\5\1
1\4\1
1\3\1
1\2\1
1\1\1
Time (2)
Space (1)

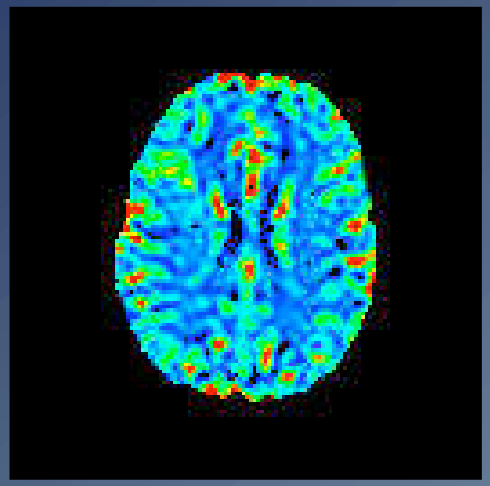

Trigger Delay Time
Temporal Position Index
Stack ID = 1
2 \ 1 \ 5
Dimension Index Values
48 ms
2
5
4
3
2
1
In-Stack Position
2\1\5
2\1\4
2\1\3
2\1\2
2\1\1
Dimension Index Pointers:
1. Temporal Position Index
2. Stack ID
3. In-Stack Position
Stack ID = 1
0 ms
1
5
4
3
2
1
In-Stack Position
1\1\5
1\1\4
1\1\3
1\1\2
1\1\1
Time (1)
Space (2)

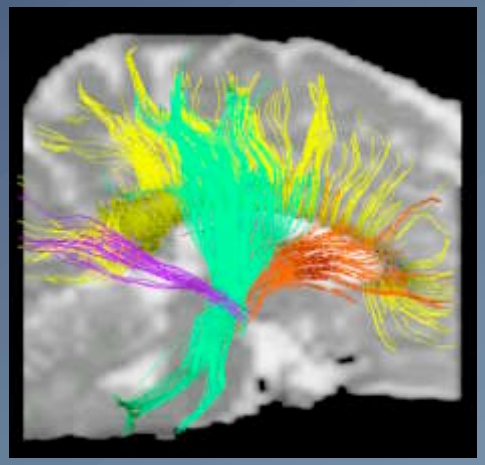

Trigger Delay Time
Temporal Position Index
Stack ID = 1
2 \ 1 \ 5
Dimension Index Values
48 ms
2
5
4
3
2
1
In-Stack Position
2\1\5
2\1\4
2\1\3
2\1\2
2\1\1
Dimension Index Pointers:
1. Trigger Delay Time
2. Stack ID
3. In-Stack Position
Stack ID = 1
0 ms
1
5
4
3
2
1
In-Stack Position
1\1\5
1\1\4
1\1\3
1\1\2
1\1\1
Time (1)
Space (2)

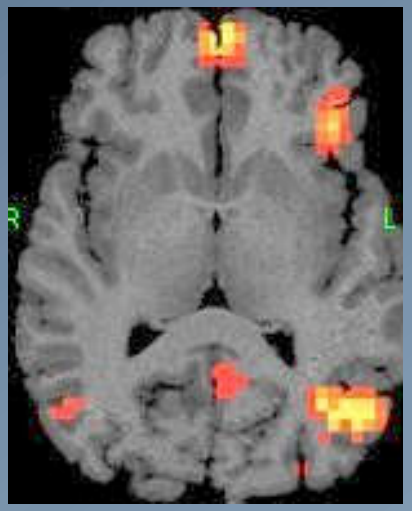
Organization of Data

- Goal is to reduce the work that the receiving application has to do to “figure out”
  - How the data is organized
  - Why it is organized that way
- Without preventing use of the data in unanticipated ways
  - E.g. 3D on a dataset not intended as a volume
- Two levels
  - The detailed shared & per-frame attributes
  - The overall dimensions, stacks and temporal positions

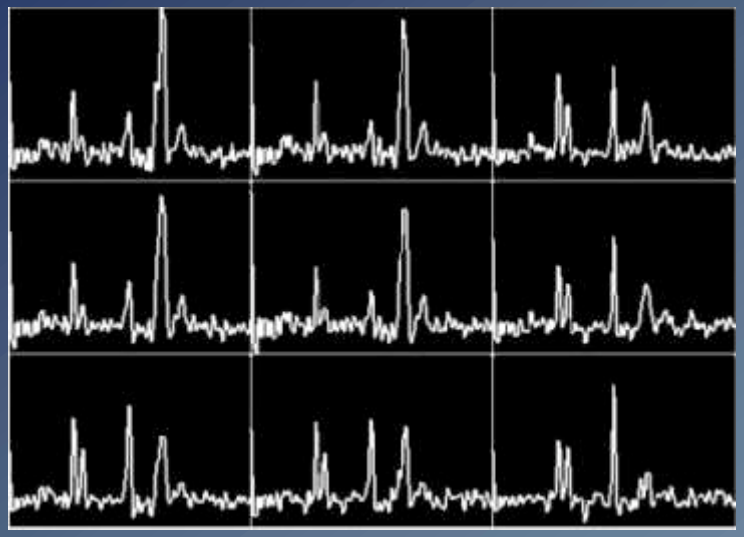
Color Information



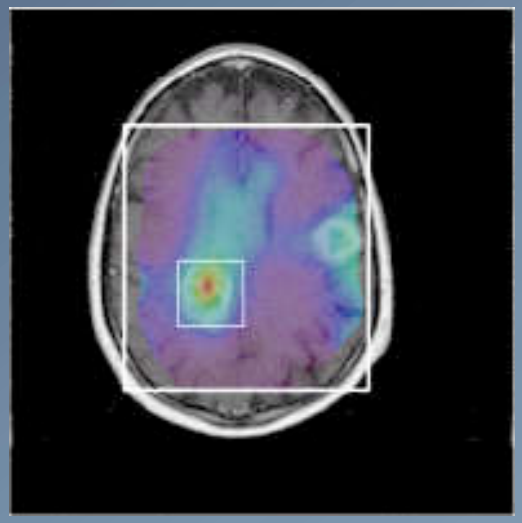




Spectroscopy

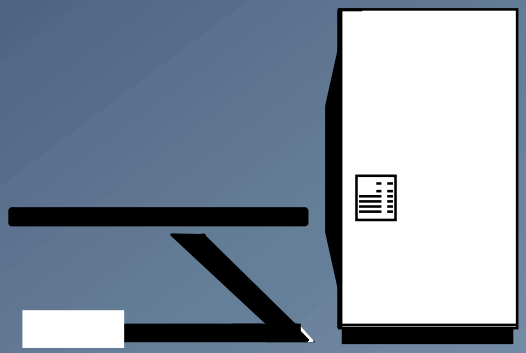


Storage of
Spectroscopy Data

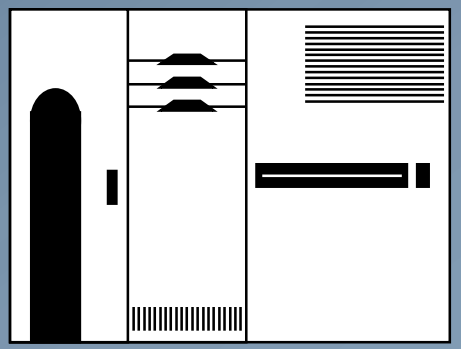


Metabolite Maps

But when ?



Modality

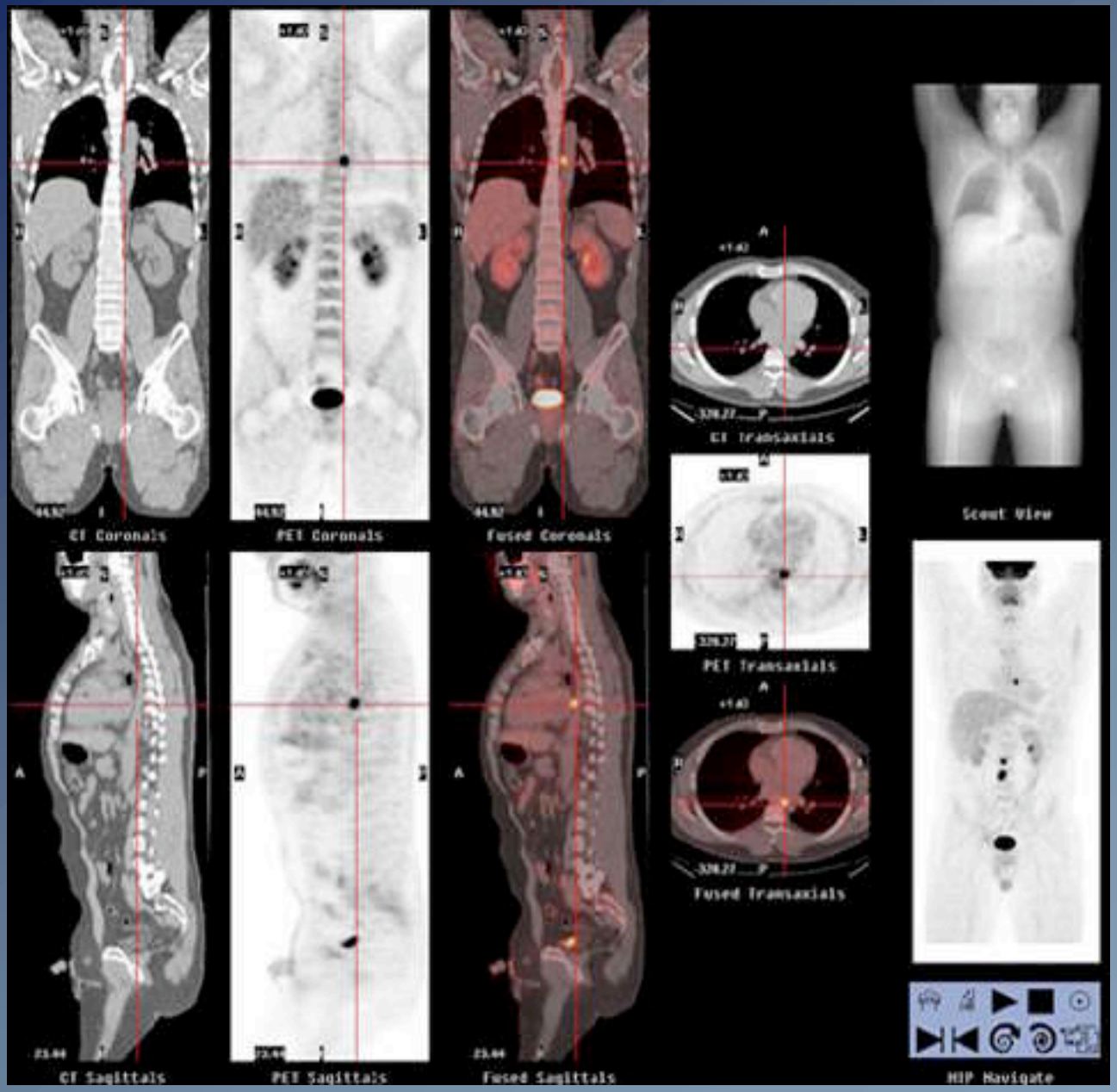


PACS

NEMA Initiatives

- MR test tools, images and spectra available
- CT test tools and images in development

- Implementation testing & demonstration
  - In conjunction with SCAR
  - May 2004 - call for participation
  - Dec 2004 - commitment by vendors
  - Jun 2005 - SCAR demonstration


CT Coronals
PET Coronals
Fused Coronals
CT Transaxials
Scout View
PET Transaxials
Fused Transaxials
CT Sagittals
PET Sagittals
Fused Sagittals
MIP Navigate

Not Just MR & CT ?

- Need for new multi-frame PET object
  - Currently single slice
  - Much renewed interest in PET-CT fusion
  - To be assessed during SNM June 2004 meeting
- X-ray angiography work in progress
  - Support for digital detectors
  - New acquisition types
  - Tomosynthesis

Summary

- Primary goal of new CT & MR objects is to support inter-operability of advanced applications
  - between multiple vendors
  - between modalities, workstations & PACS
- New objects simplify the task of a receiving application by providing guidance through multi-dimensions
- Adoption requires commitment by modality, workstations and PACS vendors
- DICOM, NEMA & SCAR promoting collaboration