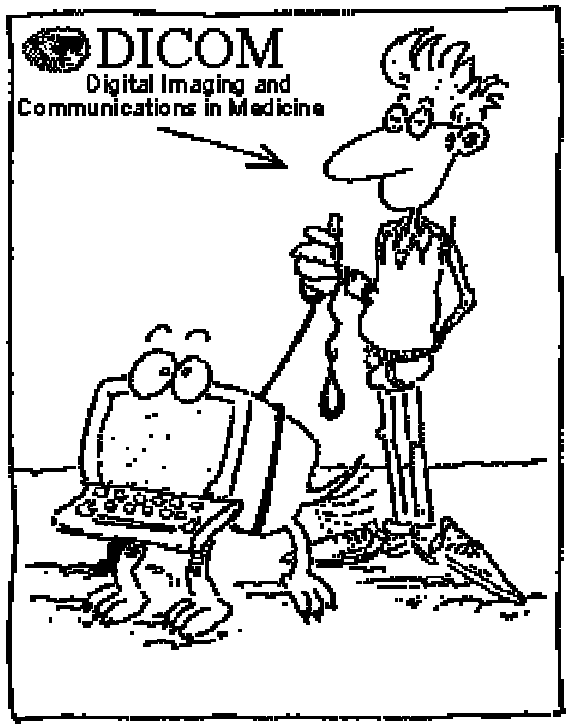
The DICOM extensions for radiotherapy



Michael Neumann
Nucletron B.V., Germany

Contents

- History of development of RT extension
- The Real World Model
- The RT Objects
  - Details for the individual RT Objects
- Patient Coordinate System(s)
- DICOM in ‘Real Life’
- Tools

Interoperability

This Standard facilitates interoperability of systems claiming conformance in a multi-vendor environment, but does not, by itself, guarantee interoperability.

DICOM PS 3.1 - “Goals of the DICOM Standard”

The RT Extension

" (...) support the transfer of radiotherapy-related data between devices found within and outside a radiotherapy department."

DICOM WG7

- Founded 1994/95 as
  "DICOM RT ad-hoc Working Group"
- Cooperation with IEC since 1995
- Currently 34 members
- All major vendors represented
  - CMS, Elekta, GE, IMPAC, Nomos, Nucletron, Philips, Siemens, TomoTherapy, Varian
- 2 to 3 meetings a year

http://groups.yahoo.com/group/dicomrt

The DICOM Real World Model

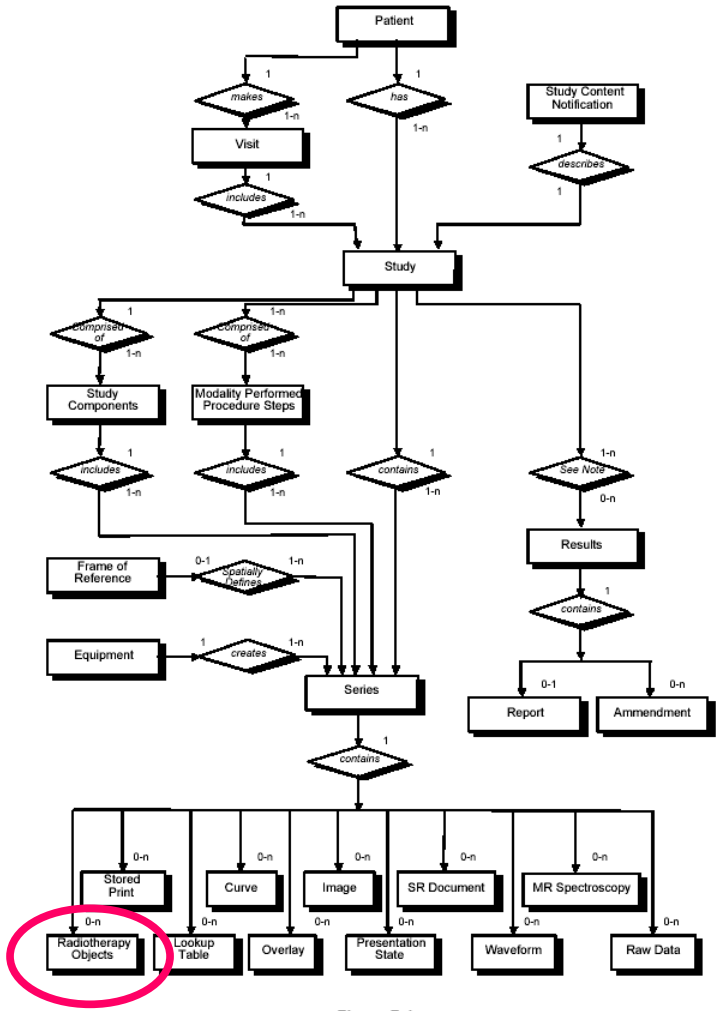


Figure 7-1a
DICOM MODEL OF THE REAL-WORLD

The DICOM Information Model

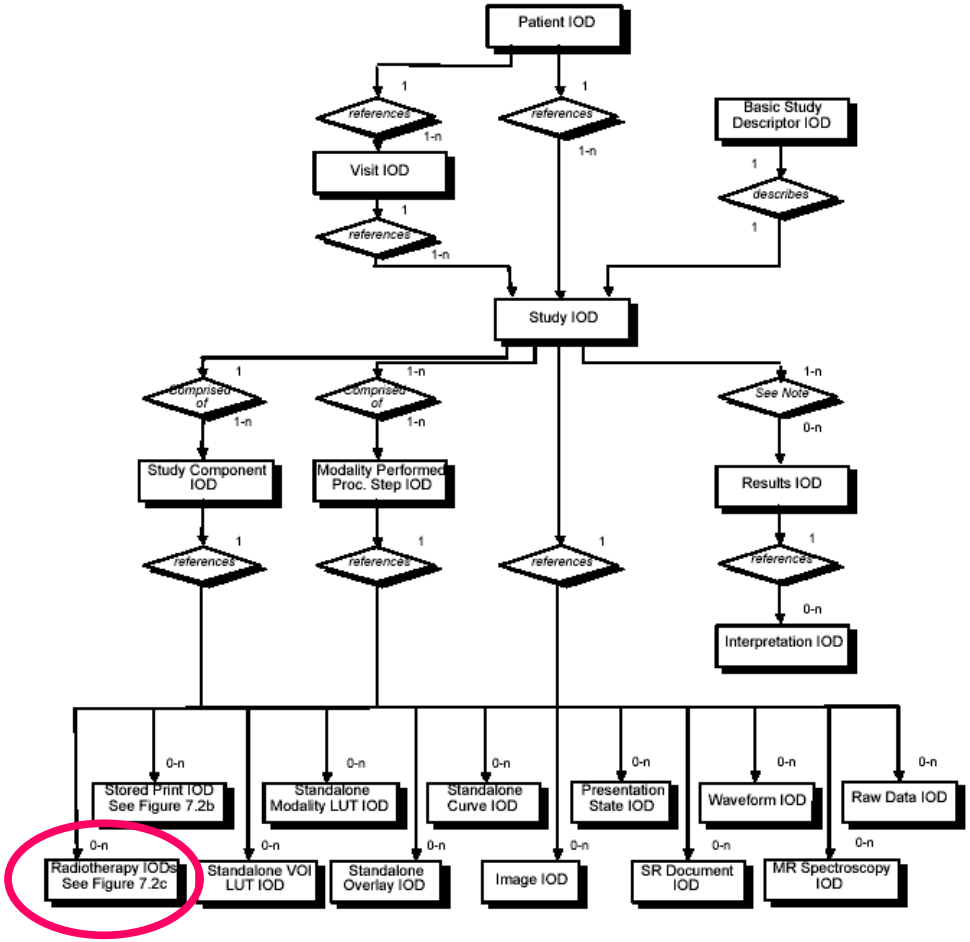
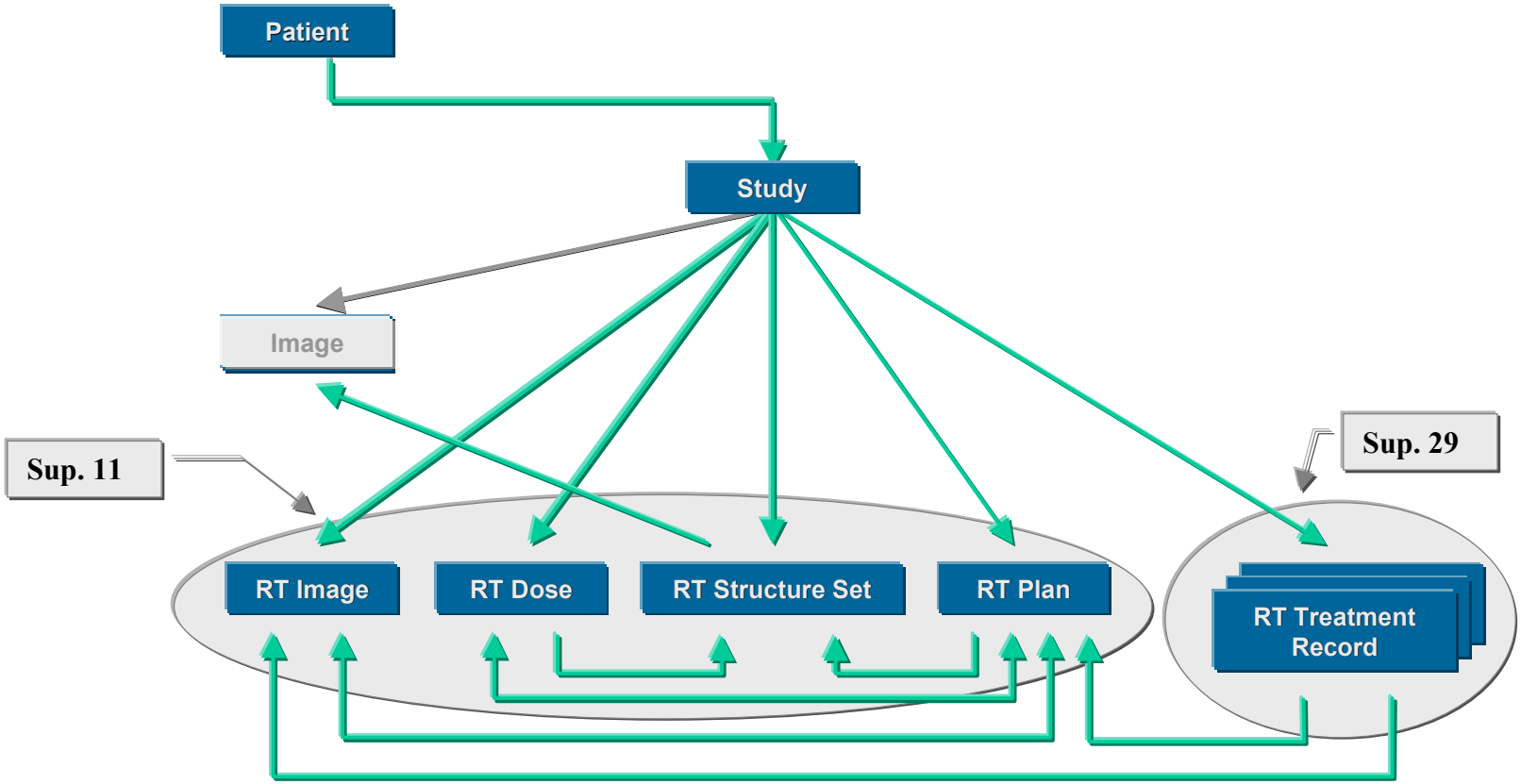


Figure 7-2a
DICOM INFORMATION MODEL

The RT Extension



The RT Extension

- RT Image IOD
  DRR, Portal Imaging, Simulator
- RT Dose IOD
  Dose Matrix, Dose Points, Isodoses, DVH
- RT Structure Set IOD
  VOIs, Dose Reference Points,
  Observations/Characterizations
- RT Plan IOD
  External&Brachy Plan, Tolerance Table, Fractionation Scheme, Patient Setup
- RT Treatment Record IODs
  Beam&Brachy Session/Summary Recording Information

The RT Extension

- Extends:
  - Part 3: Information Objects Definitions
  - Part 4: Service Class Specifications
  - Part 6: Data Dictionary

No Information Management

... due to the absence of a consistent process model for a radiotherapy department, especially in an international context.

DICOM Supplement 11 - “Radiotherapy Objects”

The RT Objects Module Tables

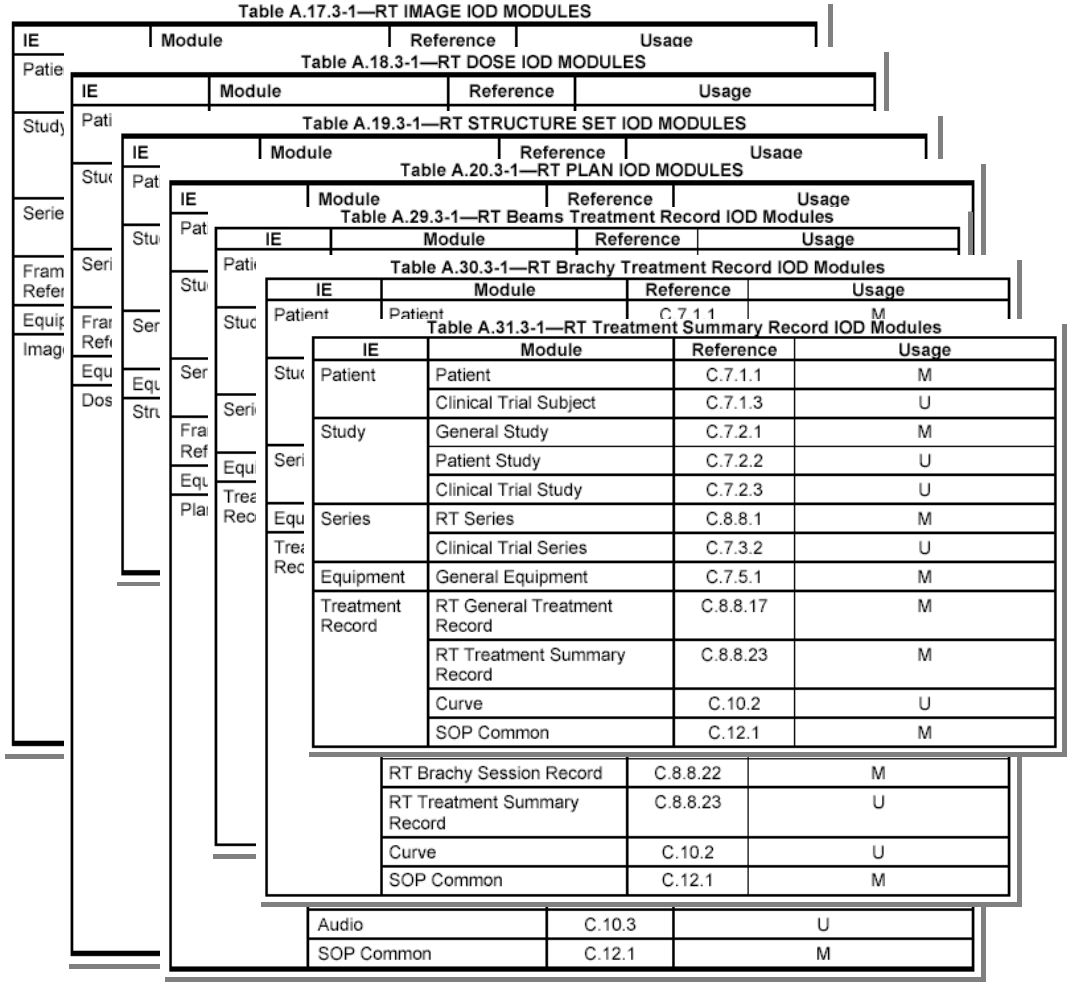


Table A.17.3-1—RT IMAGE IOD MODULES

IE	Module	Reference	Usage
Patie			
Study			
Serie			
Fram Refer			
Equip			
Imag			

Table A.18.3-1—RT DOSE IOD MODULES

IE	Module	Reference	Usage
Pati			
Stud			
Seri			
Fram Refe			
Equ			
Dos			

Table A.19.3-1—RT STRUCTURE SET IOD MODULES

IE	Module	Reference	Usage
Pat			
Stu			
Ser			
Equ			
Str			

Table A.20.3-1—RT PLAN IOD MODULES

IE	Module	Reference	Usage
Pat			
Stu			
Ser			
Fra Ref			
Equ			
Pla			

Table A.29.3-1—RT Beams Treatment Record IOD Modules

IE	Module	Reference	Usage
Pati			
Stud			
Seri			
Equi			
Trea Rec			

Table A.30.3-1—RT Brachy Treatment Record IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
Stud			
Seri			
Equ			
Trea Rec			

	RT Brachy Session Record	C.8.8.22	M
	RT Treatment Summary Record	C.8.8.23	U
	Curve	C.10.2	U
	SOP Common	C.12.1	M

	Audio	C.10.3	U
	SOP Common	C.12.1	M

Table A.31.3-1—RT Treatment Summary Record 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	RT Series	C.8.8.1	M
	Clinical Trial Series	C.7.3.2	U
Equipment	General Equipment	C.7.5.1	M
Treatment Record	RT General Treatment Record	C.8.8.17	M
	RT Treatment Summary Record	C.8.8.23	M
	Curve	C.10.2	U
	SOP Common	C.12.1	M

New IOD Modules

General Series	RT Series
Modality	Modality
Series Instance UID	Series Instance UID
Series Number	Series Number
Laterality	
Series Date	
Series Time	
Performing Physician's Name	
Performing Physician Identification Sq.	
Protocol Name	
Series Description	Series Description
Operator's Name	
Operator Identification Sq.	
Referenced Performed Procedure Step Sq.	Ref. Performed Proc. Step Sq.
>Ref. SOP Class UID	>Ref. SOP Class UID
>Ref. SOP Closs Instance UID	>Ref. SOP Closs Instance UID
Body Part Examined	
Patient Position	
Smallest Pixel Value in Series	
Largest Pixel Value in Series	
Requested Attributes Sq.	Requested Attributes Sq.
>Requested Procedure ID	>Requested Procedure ID
>Scheduled Procedure Step ID	>Scheduled Procedure Step ID
>Scheduled Procedure Step Description	>Scheduled Procedure Step Description
>Scheduled Procedure Step Code Sq.	>Scheduled Procedure Step Code Sq.
Performed Procedure Step ID	Performed Procedure Step ID
Performed Procedure Step Start Date	Performed Procedure Step Start Date
Performed Procedure Step Start Time	Performed Procedure Step Start Time
Performed Procedure Step Description	Performed Procedure Step Description
Performed Protocol Code Sequence	Performed Protocol Sequence
Comments on the Performed Procedure Step	

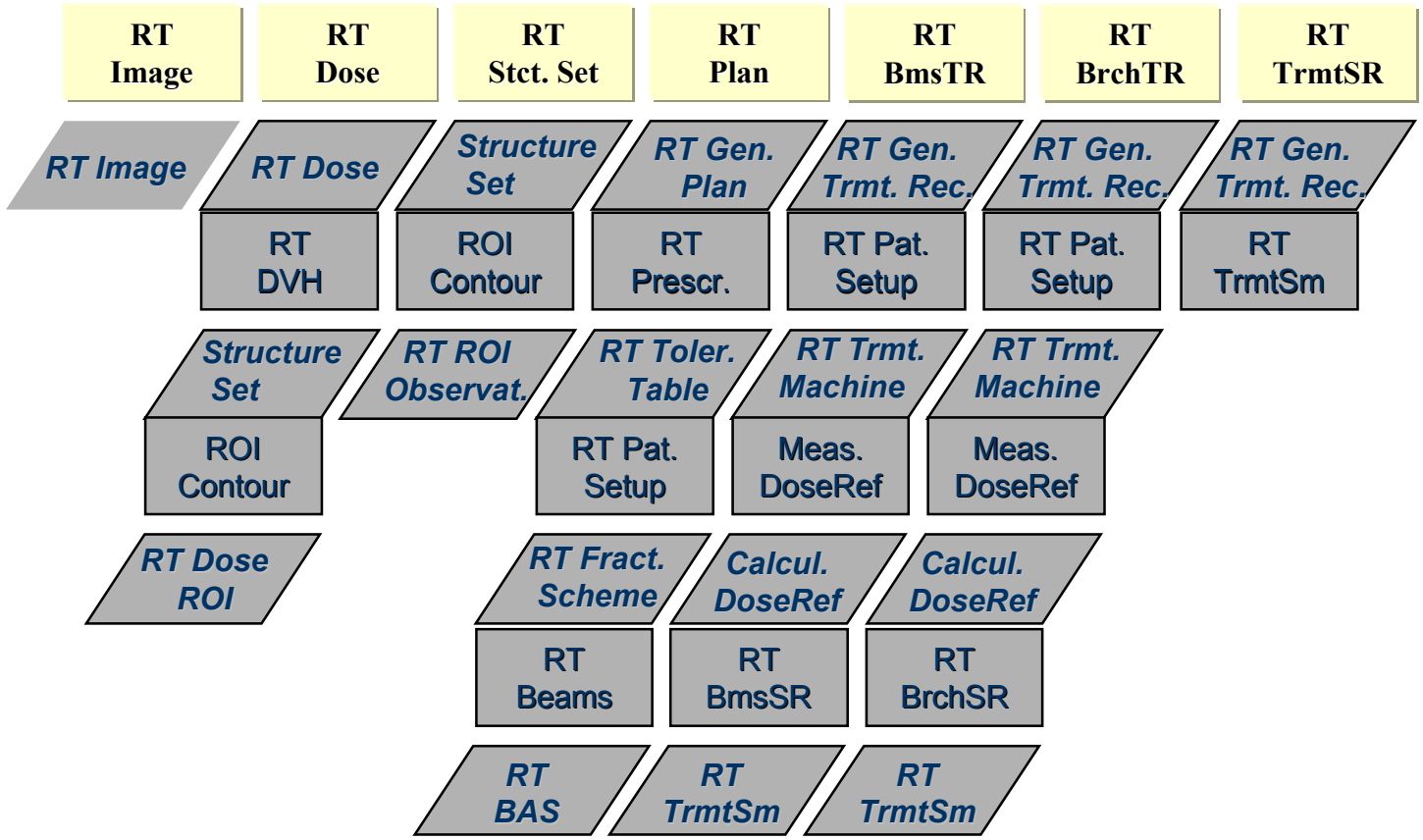
Approval Module

C.8.8.16 Approval Module

Table C.8-48—APPROVAL MODULE ATTRIBUTES

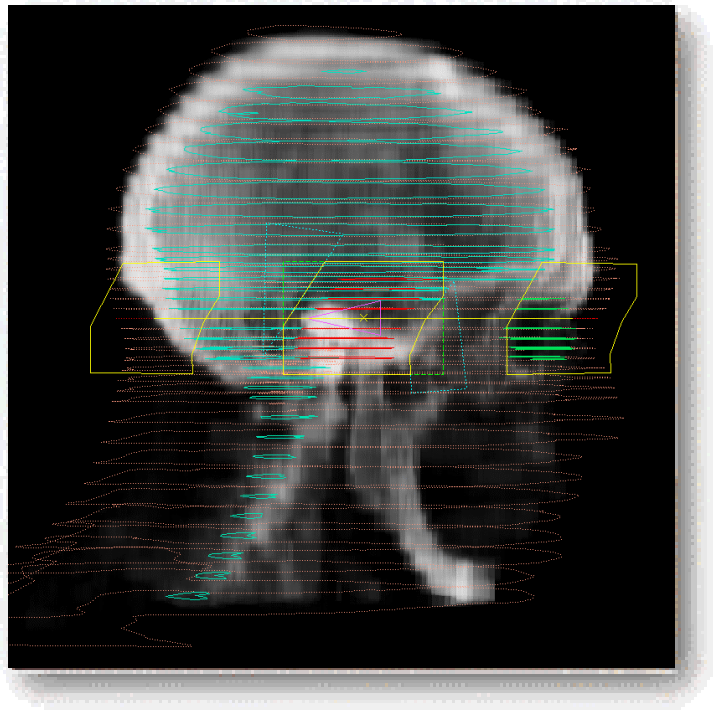
Attribute Name	Tag	Type	Attribute Description
Approval Status	(300E,0002)	1	Approval status at the time the SOP Instance was created. Enumerated Values: APPROVED = Reviewer recorded that object met an implied criterion UNAPPROVED = No review of object has been recorded REJECTED = Reviewer recorded that object failed to meet an implied criterion
Review Date	(300E,0004)	2C	Date on which object was reviewed. Required if Approval Status (300E,0002) is APPROVED or REJECTED.
Review Time	(300E,0005)	2C	Time at which object was reviewed. Required if Approval Status (300E,0002) is APPROVED or REJECTED.
Reviewer Name	(300E,0008)	2C	Name of person who reviewed object. Required if Approval Status (300E,0002) is APPROVED or REJECTED.

New IOD Modules



RT Image

- Conical Imaging Geometry
  - Radiographs
  - Digital Reconstructed Radiographs (DRR)
  - Simulator Images
  - Portal Images
- Pixel Spacing on the image plane
- Exposure Sequence
  - Multiple Exposure Images
  - Cine Images
- Information on image generation
  - Gantry Angle
  - Field shape (Block, MLC) not stored as Overlay!



RT Image Module

Image Description
Radiation Machine Description

Ref. RT Plan Sq.
Ref. Plan

Ref. Beam Number

Exposure Sq.
Exposure Description

Beam Limiting Device Sq.
Beam Limiting Device Description

Applicator Sq.
Electron Applicator Description

Block Sq.
Block Description

Gantry/Beam Lim. Dev. Angle, Table Pos.

RT Image Implementations

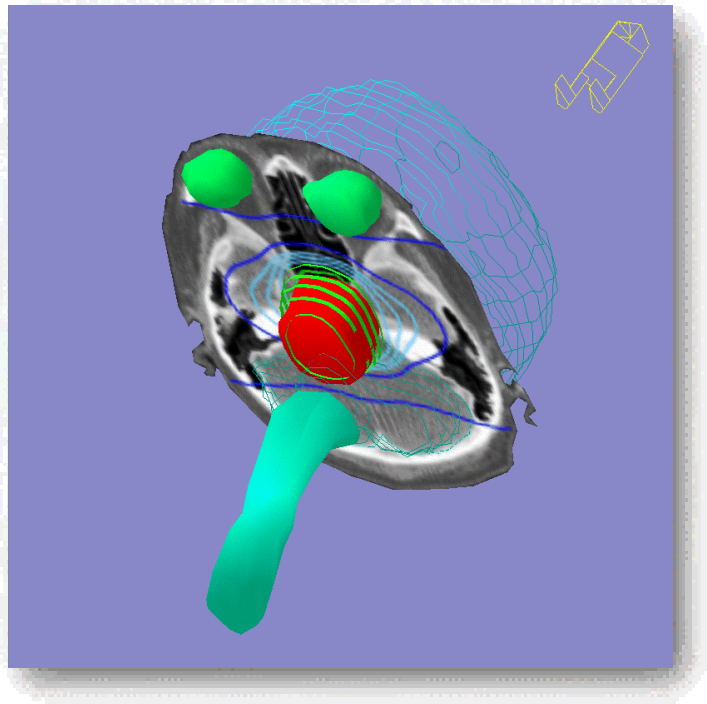
Vendor	SCP	SCU
Elekta Oncology Systems	*i*View	PrecisePlan
GE Medical Systems	AdvantageSIM	AdvantageSIM
IMPAC Medical Systems	ViewStation	QwikSIM
Merge Technologies	MergeARK	MergeARK
NOMOS	CORVUS	BAT
Nucletron	Plato, O'IMCON, TPP, O'DA	**Plato**, O'IMCON, O'VISIR, TPP, O'DA
Philips	Pinnacle, AcQSim, AcQPlan	Pinnacle, AcQSim, AcQPlan
Siemens Medical Systems	LANTIS, BeamView, **Imaging Platform**	BeamView, **Imaging Platform**
Varian Medical Systems	VARiS/Vision G6	VARiS/Vision G6

Implemented
WIP
Future Release

Data from Hans Sethi, Elekta Oncology Systems

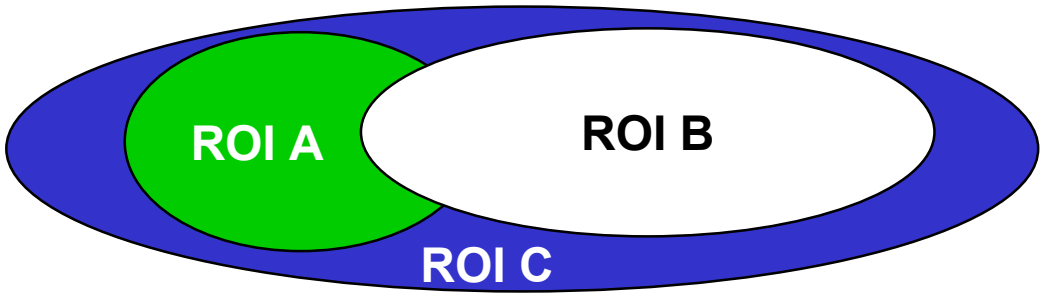
RT Dose

- 0D, 1D, 2D, and 3D
  - Dose Distribution
  - Specification for Dose Calculations (?)
- Grid-based 2D plane(s)
  - Values in Image Pixel Module (DICOM)
  - Planes identified through Grid Frame Offset Vector
- Different summation types Plan / Fraction / Beam / Brachy



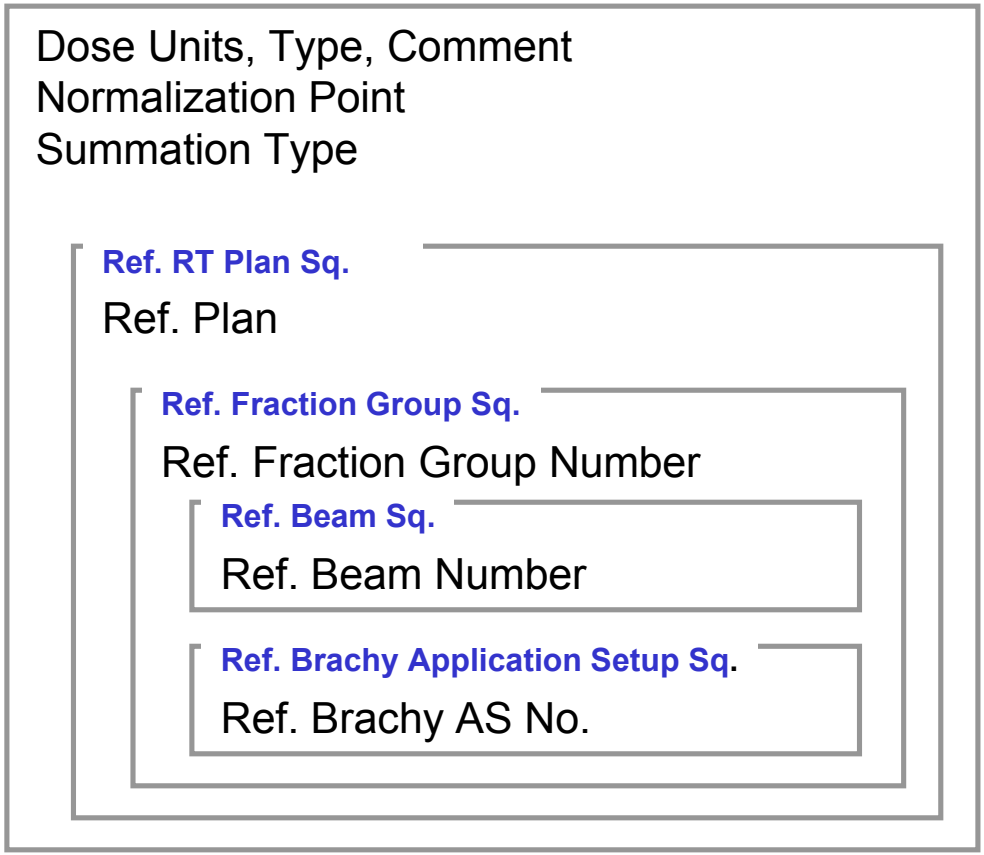
RT Dose

- Isodoses
  - Description of Isodose Lines
  - Referencing related ROI
  - Dose Units
  - Dose Value
- Dose Volume Histograms
  - Cumulative, Integral, Natural
  - Differential or Cumulative DVH
  - Reference to according ROIs
  - ROI Contribution Type
    INCLUDED, EXCLUDED

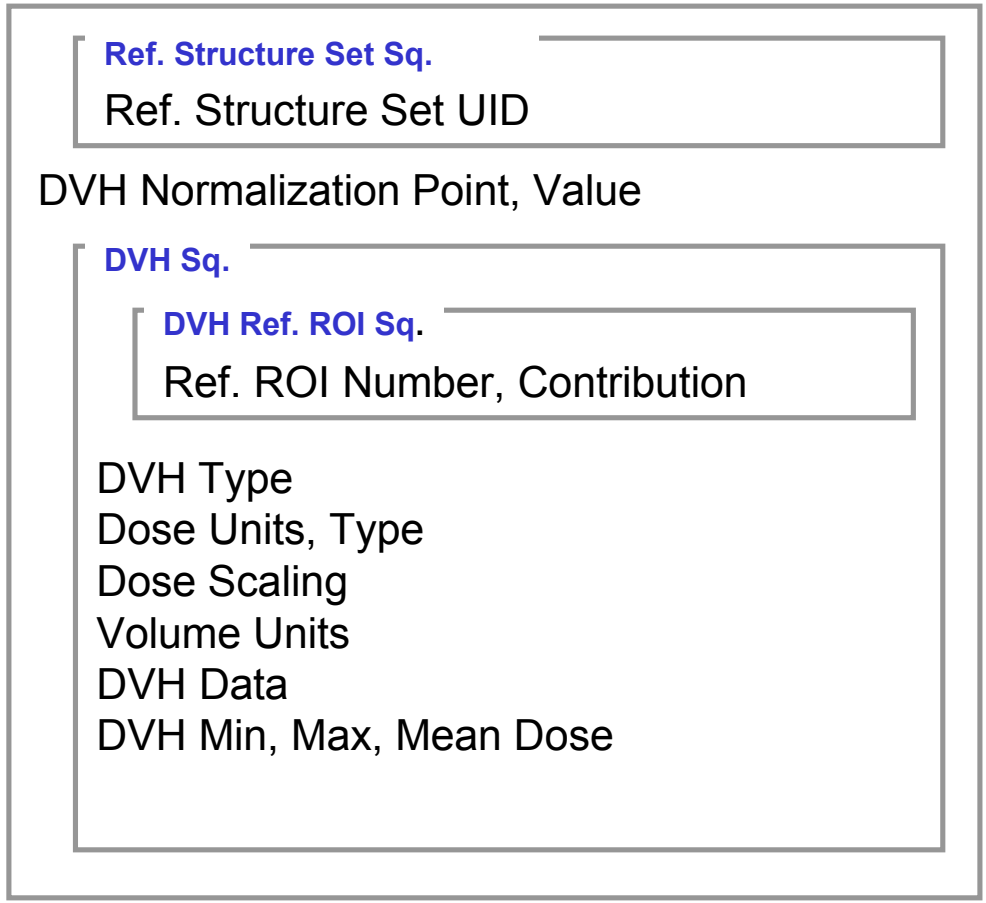


$$\text{Volume} = \bigcup (V_{INCLUDED}) - \bigcup (V_{EXCLUDED})$$

RT Dose Module



RT DVH Module



RT Dose Implementations

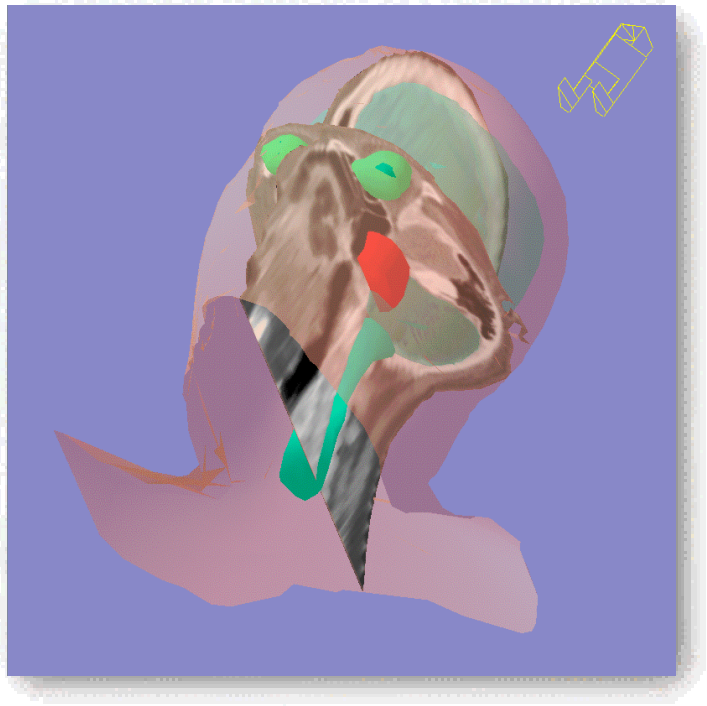
Vendor	SCP	SCU
Elekta Oncology Systems		PrecisePlan
IMPAC Medical Systems	***Future Release***	
Merge Technologies	MergeARK	MergeARK
NOMOS	**CORVUS**, BAT	
Nucletron	O'DM, TPP, O'DA	HelaxTMS, O'DM, TPP, O'DA
Philips	**Pinnacle, AcQSim, AcQPlan**	**Pinnacle, AcQSim, AcQPlan**
TomoTherapy Inc.		***Future Release***
Varian Medical Systems	**VARiS/Vision G6**	VARiS/Vision G6

Implemented
WIP
Future Release

Data from Hans Sethi, Elekta Oncology Systems

RT Structure Set

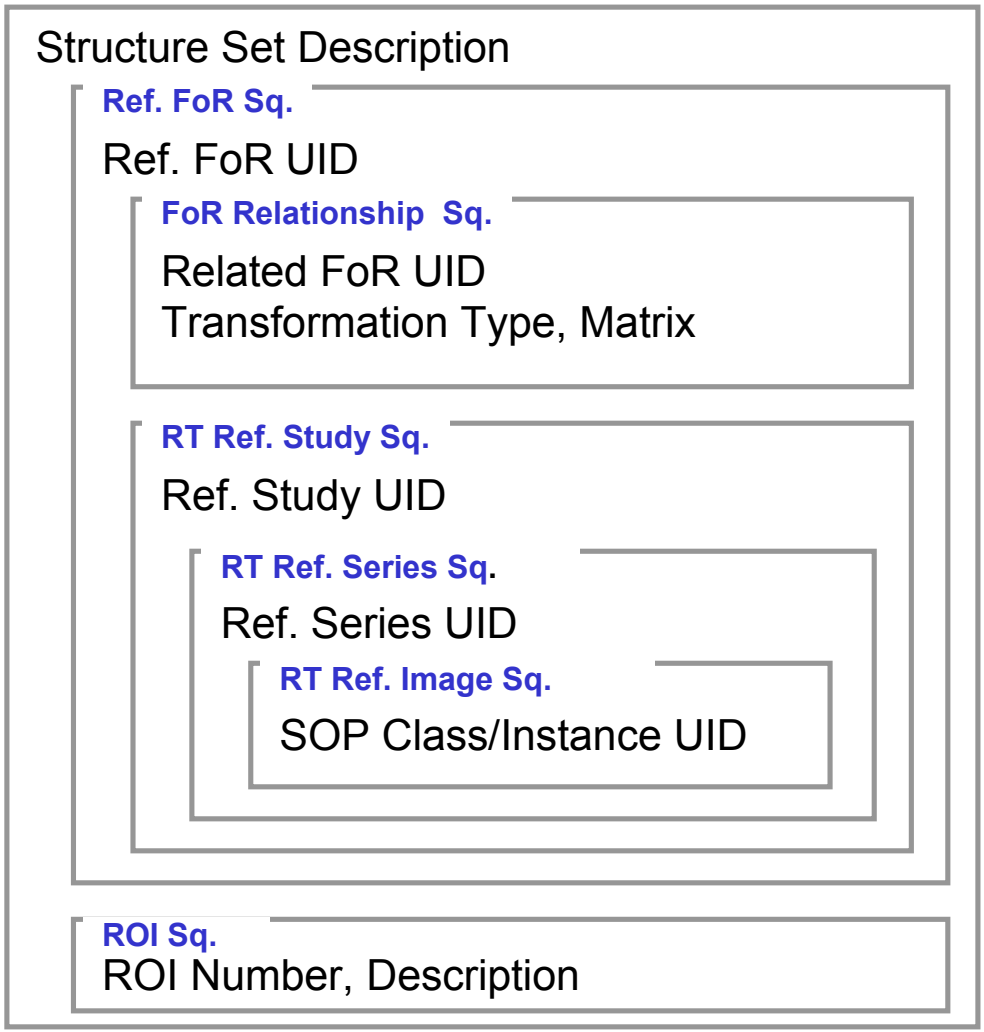
- Regions and Volumes of Interest (ROI, VOI)
- Points of Interest (e.g. Dose Points)
- 3D Objects (e.g. Bolus, Brachytherapy Applicator)
- Associated with 0-N images
- Frame of Reference Relationship
- ROIs referencing images
- ROI Generation algorithm
  AUTOMATIC,
  SEMIAUTOMATIC,
  MANUAL



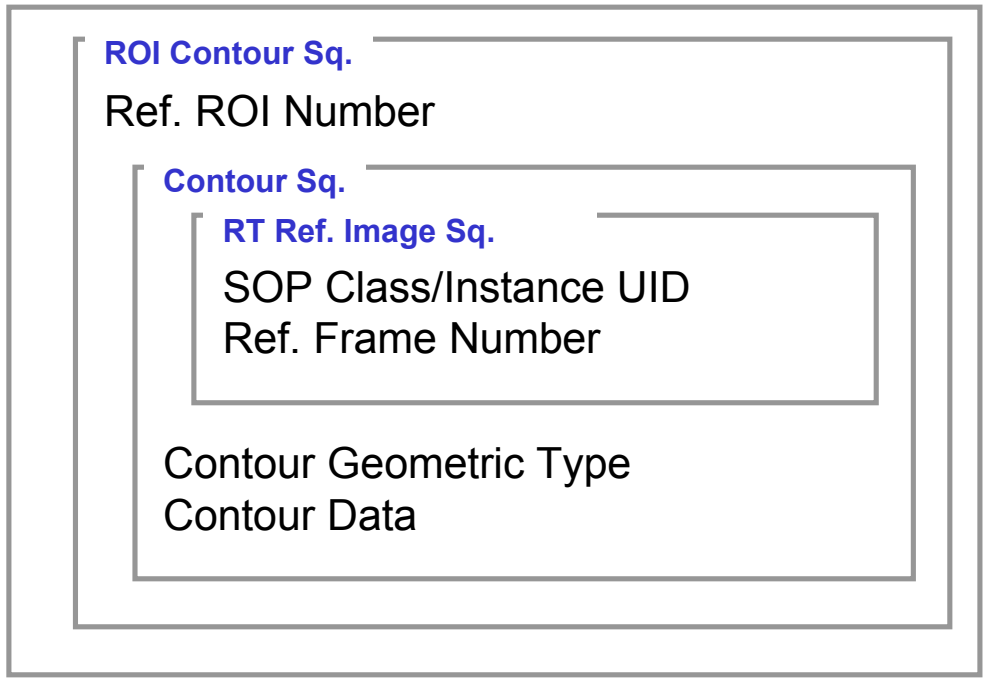
RT Structure Set

- Contours
  - Contour Data for ROI
  - Contours not necessarily in one plane
  - Associated with 0-N images
  - Geometric Type
    POINT,
    OPEN_PLANAR,
    OPEN_NONPLANAR,
    CLOSED_PLANAR
  - Contour Slab
- ROI Obervations
  - Identification, Interpretation
  - Specification of Coding Scheme
    (SDM, NLM TeRMS)
  - ROI Interpreted Type
  - ROI Material ID
  - ROI Physical Property

RT Structure Set Module



RT ROI Contour Module

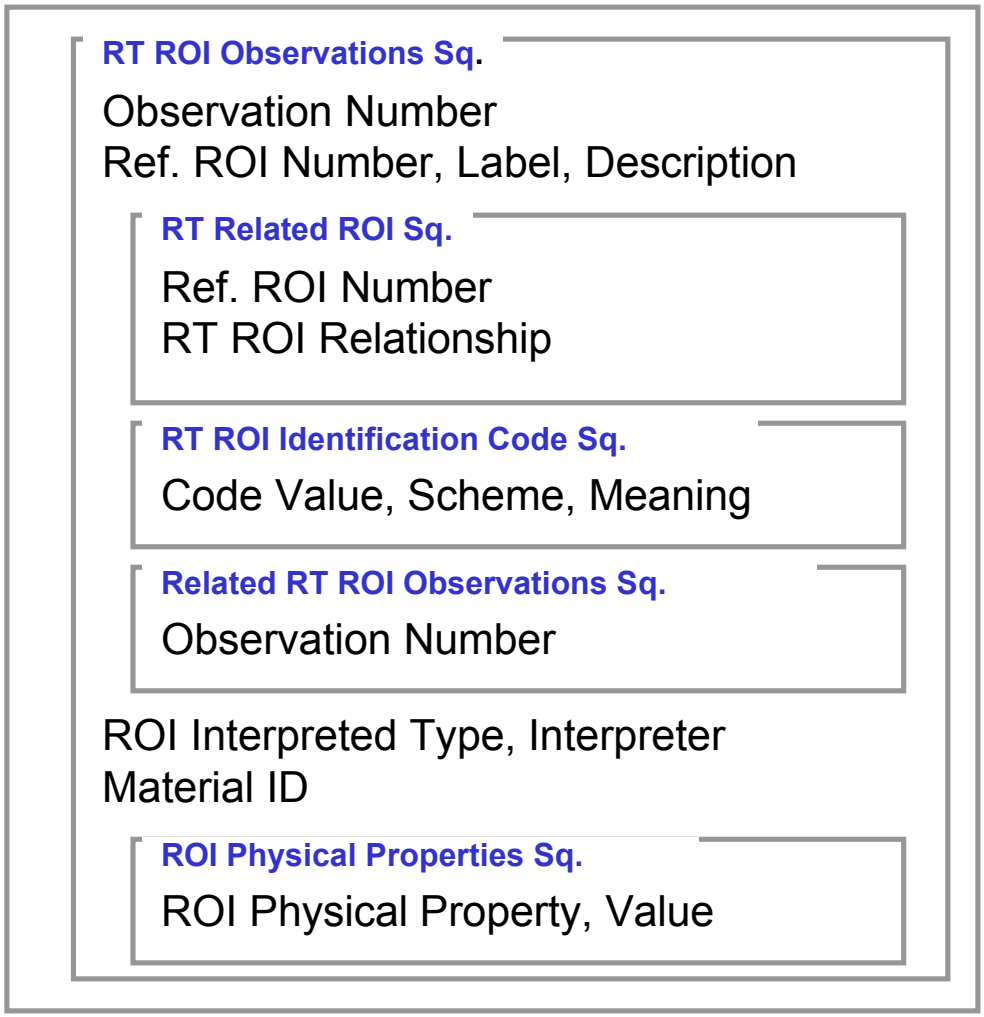


RT Dose ROI Module

RT Dose ROI Sq.

Ref. ROI Number
Dose Units
Dose Value

RT ROI Observations Module



RT Structure Set Implementations

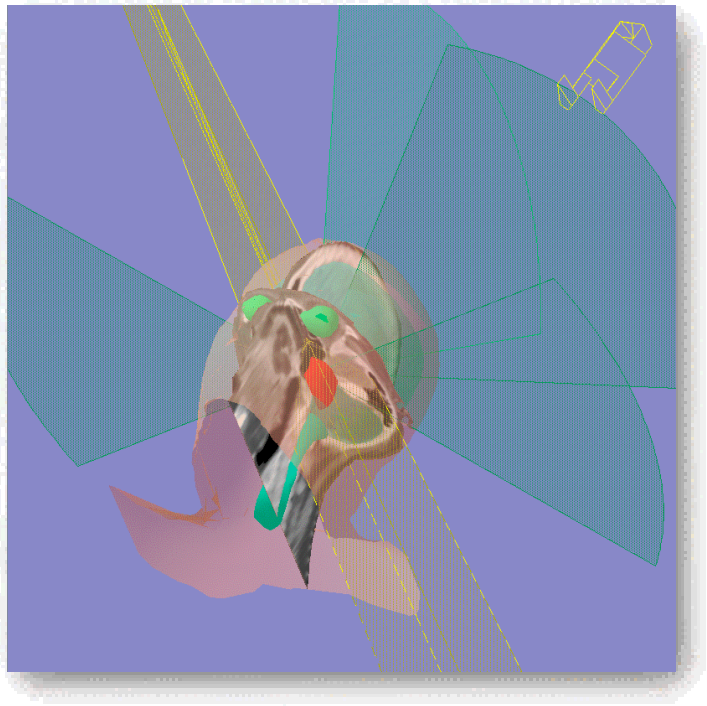
Vendor	SCP	SCU
CMS	*XiO*	**FocalSIM**
Elekta Oncology Systems	PrecisePlan, ***iView***	PrecisePlan
GE Medical Systems	AdvantageSIM	AdvantageSIM
IMPAC Medical Systems	***Future Release***	QwikSIM
Merge Technologies	MergeARK	MergeARK
NOMOS	CORVUS, BAT	**CORVUS**
Nucletron	Plato, HelaxTMS, O'DM, TPP, O'DA	**Plato**, HelaxTMS, TPP, O'DA
Philips	Pinnacle, **AcQSim, AcQPlan**	Pinnacle, AcQSim, AcQPlan
Siemens Medical Systems	**Imaging Platform**	**Imaging Platform**
TomoTherapy Inc.	***WIP***	
Varian Medical Systems	VARiS/Vision G6	VARiS/Vision G6

Implemented
WIP
Future Release

Data from Hans Sethi, Elekta Oncology Systems

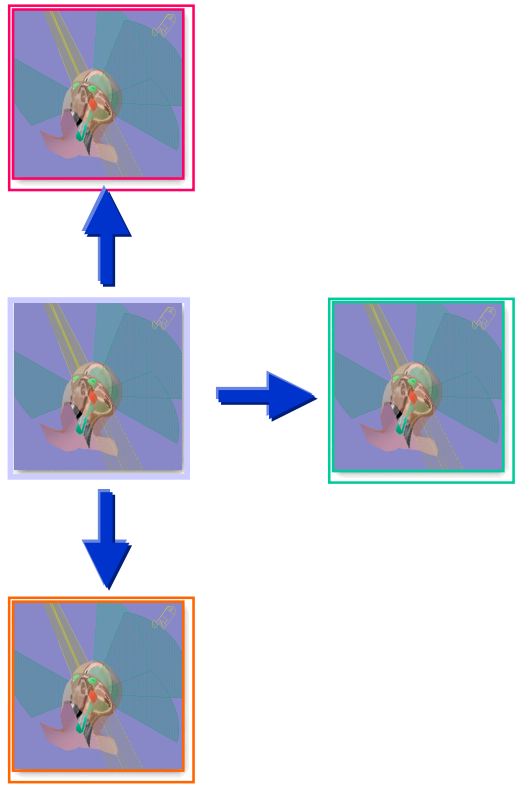
RT Plan

- Tele-Therapy and Brachytherapy
- Fractionation, Tolerance Tables, Positioning
- Reference to Dose Distribution (RT Dose)
- Reference to Frame of Reference
- Plan Relations
  - Versions
  - Alternative Plan
- Control Point Concept
  - MLC, Dynamic Therapy, IMRT



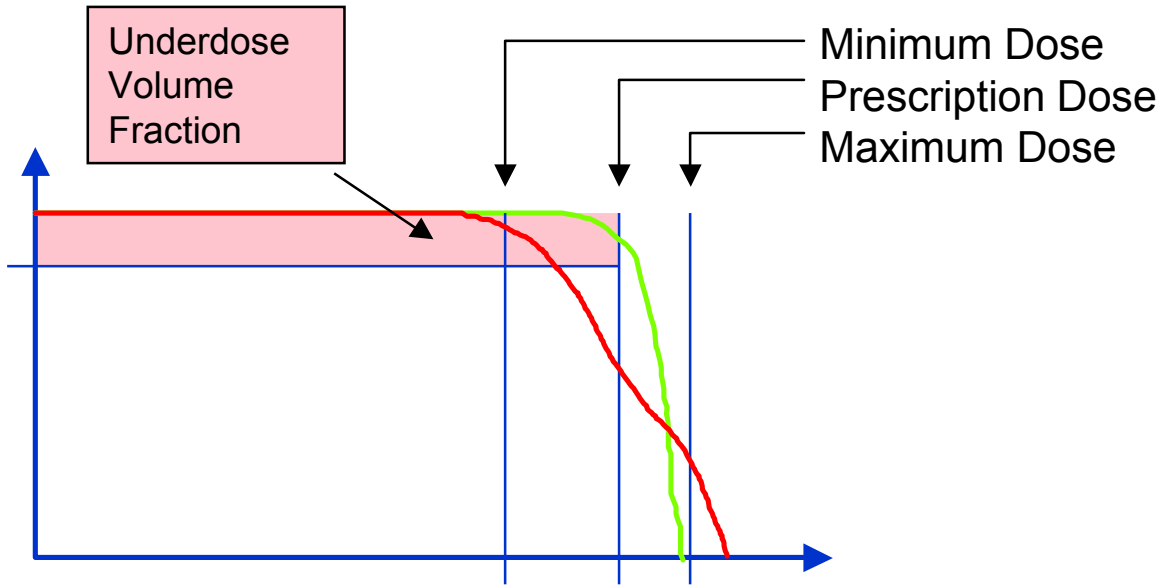
Plan Relationship

Referenced RT Plan Sequence	(300C,0002)	3	Introduces sequence of related SOP Class/Instance pairs describing related instances of RT Plan. One or more items may be included in this sequence.
>Referenced SOP Class UID	(0008,1150)	1C	Uniquely identifies the referenced SOP Class. Required if Referenced RT Plan Sequence (300C,0002) is sent.
>Referenced SOP Instance UID	(0008,1155)	1C	Uniquely identifies the referenced SOP Instance. Required if Referenced RT Plan Sequence (300C,0002) is sent.
>RT Plan Relationship	(300A,0055)	1C	Relationship of referenced plan with respect to current plan. Required if Referenced RT Plan Sequence (300C,0002) is sent. Defined Terms: PRIOR = plan delivered prior to current treatment ALTERNATIVE = alternative plan prepared for current treatment PREDECESSOR = plan used in derivation of current plan



RT Plan

- Prescription
  - Dose Specification Information
  - Target and Organ at Risk Dose



RT Plan

- Tolerance Table
  - One or more Tolerance Tables for entire Plan
  - Comparing planned / delivered machine parameters
  - Accounting for different techniques
  - Referenced from Beams
- Patient Positioning
  - Fixation Devices
  - Shielding Devices
  - Setup Technique
  - 'Displacement' information
  - Referenced from Beams and Treatment Record

RT Plan

- Fractionation Scheme
  - One or more schemes for treatment
  - Dose specification (RT Prescription)
  - Fractionation information
  - Applied to Beams / Brachy Appl. Setup
  - Allows reusing of Beams / Brachy AS
- Fractionation Pattern:

Mon	Tue	Wed	Thu	Fri	Sat	Sun
0/1	0/1	0/1	0/1	0/1	0/1	0/1

- Pattern Length:

Pattern Length = NumFractionPatternDigitsPerDay x 7 x RepeatCycleLength

RT Plan

- Fractionation Examples
  - 1 Fraction Group,
    1 Fraction/Day, Mon-Fri
    FG1: 1111100
  - 2 Fraction Groups,
    2 alternating Fractions/Day, Mon-Fri
    FG1: 10101010100000
    FG2: 01010101010000
  - 2 Fraction Groups,
    1 Fraction/Day and 2 Fractions/Day, Mon-Fri
    FG1: 1111100
    FG2: 11111111110000

RT Plan

- Beams
  - Beam identification
  - Treatment Unit description
  - RT Image acquisition information
  - Wedges, Compensators, Boli, Blocks, Applicators
  - Control Point Concept
  - Control Point specific Dose References

RT Plan

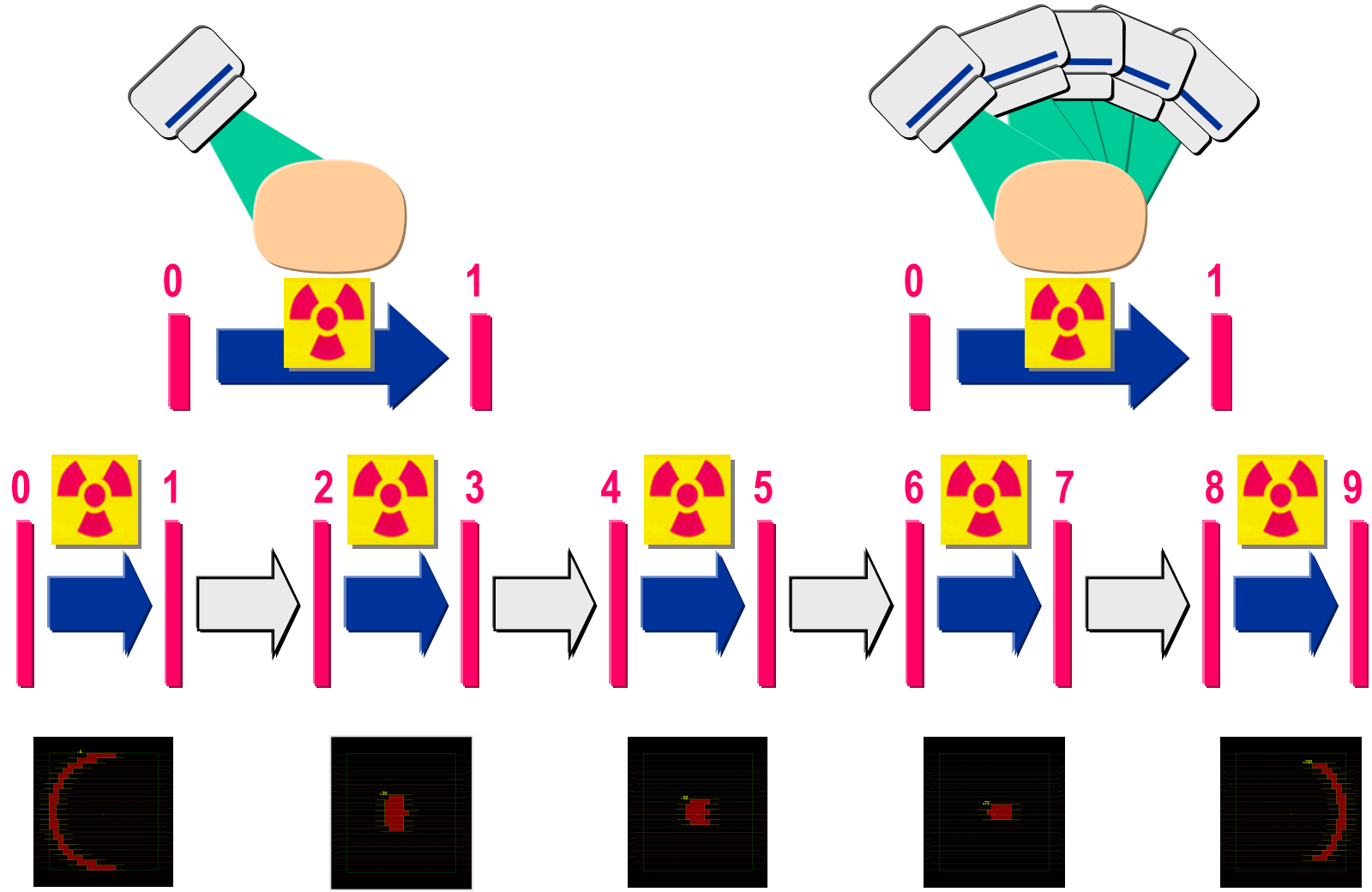
- Control Point Concept

A Control Point describes which parameters (including MU/Time) of the Treatment Unit change during beam delivery.

  - CP0: Initial Setup; All applicable parameters
  - CP1-N: Parameters which change at any CP

Behaviour between Control Points not described.

DICOM Control Points



RT Plan

- Absolute / Relative Positions

  All positions except Table Translations are absolute.

- Table Translations
  - relative:
    No initial value specified
  - absolute:
    Initial value specified

- Dose Specification
  absolute MU/Time / relative MU/Time

$$CPMS = BeamMS \times \frac{CumulMSWeight}{FinalMSWeight}$$

- absolute:
  BeamMS = FinalMSWeight
- relative:
  BeamMS ^{1} FinalMSWeight

RT Plan

- Brachy Application Setup
  - Generalized Model from Remote AL
  - Application Setup [1] Source Applicator
  - Brachy Accessory Devices
    - Shield
    - Mold
    - Plaque
    - Dilatation
  - ROI based description of 3D Structures
  - Channel = Source Applicator + Transfer Tube
  - Sources referenced from Channel
  - Control Point Concept
  - Specification of Transit Times

RT General Plan Module

Plan Description, Treatment Intent
RT Plan Geometry

Ref. Sructure Set Sq.

Ref. SOP Class/Instance UID

Ref. Dose Sq.

Ref. SOP Class/Instance UID

Ref. RT Plan Sq.

Ref. SOP Class/Instance UID
Ref. Plan Relationship

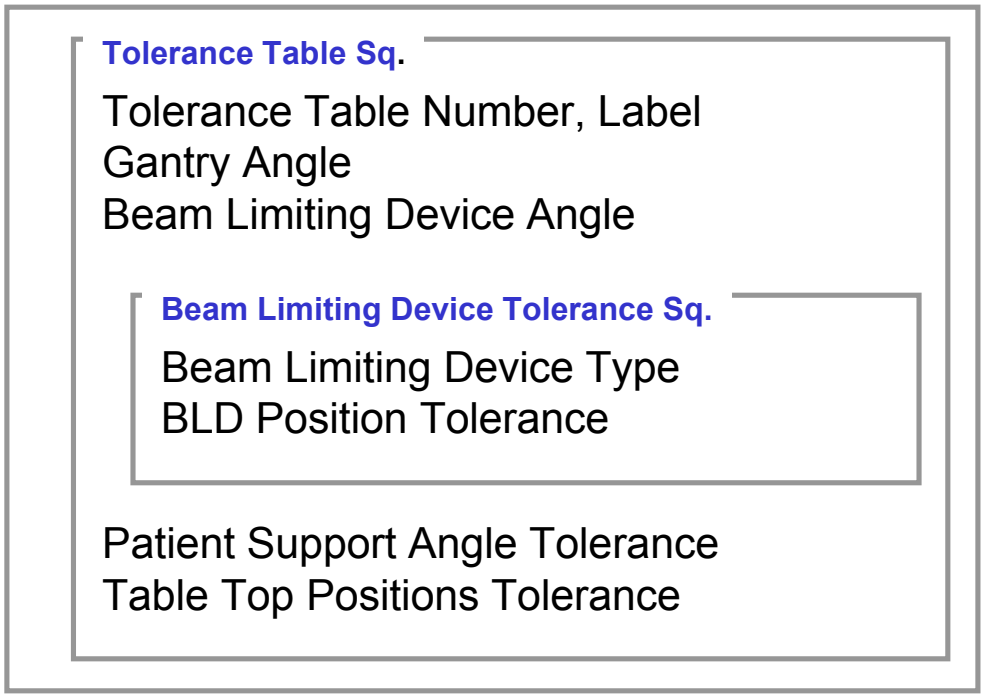
RT Prescription Module

Prescription Description

Dose Reference Sq.

Dose Reference Number
Dose Reference Structure Type
Referenced ROI Number
Reference Point Coordinates
Dose Reference Type
Constraint Weight
Dosage Information

RT Tolerance Table Module



RT Patient Setup Module

Patient Setup Sq.

Patient Setup Number
Patient Position, Additional Position

Fixation Device Sq.

Fixation Device Description

Shielding Device Sq.

Schielding Device Description

Setup Technique, Description

Setup Device Sq.

Setup Device Description

Table Displacements

RT Fraction Scheme Module

Fraction Group Sq.

Fraction Group Number
Ref. Patient Setup Number

Ref. Dose Sq.

Ref. SOP Class/Instance UID

Ref. Dose Reference Sq.

Ref. Dose Reference Number
Constraint, Dosage Information

Number of Fractions, Fractions/Day
Fraction Pattern

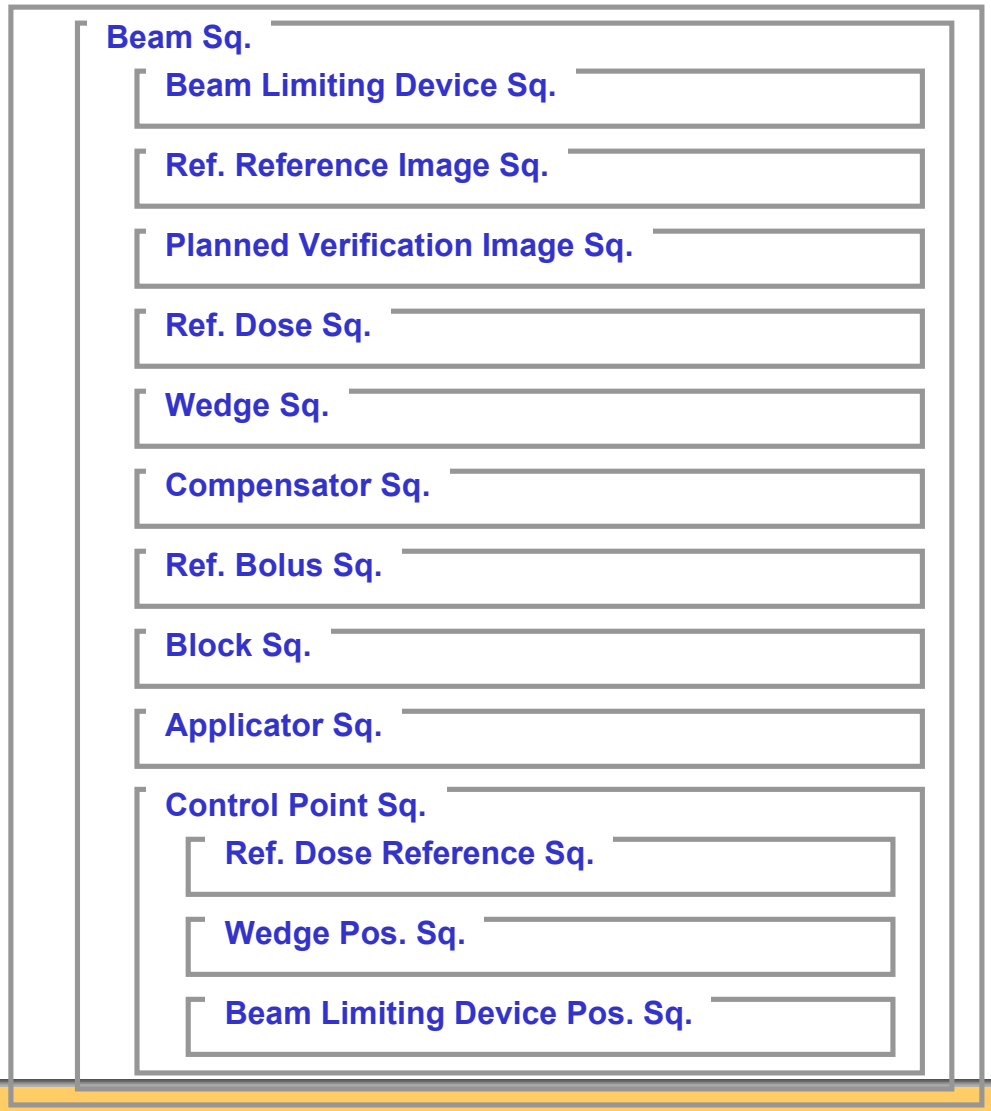
Ref. Beam Sq.

Beam Number, Dose

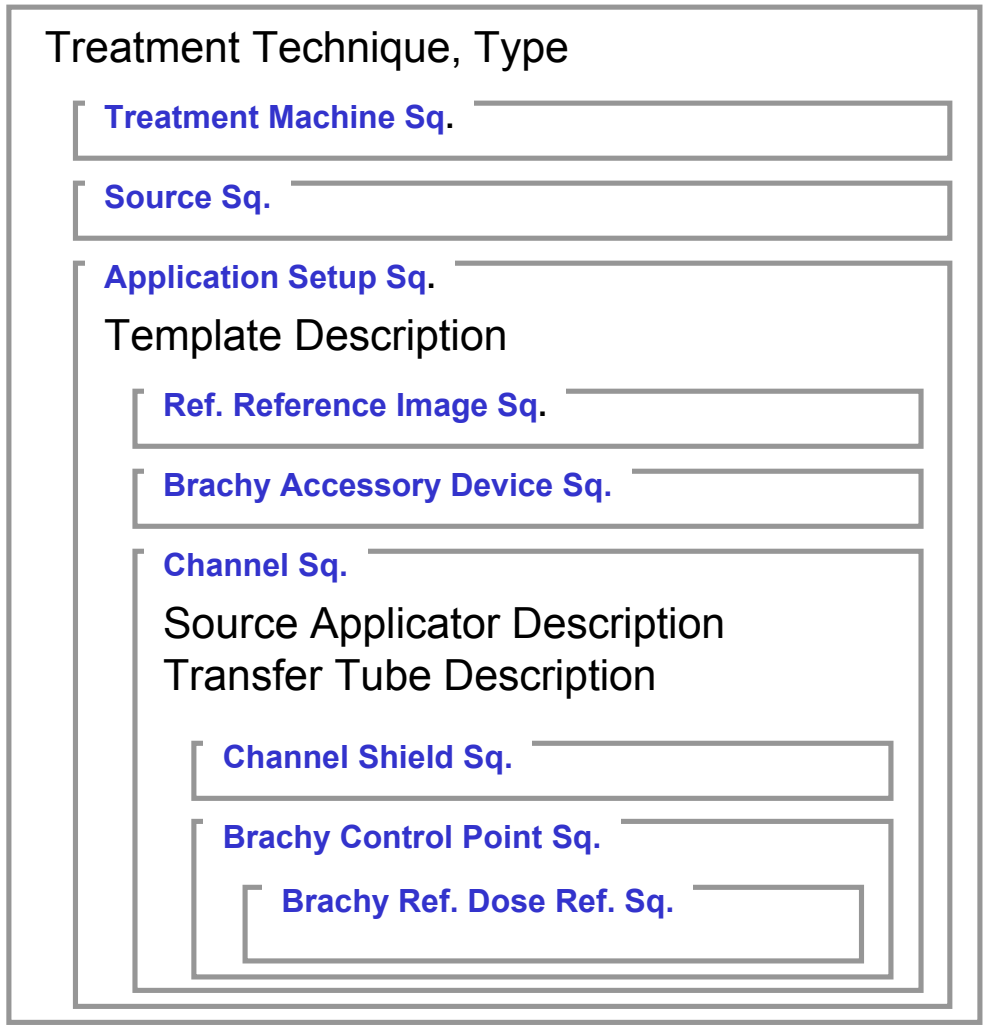
Ref. Brachy Application Setup Sq.

Brachy AS Number, Dose

RT Beams Module



RT Brachy Applications Setup Module



RT Plan Implementations

Vendor	SCP	SCU
CMS	X*i*O	**X*i*O, FocalSIM**
Elekta Oncology Systems	PreciseDesktop, PrecisePlan, ***i*View**	PrecisePlan
GE Medical Systems	AdvantageSIM	AdvantageSIM
IMPAC Medical Systems	MultiACCESS	QwikSIM
Merge Technologies	MergeARK	MergeARK
NOMOS	BAT	CORVUS
Nucletron	Plato, HelaxTMS, O'IMCON, O'VISIR, O'DM, TPP, O'DA	Plato, HelaxTMS, O'IMCON, O'VISIR, O'DM, TPP, O'DA
Philips	Pinnacle, AcQSim, AcQPlan	Pinnacle, AcQSim, AcQPlan
Siemens Medical Systems	LANTIS, IMFast, **Imaging Platform**	IMFast, **Imaging Platform**
Varian Medical Systems	VARiS/Vision G6	VARiS/Vision G6

Implemented
WIP
Future Release

Data from Hans Sethi, Elekta Oncology Systems

RT Treatment Record

- Tele-Therapy and Brachytherapy
- Session and Summary Record Information
  - 3 IODs
- Contains all Treatment-parameters
- Dose Calculations
- Dose Measurements
- References related RT Plan
- References related Treatment Records

RT Treatment Record

- Beams / Brachy Session
  - Measured / Calculated Dose
  - All Treatment Parameters
  - Additionally
    - Date, Time, Fraction Number
    - Termination Status, Code, Verification
    - Specified / Delivered Monitor Units/Time
- Treatment Summary
  - Current Treatment Status
  - First, Most Recent Treatment Date
  - Fraction Group Status
  - Fraction Status
  - Cumulative Measured / Calculated Dose to Dose References

RT General Treatment Record Module

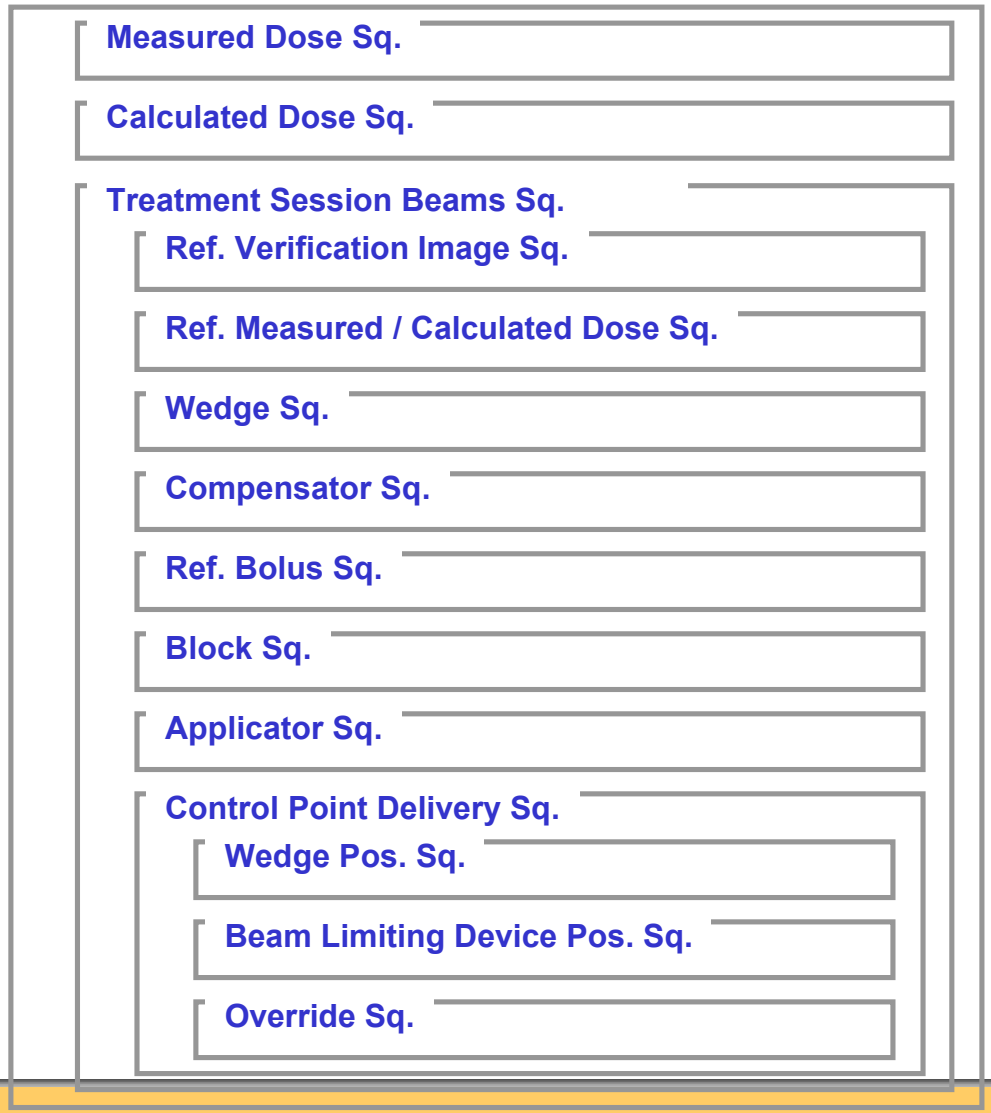
Ref. RT Plan Sq.

Ref. SOP Class/Instance UID

Ref. Treatment Record Sq.

Ref. SOP Class/Instance UID

RT Beam Session Record Module



RT Brachy Session Record Module

Treatment Technique, Type

- **Measured Dose Sq.**
- **Calculated Dose Sq.**
- **Treatment Session Application Setup Sq.**
  - Template Number
  - **Ref. Verification Image Sq.**
  - **Ref. Measured / Calculated Dose Sq.**
  - **Brachy Accessory Device Sq.**
  - **Channel Sq.**
    - Source Applicator Number
    - Transfer Tube Number
    - **Ref. Meas. / Calc. Dose Sq.**
    - **Channel Shield Sq.**
    - **Control Point Delivery Sq.**
      - **Override Sq.**

RT Treatment Summary Record Module

Treatment Status / Status Comment
First / Most Recent Treatment Date

Fraction Group Summary Sq.

Ref. Fraction Group Number
Faction Group Type
Number of Fractions Planned/Delivered

Fraction Status Summary Sq.

Ref. Fraction Number
Treatment Date / Time / Term. Status

Treatment Summary Meas. Dose Ref. Sq.

Ref. Dose Reference Number, Descr.
Cumulative Dose to Dose Reference

Treatment Summary Calc. Dose Ref. Sq.

Ref. Dose Reference Number, Descr.
Cumulative Dose to Dose Reference

RT Treatment Record Implementations

Vendor	SCP	SCU
Elekta Oncology Systems	PreciseDesktop	
IMPAC Medical Systems	MultiACCESS	MultiACCESS
Merge Technologies	MergeARK	MergeARK
Nucletron	O'VISIR	O'VISIR
Varian Medical Systems	VARiS/Vision G6	VARiS/Vision G6

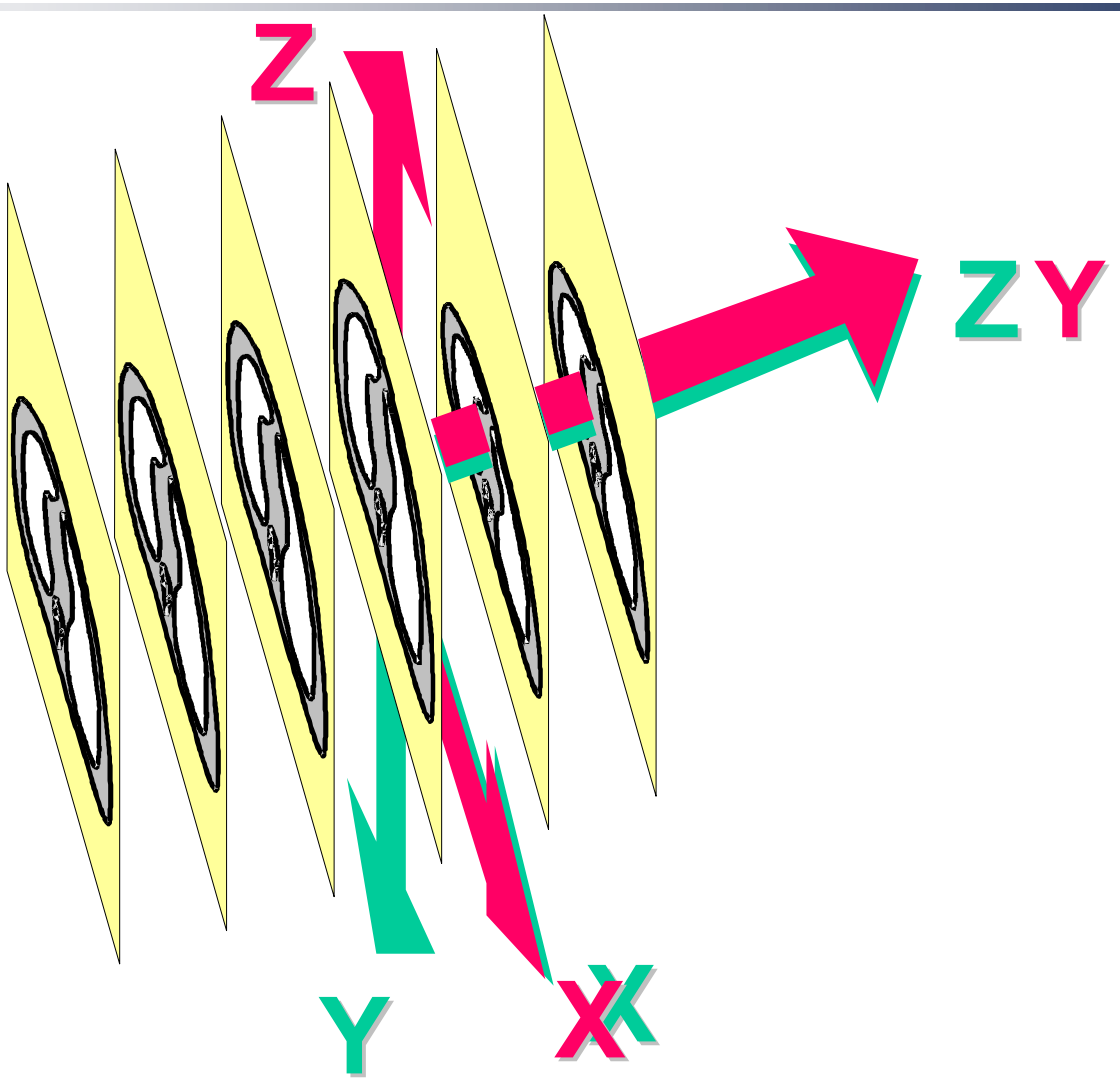
Implemented
WIP
Future Release

Data from Hans Sethi, Elekta Oncology Systems

Patient Coordinate Systems

DICOM

IEC



DICOM Coordinate System

- Right-handed
- Fixed with resp. to the patient

  „When a Frame of Reference is identified, it is not important how the Patient is positioned relative to the imaging equipment or where the origin of the Frame of Reference is located. It is important that the position of the Patient and the origin are constant in relationship to a specific Frame of Reference.“
  (Part 3, p.83)
- Origin arbitrary but fixed
- RT-DICOM: FoR Relationship
  Relating coordinate systems through
  - RT Structure Set
  - RT Plan

‘DICOM in Real Life‘

The ‘Communication’ part works.
The ‘Interoperability’ part may be difficult.

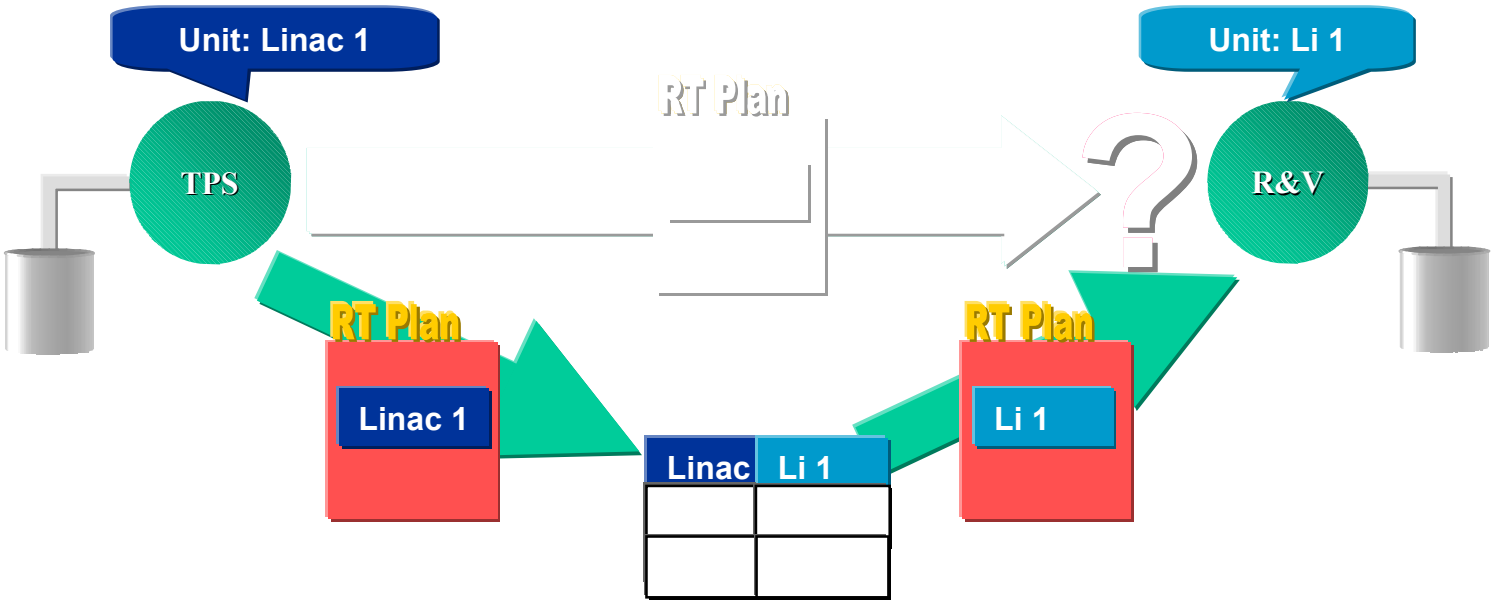
- Configuration
- Label and ID Mapping
- Interpretation
- Optional Elements
- Keep DICOM Elements in dynamic Objects
- ...Errors in the implementation

Configuration

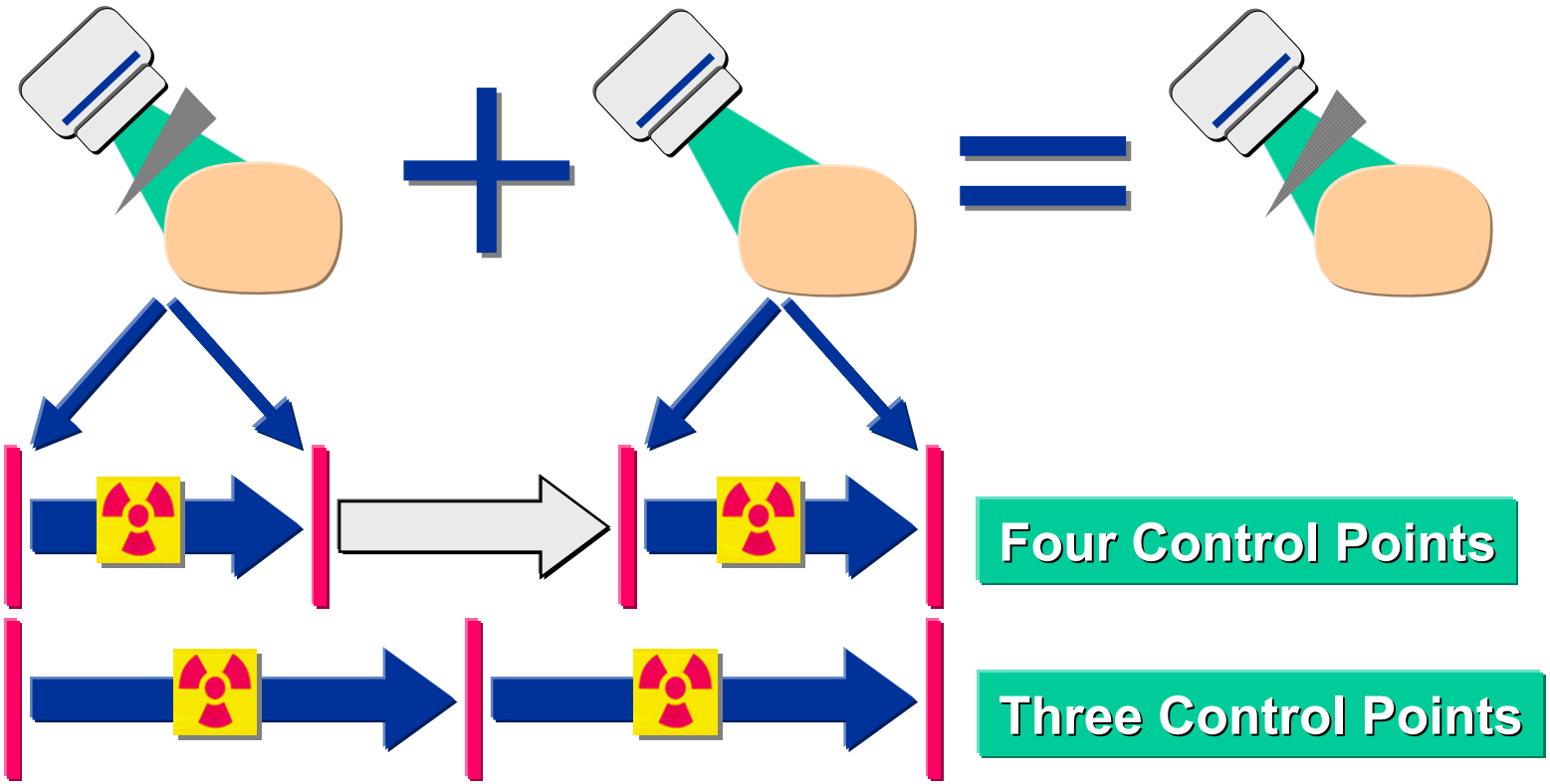
- IP Address / Host Name
  - IP Address — Wrong IP Address
  - Upper/Lower case — ADVSIM or advsim
  - Alias — No / Wrong Alias (host, lmhosts)
- Port Number
  - Wrong Port
  - Privileged Port — 104, 4006
- Application Entity Title
  - Upper/Lower case — MyAETitle or MYAETITLE
  - Spaces — MyAETitle _ _ _ _ _ _ _ _

Label and ID Mapping

- Treatment Units, Wedges, Electron Tubes



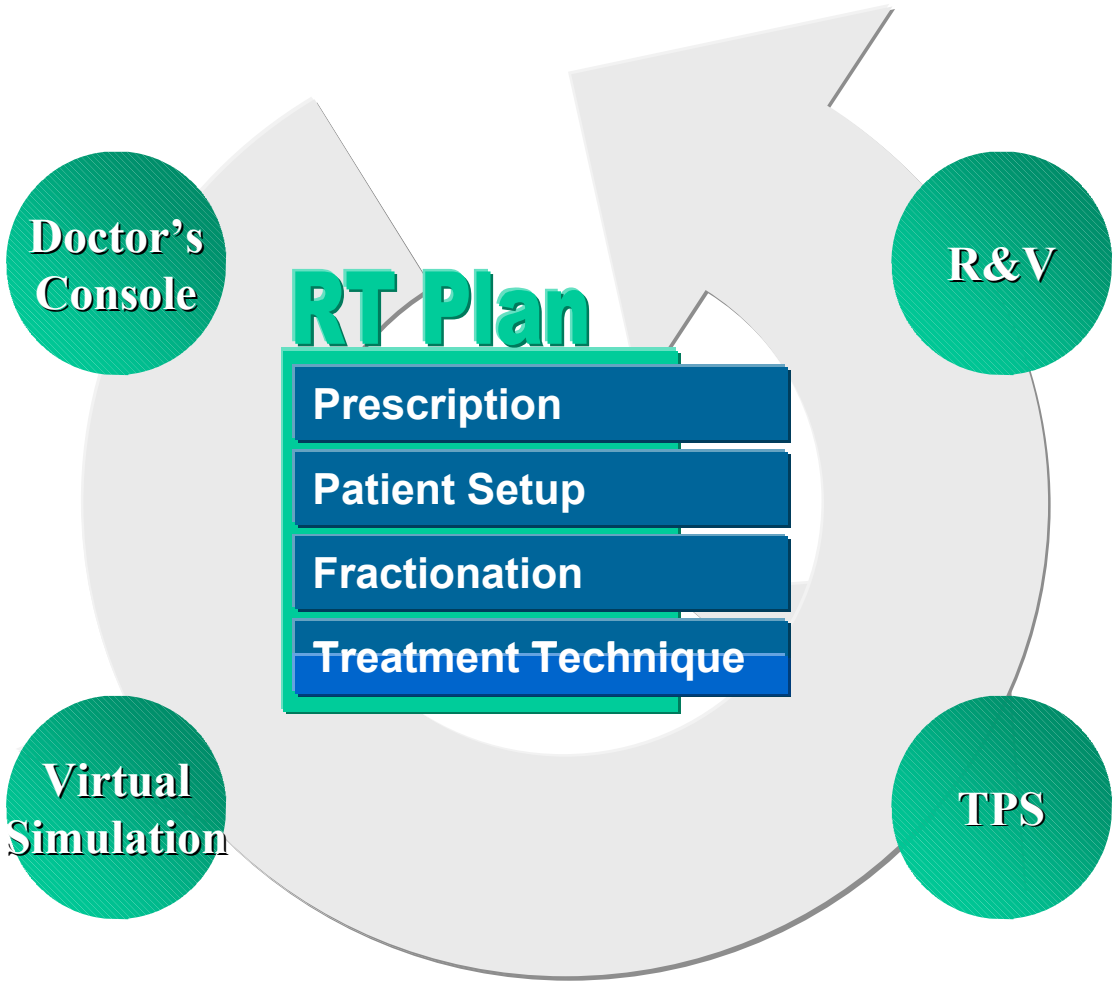
Interpretation



Optional Elements

- Patient Position
  - Important for 3D Model
  - User interaction possible
- Model Name of Imaging Modality
  - Adapt to specific ‘Interpretations’
- Structure Set Reference in RT Plan
  - Reference to coordinate system used (Frame of Reference)

Dynamic Objects



... anything is possible

- Date of Birth
  - Patient's Birthdate - (0010,0030) - Type 2 - 'YYYYDDMM' or 'YYYY.MM.DD'
  - '_ _ _ _._ _._ _'
  - '99.07.05'

DICOM Tools

- OFFIS DICOM Software

- Agfa DICOM Validation Tool
- Etiam DicomEye
- eFilm
- Others
  - ezDICOM, MRIcro, Rubo Medical, AccuView

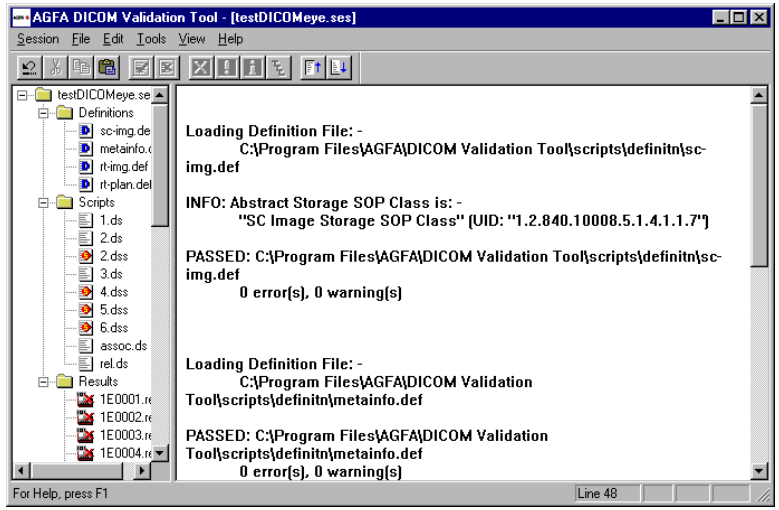
OFFIS DICOM Software

- Simple Routines
  - CTN, Store SCU/SCP, Query/Retrieve SCU/SCP, Worklist
- Source Code
- Different Plattforms
  - Windows, Linux, Solaris, SunOS, OSF/1, Ultrix, IRIX, NextStep
- Some other DICOM Utilities

http://www.offis.uni-oldenburg.de/projekte/dicom/project_dicom4.htm

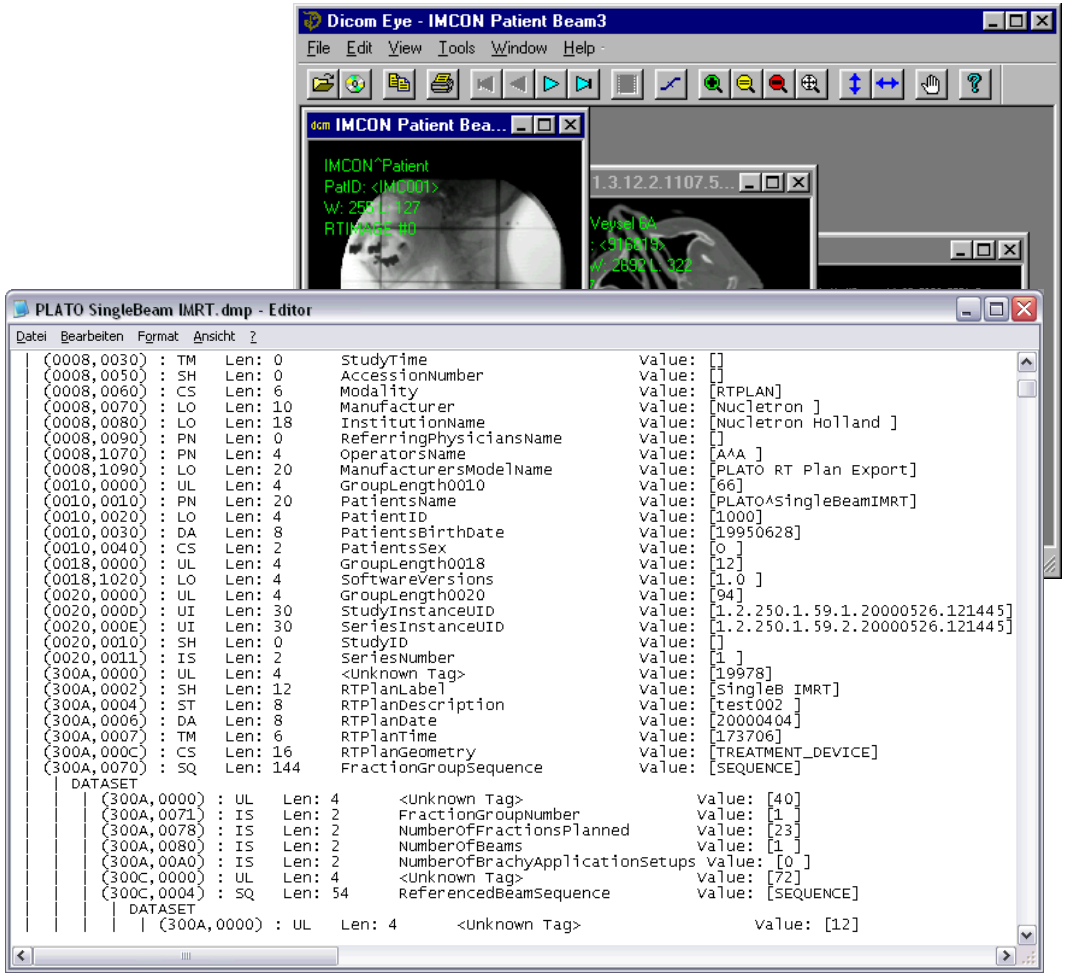
Agfa DICOM Validation Tool

- Evaluation of DICOM Files
- Evaluation of DICOM network communication
- Scripting
- Own definition of Objects
- Faulttolerant



Etiam DicomEye

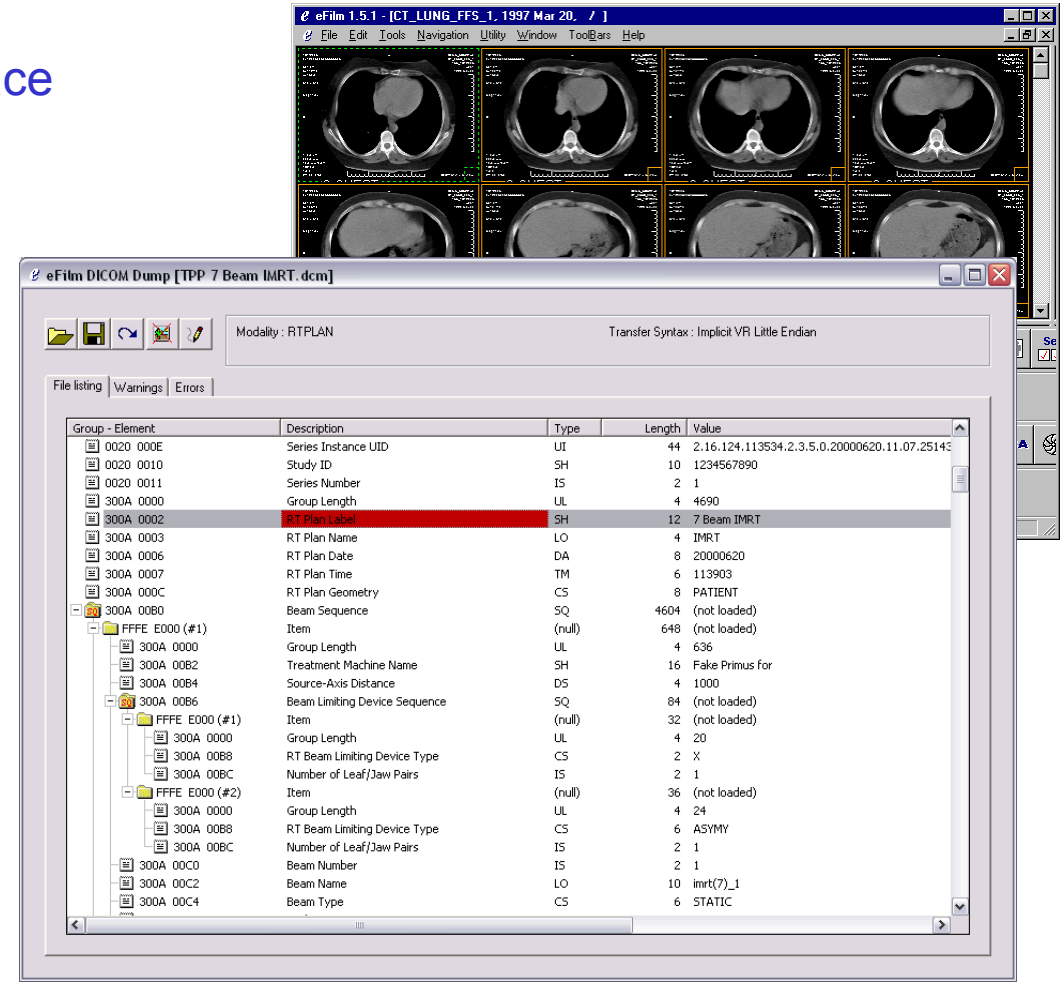
- Viewer
- Browser
- Query/Retrieve
- Cine support
- DICOM Print
- DICOM Dump
- Easy to use
- Affordable (790 EUR)



eFilm

- Viewer
  - clean User Interface
  - several Series
- Browser
- Query/Retrieve
- DICOM Print
- Create Sub-Set
- Nice DICOM Editor

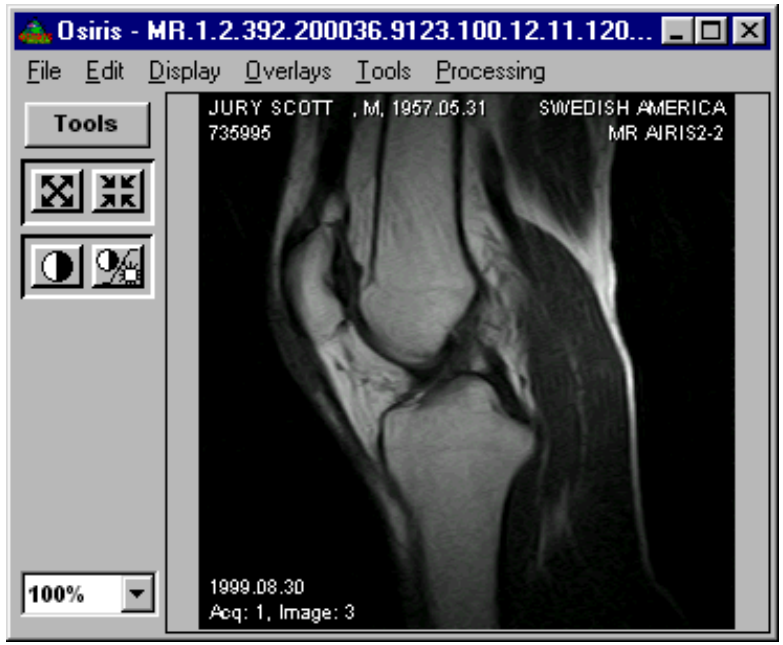
- Removes Pixel Size (Sub-Set)
- No RT support



Osiris

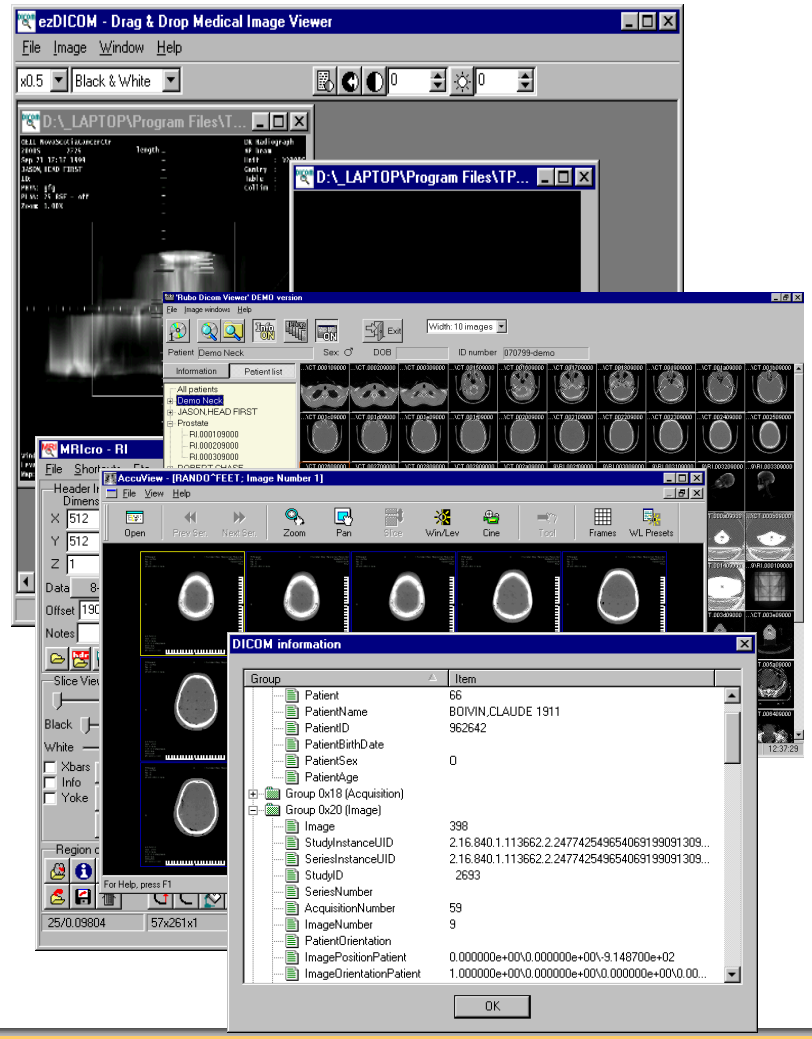
- Viewer
- Browser
- PAPYRUS format
- Image processing

- Old fashioned User Interface



Other Tools

- ezDICOM
  - Drag & Drop
- MRIcro
  - ROIs, Image processing
- Rubo Medical
  - Files, CDs
- AccuView
  - Files, DICOM Info
- Web Browser Plugins



Thank you for your attention.

Questions ?