Supplement 214: Cone Beam CT RDSR

SUPPLEMENT IS DEVELOPED BY DICOM WORKING GROUPS 02 AND 28

(WG-02 PROJECTION RADIOGRAPHY AND ANGIOGRAPHY)

(WG-28 PHYSICS)

Background

- Provide a framework that will allow for a more complete description of CBCT radiation
- In addition, much of the irradiation information is universal for all modalities
  - The generation of radiation, filtration, and beam restriction of x-ray systems use similar, and in many instances, identical methods
- Therefore, the proposal is to create an RDSR that does not require the modality to be defined, and include existing modality-specific information when needed
  - CBCT as a modality with specific requirements remains poorly defined
  - Modalities are evolving, and new hybrid systems may be created
  - Making a modality-agnostic RDSR will reduce or eliminate the need for CPs to accommodate new technology or uses
  - Legacy, regulatory, and other dose information from existing RDSRs can still be included
- This CBCT RDSR may allow for other modalities to take advantage of this generalizability

Requirements

- Removes requirement to define characteristics by Irradiation Event
- Define geometry
  - Use frame of reference (FOR) for complete beam description

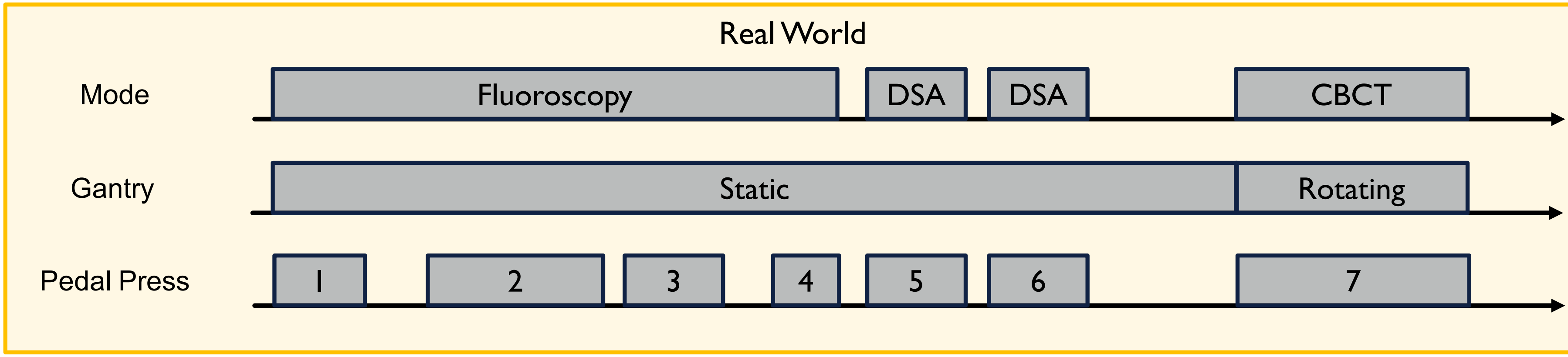
Event Timing

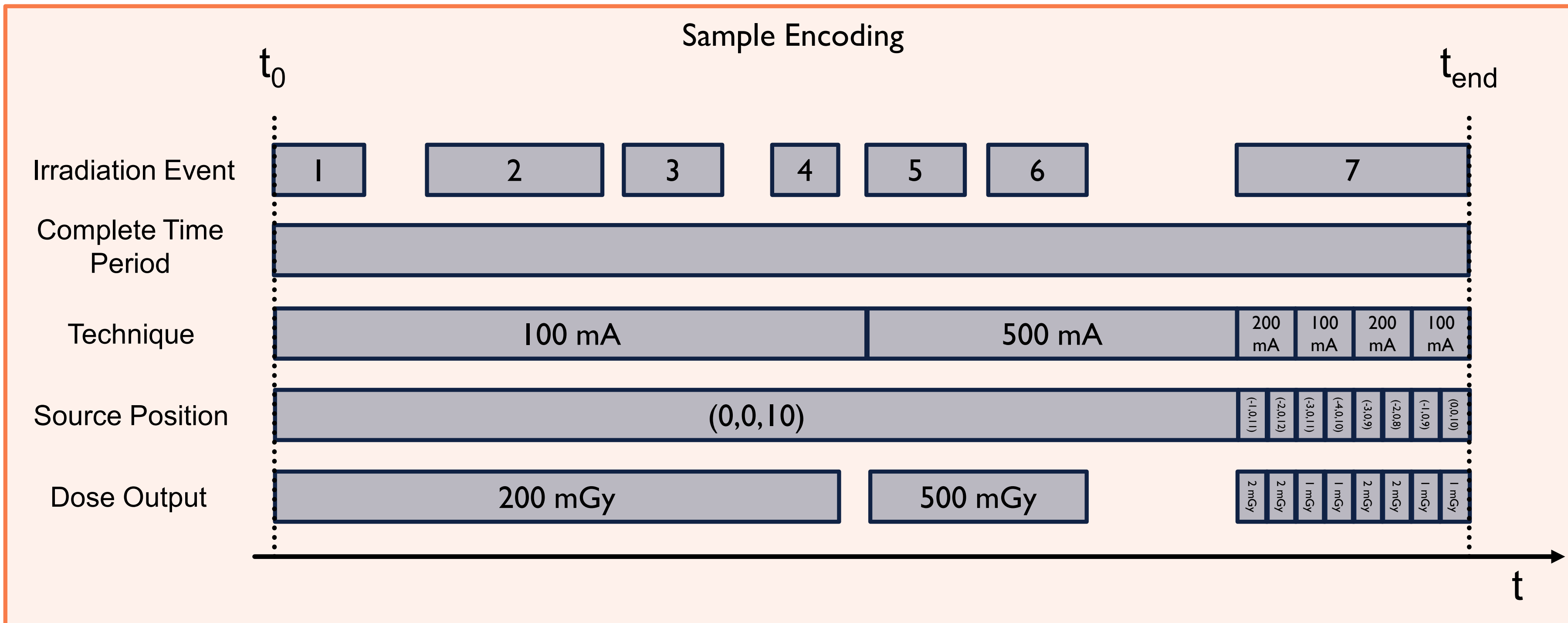
- Current RDSR framework requires parameters to be described per irradiation event
  - Limited methodology for describing parameters beyond an event
- Proposed RDSR framework describes a begin and end time of parameters
- Allows for describing radiation-dose-related characteristics of a system in two ways:
  - Dependent solely on irradiation event
    - For each irradiation event, describe the timing and all template content for each irradiation event individually
  - Independent of irradiation events
    - **<u>Parameter is characterized by a single value or table of values during specified period of time</u>**
    - For characteristics that remain constant (or within some tolerance), create larger time periods that span several irradiation events.
      - For example, if the same technique is used across several irradiation events, the template can encode a single template that indicates a constant technique across events
    - For characteristics that change within an irradiation event, create smaller time periods that describe the changes during the irradiation event
      - For example, a rotating gantry during a CBCT run in XA can have many time windows that describe the position of the gantry.

Event Timing

- The methodology for beginning/ending the timing associated with a parameter is implementation dependent
  - Wait for a change in the characteristic to meet some threshold
    - Percent change
    - Absolute change
    - Time dependent (every X seconds)
    - By irradiation events
- All mandatory characteristics must be described completely for the entire time spanned by each irradiation event
- There may be gaps between descriptions of parameters
  - The information between irradiation events is not relevant for radiation dose purposes.
    - Characteristics may or may not be populated between irradiation events

Timing Example

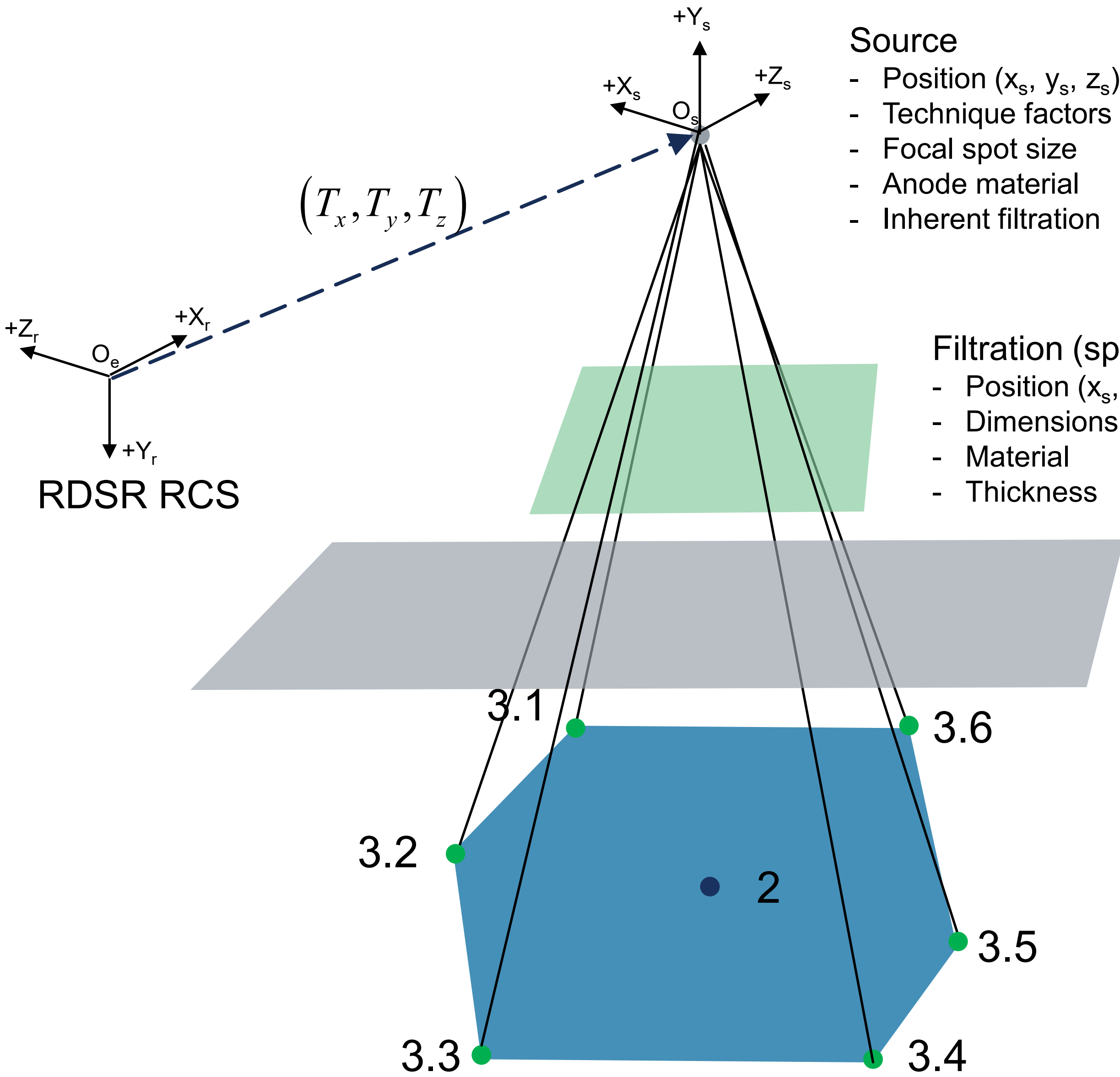




Geometry

- A complete geometric description of all system components is required for a complete understanding of dose distribution and potential patient impact
  - Describing all components within a reference coordinate system improves downstream users and systems to perform further dosimetry analysis
- Many radiographic systems have rotating sources
  - Objects in the rotating frame of reference may not move in the rotating frame
  - The proposed supplement uses a transformation matrix to relate a reference coordinate system used by the system to a source coordinate system which may be moving

Geometry



Source
- Position (x_s, y_s, z_s) = (0, 0, 0)
- Technique factors (potential, current, time)
- Focal spot size
- Anode material
- Inherent filtration

Filtration (spectral filters, attenuating filters)
- Position (x_s, y_s, z_s)
- Dimensions
- Material
- Thickness

Attenuators (e.g., patient support, compression paddle)
- Position (x_r, y_r, z_r)
- Dimensions
- Material
- Thickness

Radiation Output Information
- iAK at Point 2 (x_s, y_s, z_s)

Collimated field
- Shape (x_s, y_s, z_s) (Points 3.1-6)

Transformation Matrix

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X-Ray Source Transformation Matrix

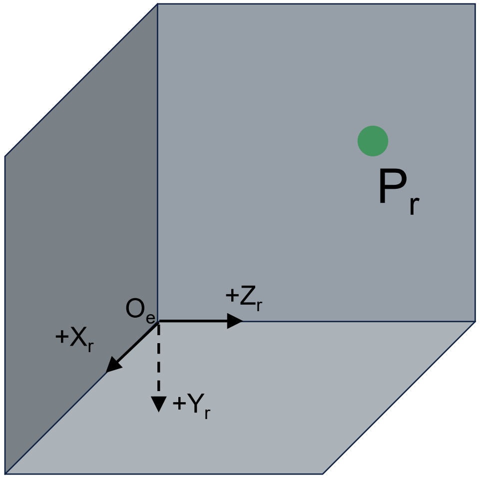
$$\begin{bmatrix} x_r \\ y_r \\ z_r \\ 1 \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} & M_{13} & T_x \\ M_{12} & M_{22} & M_{23} & T_y \\ M_{31} & M_{32} & M_{33} & T_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_s \\ y_s \\ z_s \\ 1 \end{bmatrix}$$

RDSR Reference Coordinate System

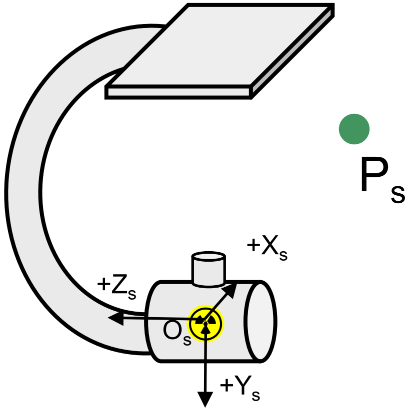
$$P_r = (x_r, y_r, z_r)$$

Source Coordinate System

$$P_s = (x_s, y_s, z_s)$$



RDSR RCS



Rotating Source

- Rotating source descriptions can be simplified for many image acquisitions
  - For sources rotating in a plane, a description of initial positioning within the coordinate system, rotation radius, and rotation axis is sufficient to determine future positions and transformation matrices
  - A simplified encoding scheme reduces the burden for implementation and relies on the end user for calculation if desired

Rotating Sources

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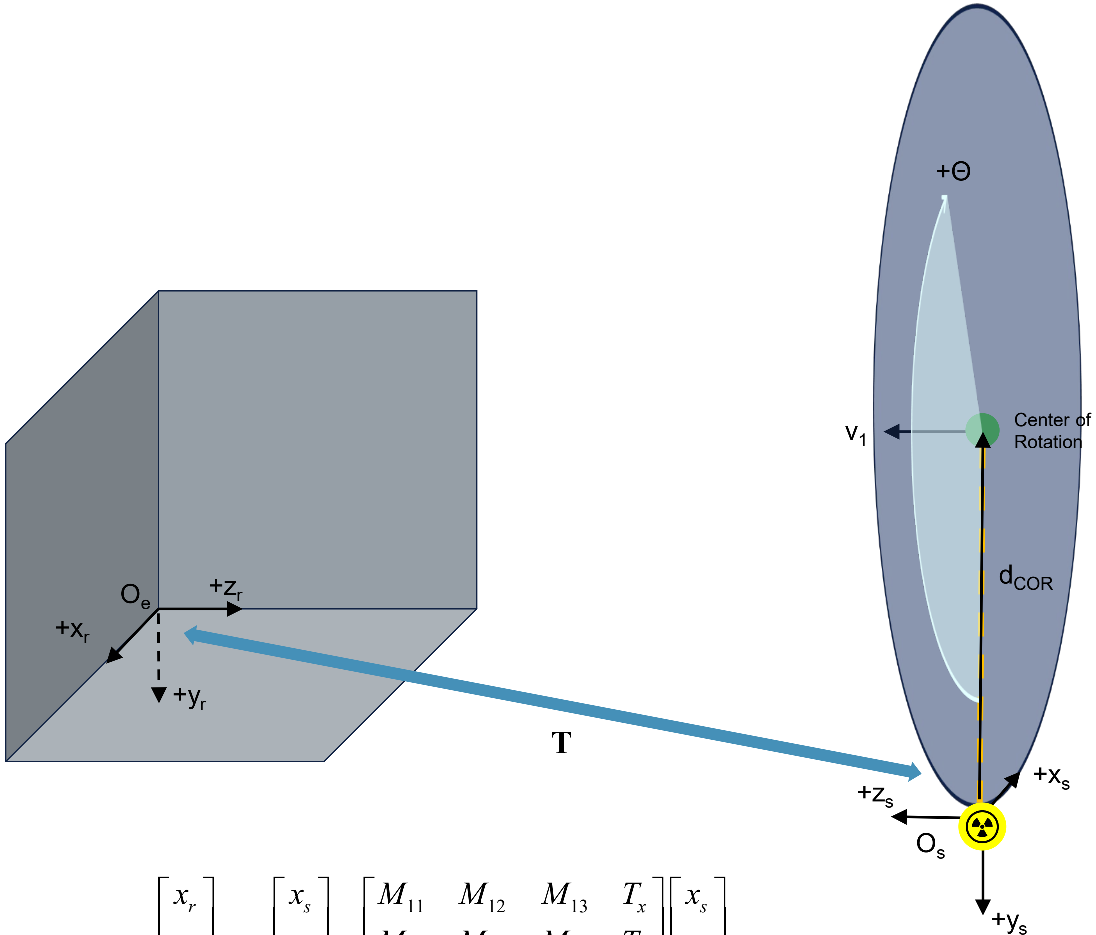
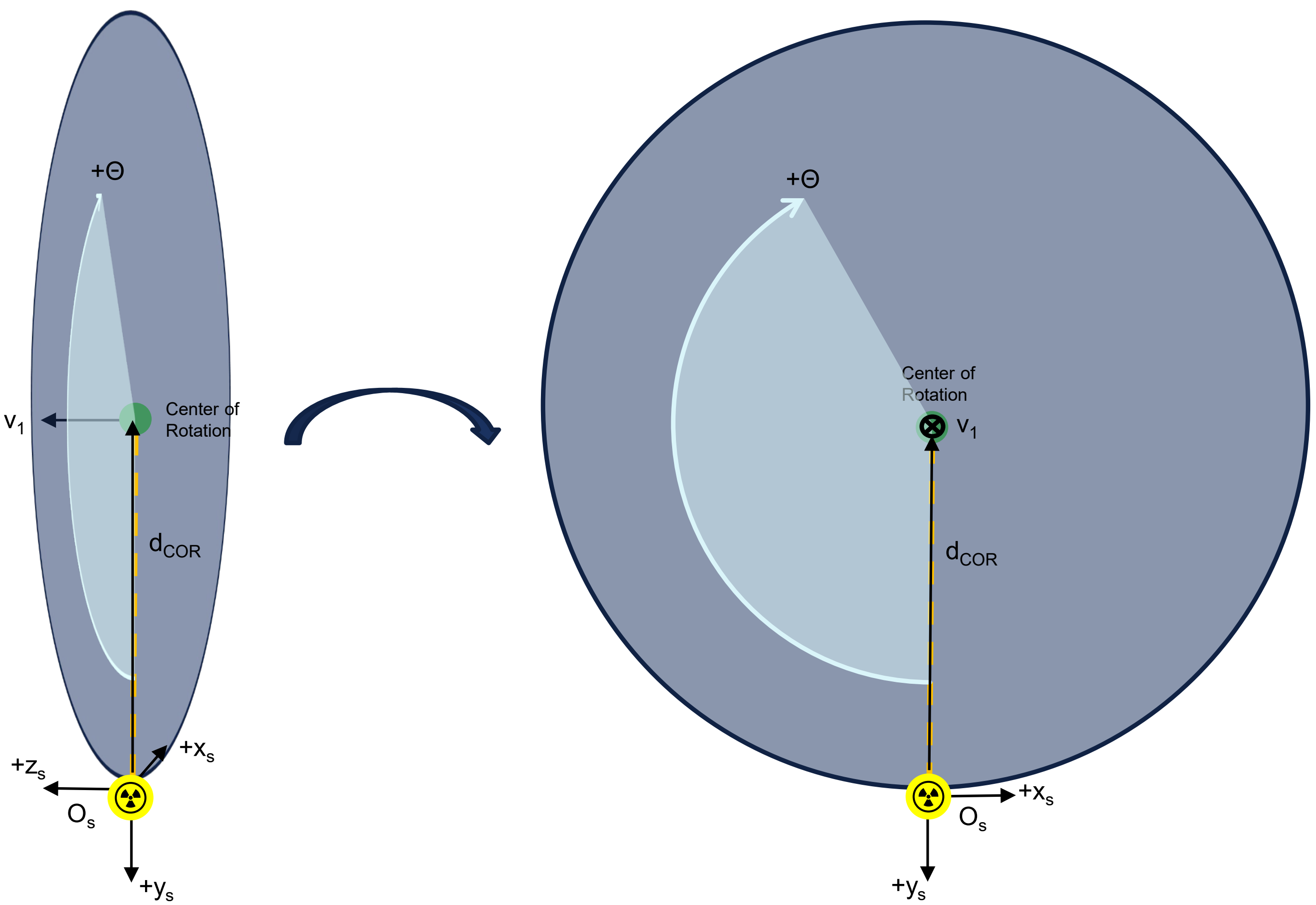


$v_1 = <0,0,1>$
$COR = <0,-d_{COR},0>$

DT	Θ
DT_1	$Θ_1$
DT_2	$Θ_2$
DT_3	$Θ_3$
DT_4	$Θ_4$
…	…

$$\begin{bmatrix} x_r \\ y_r \\ z_r \\ 1 \end{bmatrix} = \mathbf{T} \begin{bmatrix} x_s \\ y_s \\ z_s \\ 1 \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} & M_{13} & T_x \\ M_{12} & M_{22} & M_{23} & T_y \\ M_{31} & M_{32} & M_{33} & T_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_s \\ y_s \\ z_s \\ 1 \end{bmatrix}$$

Rotating Sources



Supplement Structure

- Creating templates that group related parameters can simplify the encoding methodology and improve usability of the RDSR
  - Items that change together can be updated together in the templates
  - Related positions or machine characteristics are found in the same template

Structure

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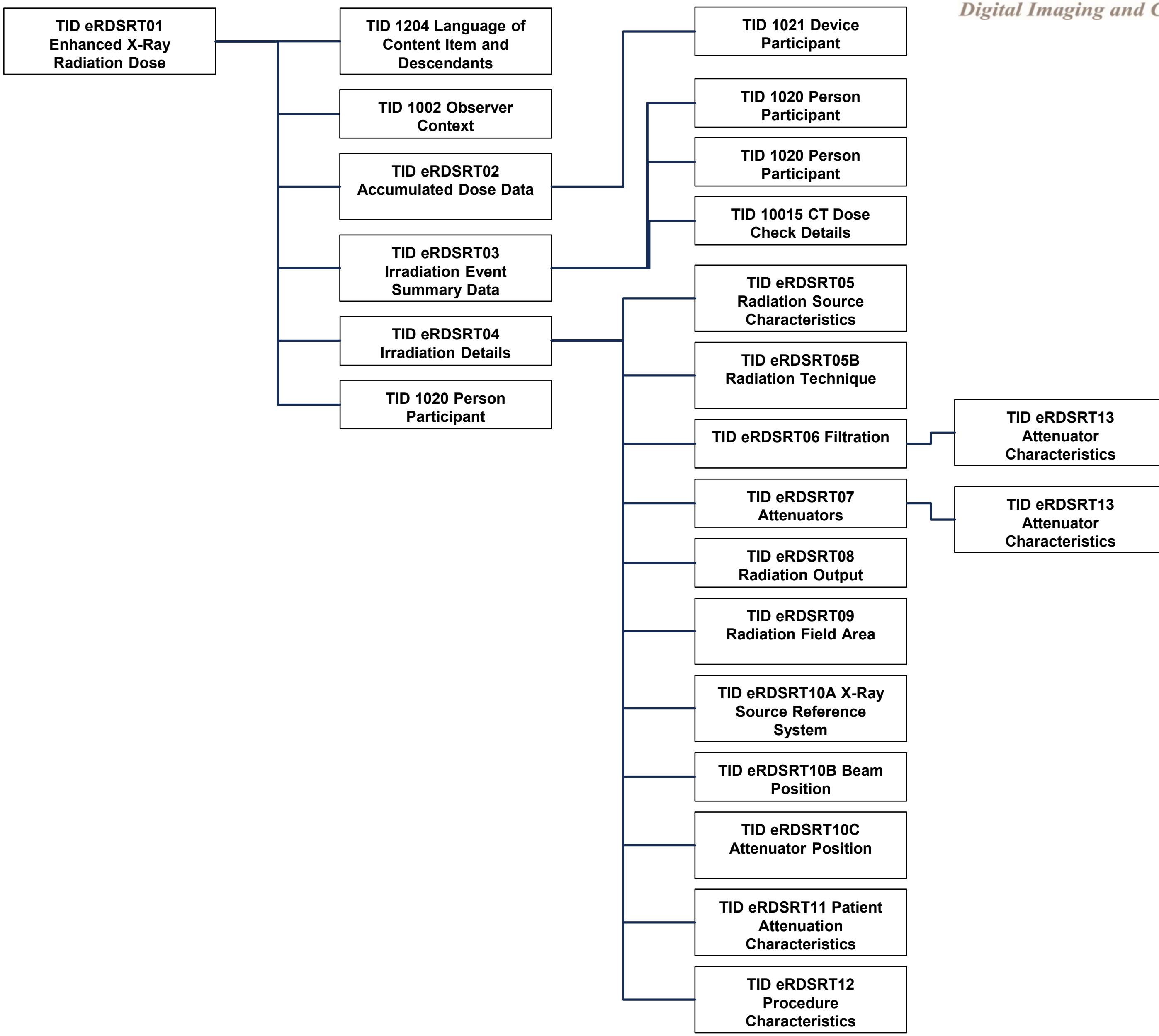

Notes

- Promote mandatory technical information that allows the precise definition of needed features of the system, e.g., the whole geometry and characteristics of the X-Ray beam, that are related to dose.

- Reduce constraints of mandatory "summary" radiation information.
  - It is the role of regulators, not DICOM, to mandate of the presence of dose information
  - These regulations are evolving (IEC, etc.), country-dependent, and they may mandate different information depending on the "category" or "classification" of products within the same modality. Therefore, the manufacturers shall fill the information in the RDSR based on their applicable regulations, case by case.

Author Contacts

- Nicholas Bevins (editor) nickb@rad.hfh.edu
- Heinz Blendinger heinz.blendinger@t-online.de
- Steve Massey steve.massey@pacshealth.com
- Donald Peck donaldp@mtu.edu
- Francisco Sureda francisco.sureda@med.ge.com
- Annalisa Trianni annalisa.trianni@asufc.sanita.fvg.it

- DICOM Secretariat: dicom@medicalimaging.org