Departments of Oncology and
Medical Biophysics

The Modern Technology of Radiation Oncology

Jacob (Jake) Van Dyk
Western University
London, Ontario, Canada

26 October 2017

Schulich
MEDICINE & DENTISTRY

Western

Disclosures

- License agreement with Modus Medical Devices, London, Canada
  - QUASAR™ QA devices
- Author/Editor of 3 Volumes on *The Modern Technology of Radiation Oncology*
  - Medical Physics Publishing
  - 1999, 2005, 2013

~2100 pages!
In 15 minutes?
Description, acceptance, commissioning & QC

Objective

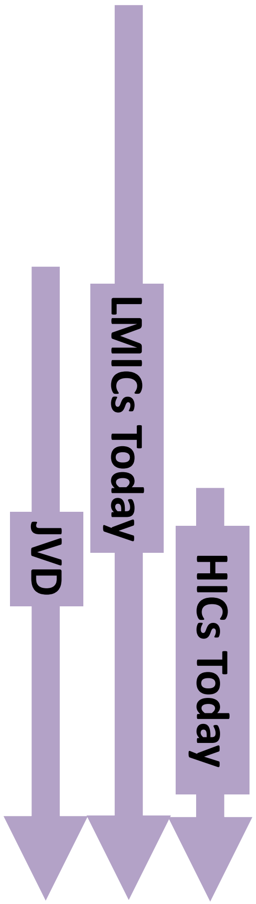
- To provide an overview of the technology of radiation oncology for non-experts in radiation oncology

Road Map

- Brief history
- Radiation therapy linacs
- Radiation treatment process
- Practical considerations
- Trends in Radiation Oncology

Past and Present in Radiotherapy

Phase	Time	Technology	Issues/Benefits
1	1895-1940s	100-400 kV x-rays	Non-uniform dose at depth, high skin dose, high bone dose
		Brachytherapy	Radium/radon, calculation systems
2	1950s	Cobalt-60 4-8 MeV linacs ≥20 MeV betatrons	Skin sparing, uniform dose at depth, manual treatment planning
3	1960s-70s	Multi-modality linacs Tr Planning Systems Simulators	Rotational machines, more physicists, detailed QA
4	1970s-80s	CT, 3D-CRT, LDR/HDR brachy afterloading	Improved targeting, improved dose computations
5	1990s-now	MLC, IMRT, IGRT, ART, 4-D, US, PET/CT, SPECT, MRI/MRS	In-room imaging, dose escalation, arc therapy, gating, smaller margins



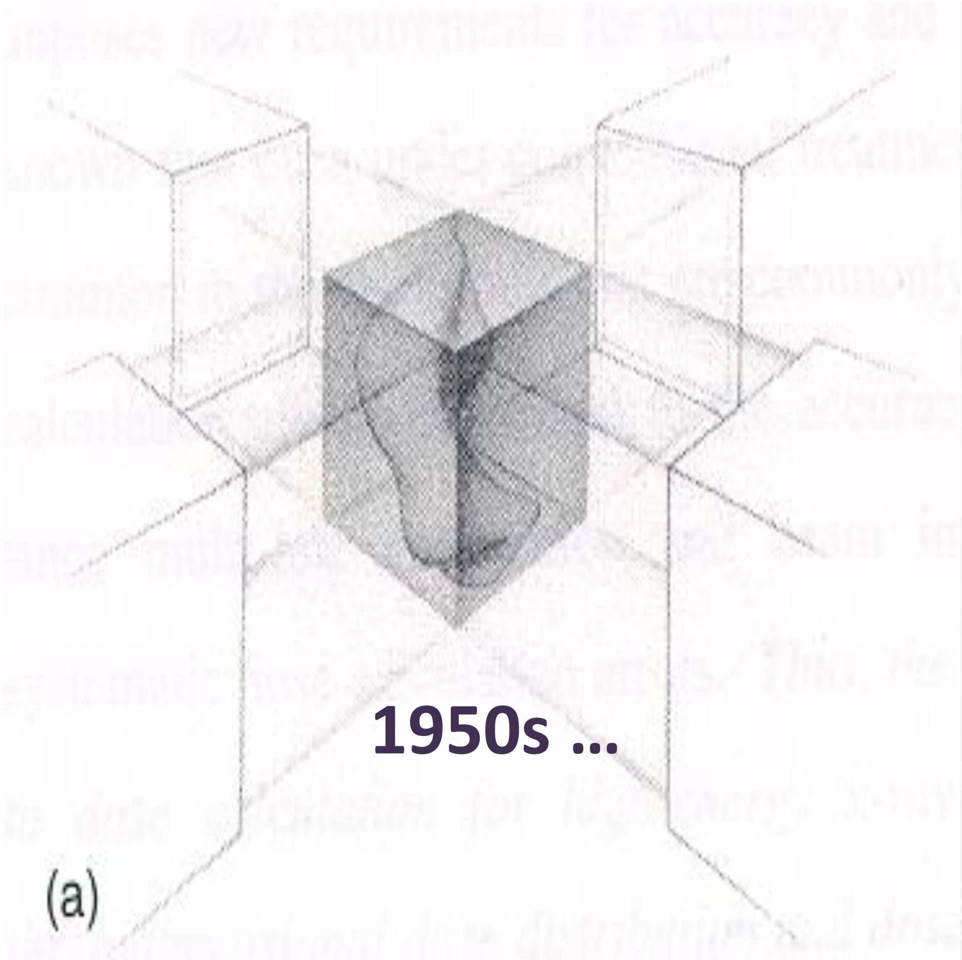
Evolution of Radiation Therapy

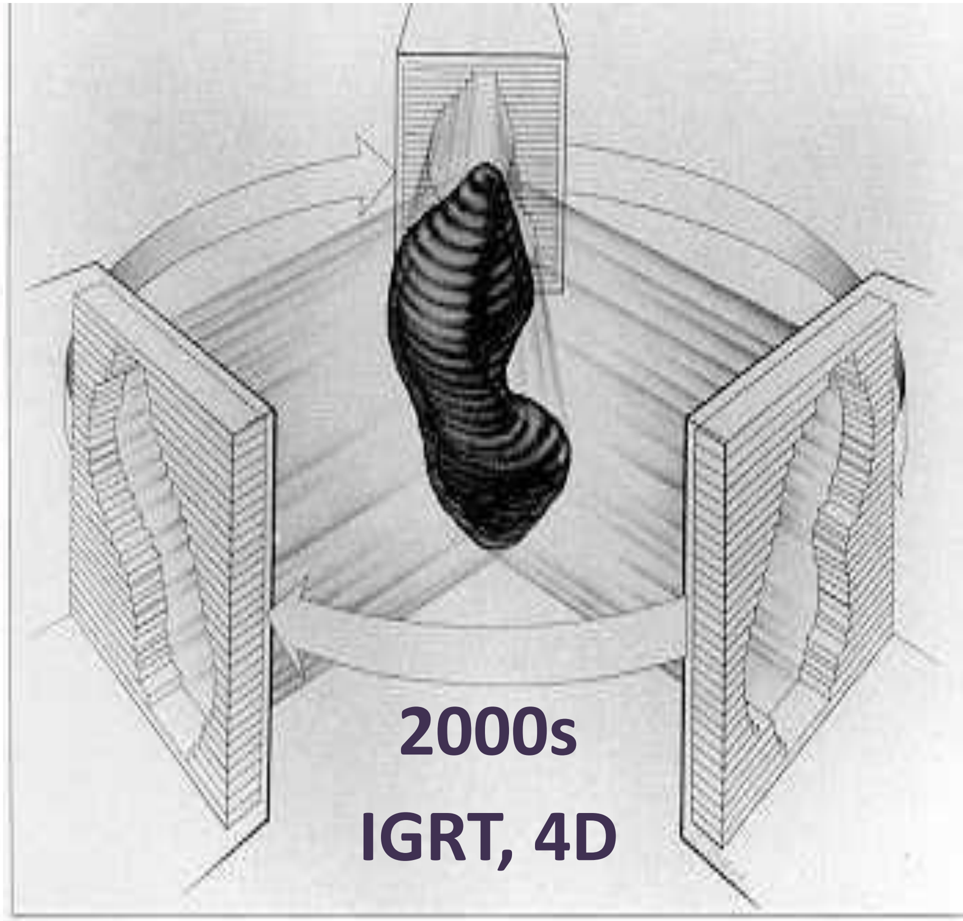
Time

Tumour **Margin Size**

Technique	Improvements	Planning
Fixed SSD RT		
Isocentric RT	Better set-up	Computer planning
Conformal RT	Better targeting	3D planning
	Better dose control	
IMRT		Inverse planning
IGRT	Less patient variability	
Adaptive RT		4D planning

RT…The Past to the Present





Lichter, Fraass, McShan 1988

Megavoltage
Isocentric

→

Blocks
Wedges
Comps

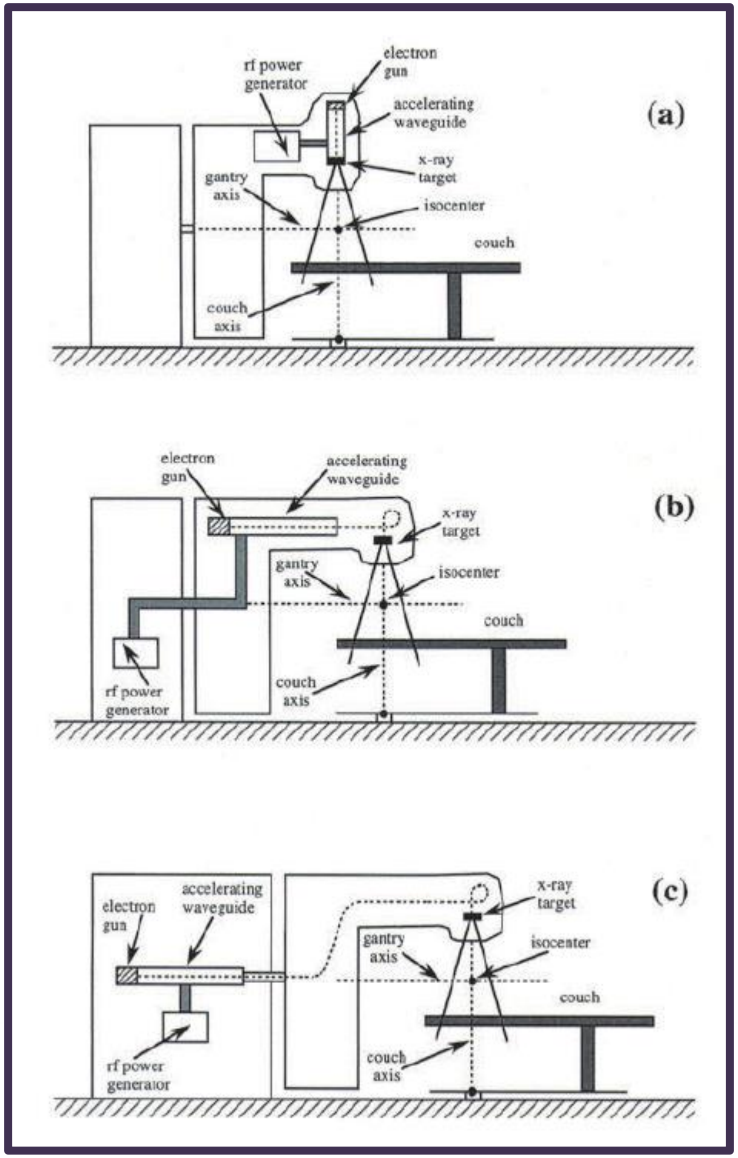
→

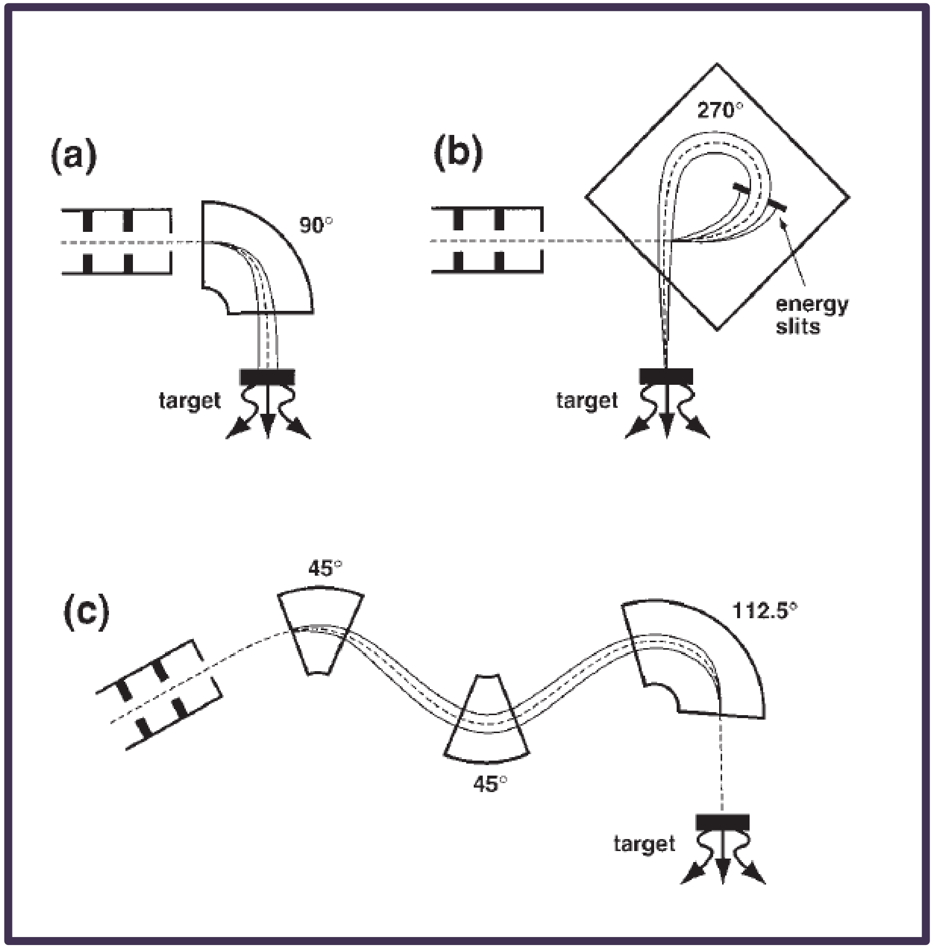
MLC
Dynamic treatments

JVD in Geneva 1974-75

- Centre de Radiothérapie de Génève, l'Hôpital Cantonal de Génève
  - Siemens betatron donated to CERN
    - For bubble chamber experiments
  - Installed Varian Clinac-18 … first in Europe
    - 10 MV photons; 6, 9, 12, 15, & 18 MeV electrons
    - No portal imaging
      - Port films
    - CERN scientist performed neutron measurements with various detectors

RT Linac Designs





Podgorsak, MTRO, Vol 1, 1999

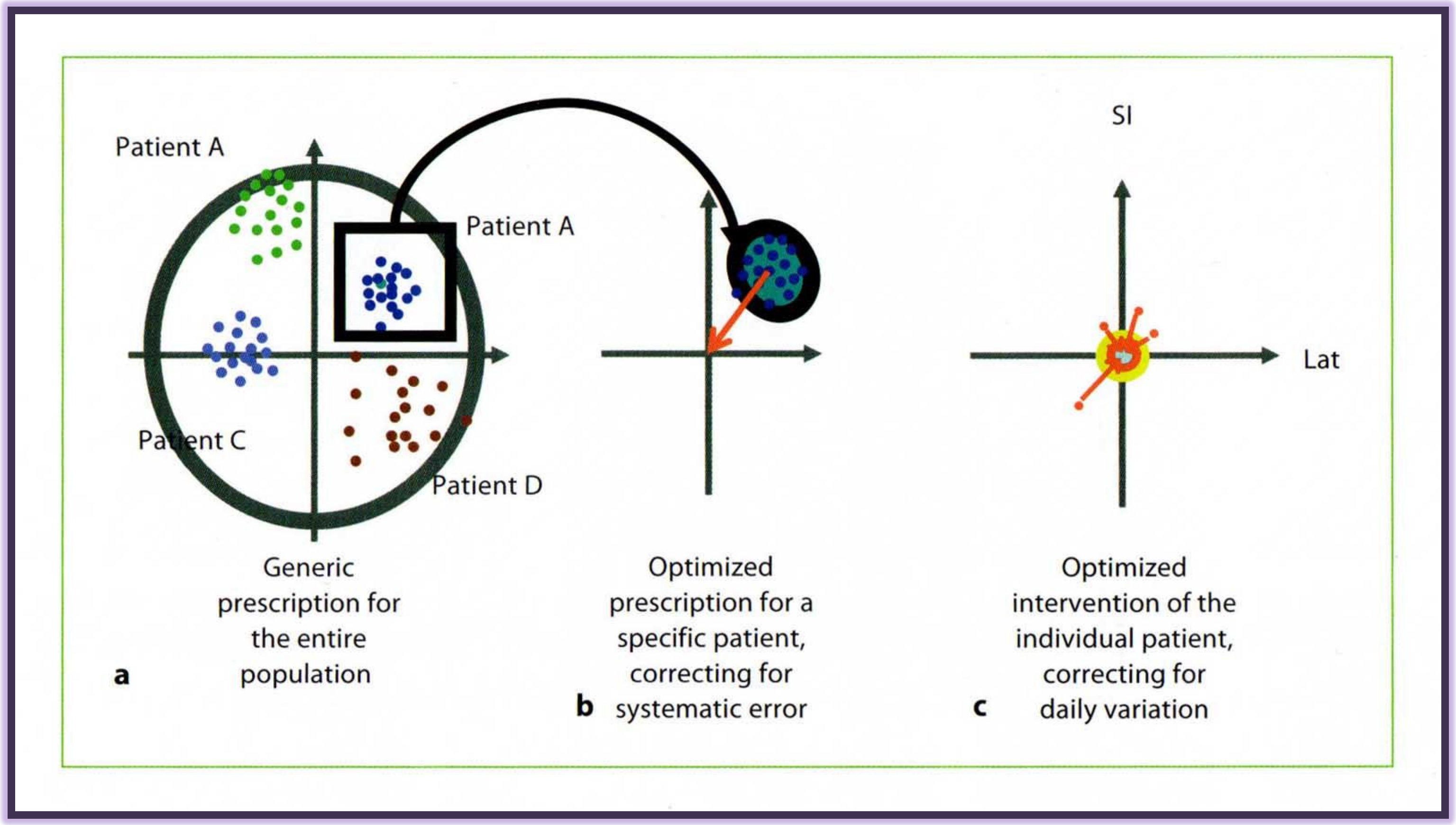
Technologies on Linacs

- Electronic portal imaging … MV … 1980s
- Multi-leaf collimator … 1990s
  - IMRT
- Cone-beam CT … kV or MV … 2000s
  - IGRT
- Digital/solid state controls
  - Improved stability
  - "Golden" data sets
    - 2000s

http://abrahao-radiologia.blogspot.ca/

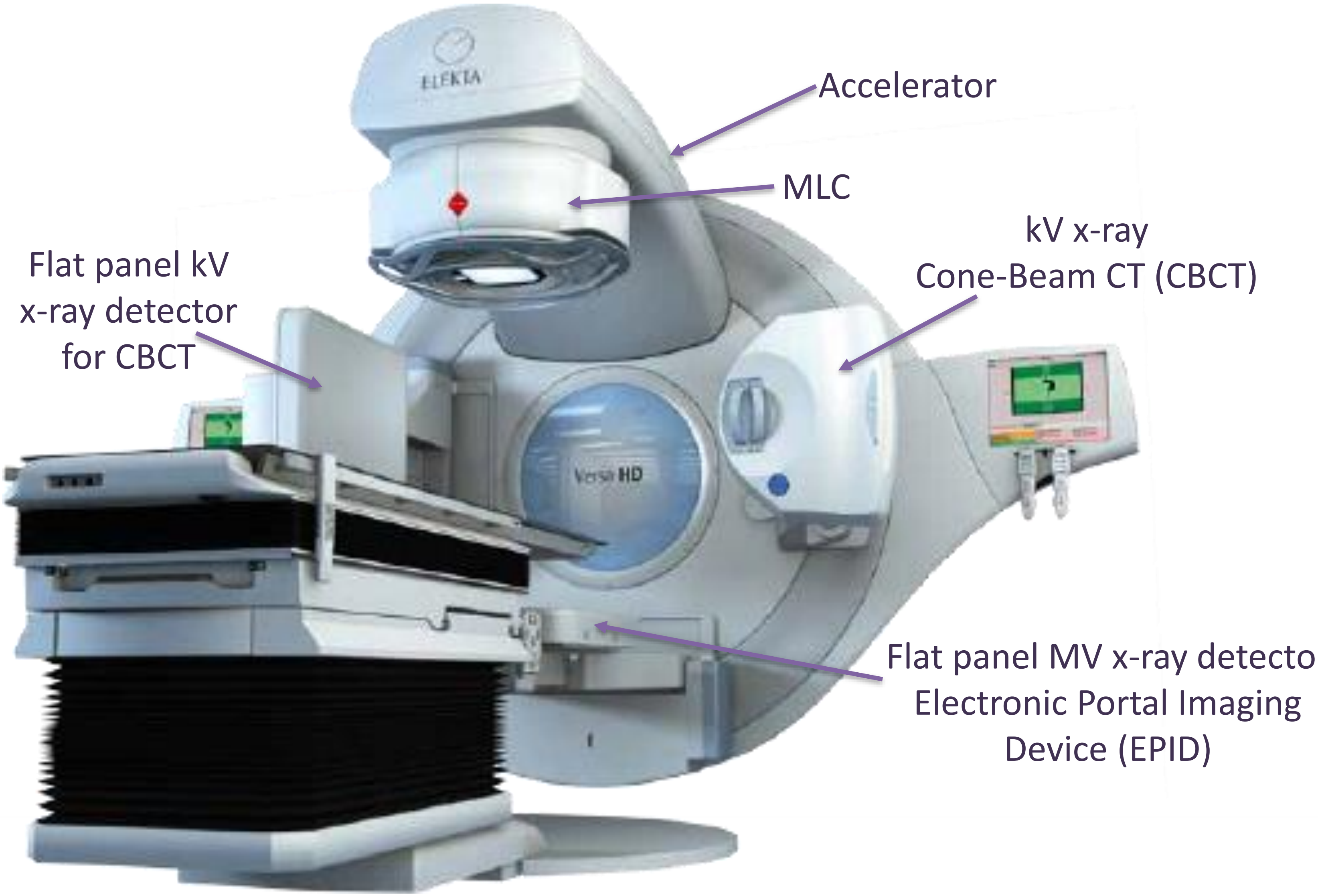
Daily Treatment Set-up

- Image-guided radiation therapy (IGRT)



Meyer *et al*, Front RT & Oncol. 40:10; 2007

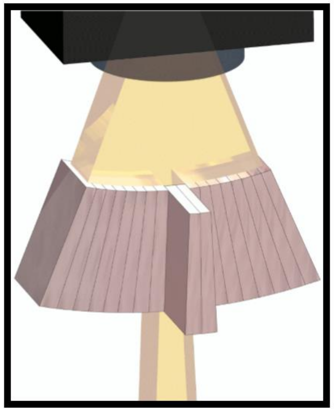
Linac with IMRT & IGRT … today

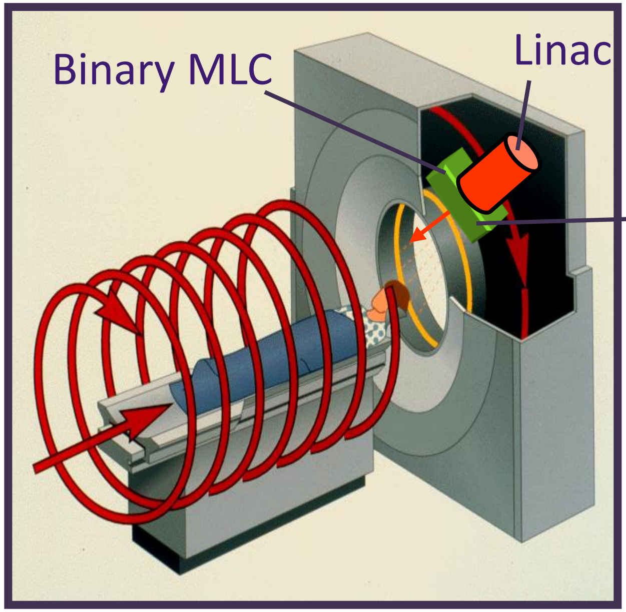


TomoTherapy … 2003

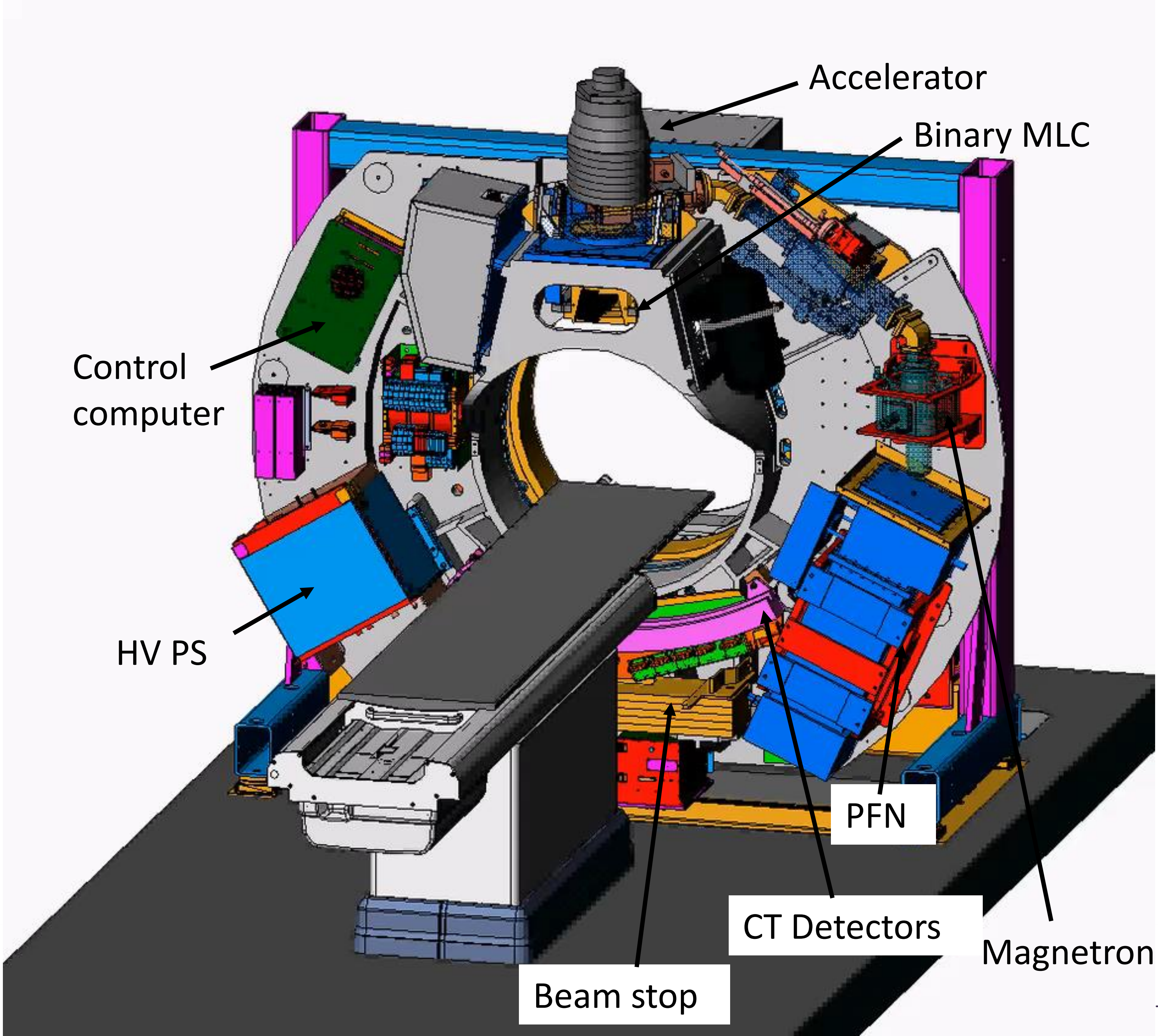
- One of 1st 3 prototypes in London, Canada
- On-board CT guidance
- Helical imaging … fan beam … MV CT
- Helical delivery … fan beam … Binary MLC

Fan beam





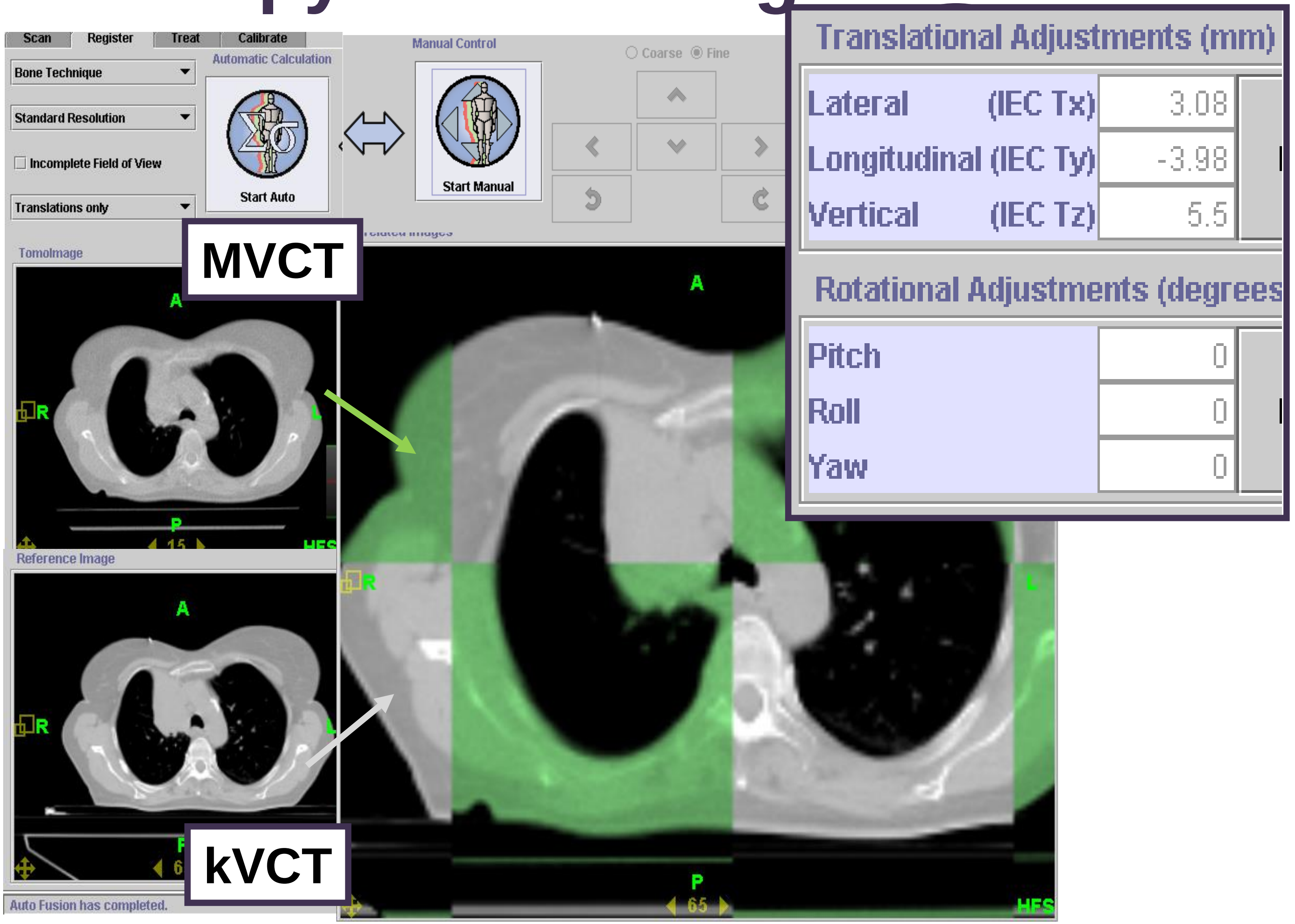
Binary MLC


Accelerator
Binary MLC
Control computer
HV PS
PFN
CT Detectors
Magnetron
Beam stop

TR Mackie

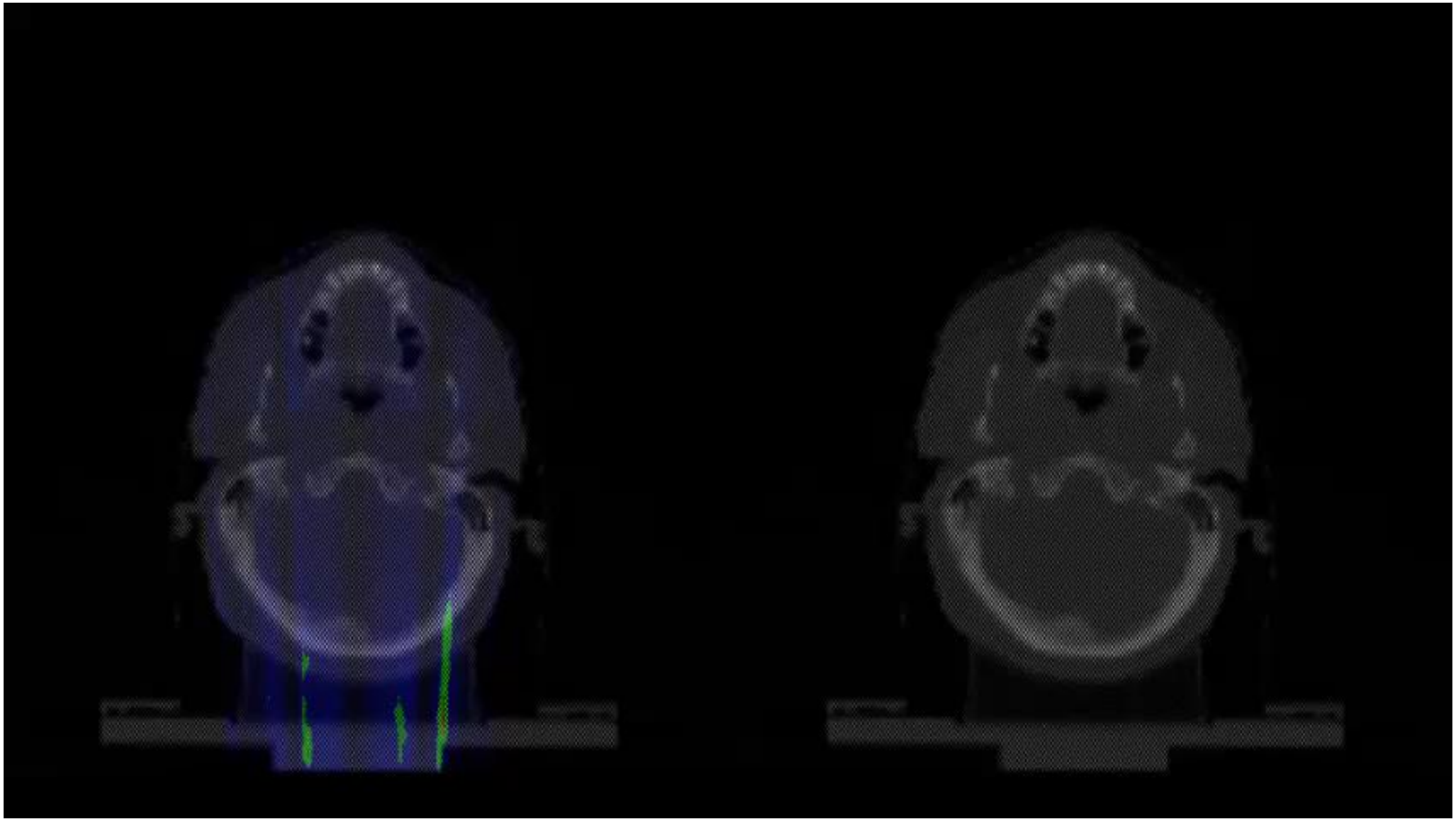
Tomotherapy MV CT Image Guidance

Manual alignment or grey scale alignment with **mutual information** algorithm



HT Simulation: Head and Neck

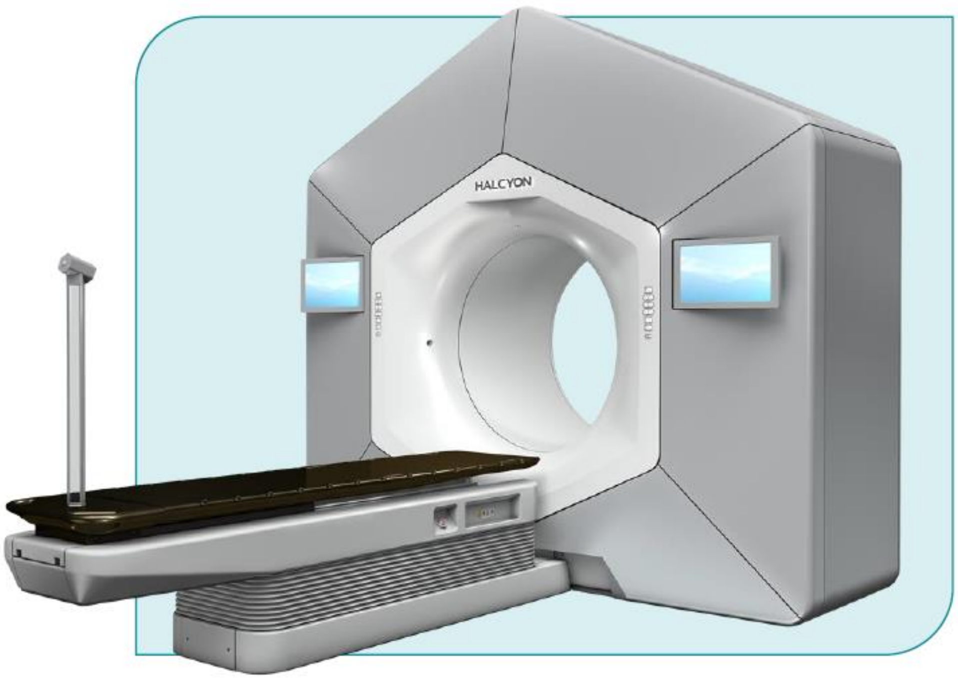
Dose Rate | Total Dose

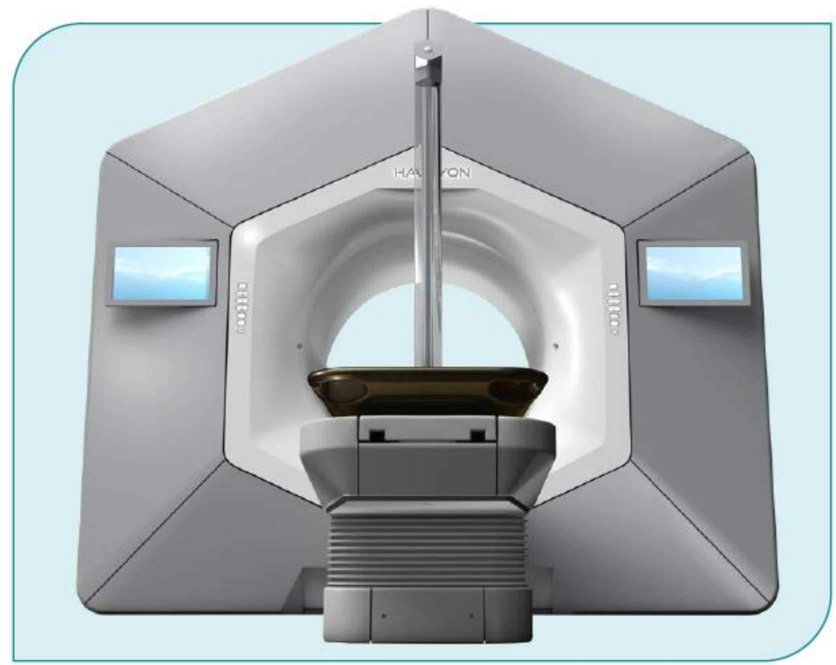


TR Mackie

0 to 30%	30 to 90%	90 to 100%

Varian Halcyon … 2017





Courtesy Paritosh Ambekar, Varian

Varian Halcyon … 2017

TECHNICAL SYSTEM OVERVIEW

GANTRY	100 cm bore, linear-drive ring motor
STAND	Small footprint, no modulator cabinet, beam stopper
BEAM	6 FFF @ 800 cGy/min Cone beam … Max field size: 28 cm x 28 cm
COLLIMATION	New, patented dual-layer MLC
IMAGING	100% IGRT, ~15 second MV CBCT Optional kV CBCT
CONSOLE & CONTROL SYSTEM	Shared with TrueBeam™

Courtesy Paritosh Ambekar, Varian

Power Specifications

Power Specifications

Table 9: Supported Power Configuration Specifications

Specifications	
Input Voltage for 3 Phase AC Power[1]	380 V: 50/60 HZ[2] Or 400–480 V: 50/60 HZ
Maximum Power[1]	18 kVA[2] Or 15 kVA

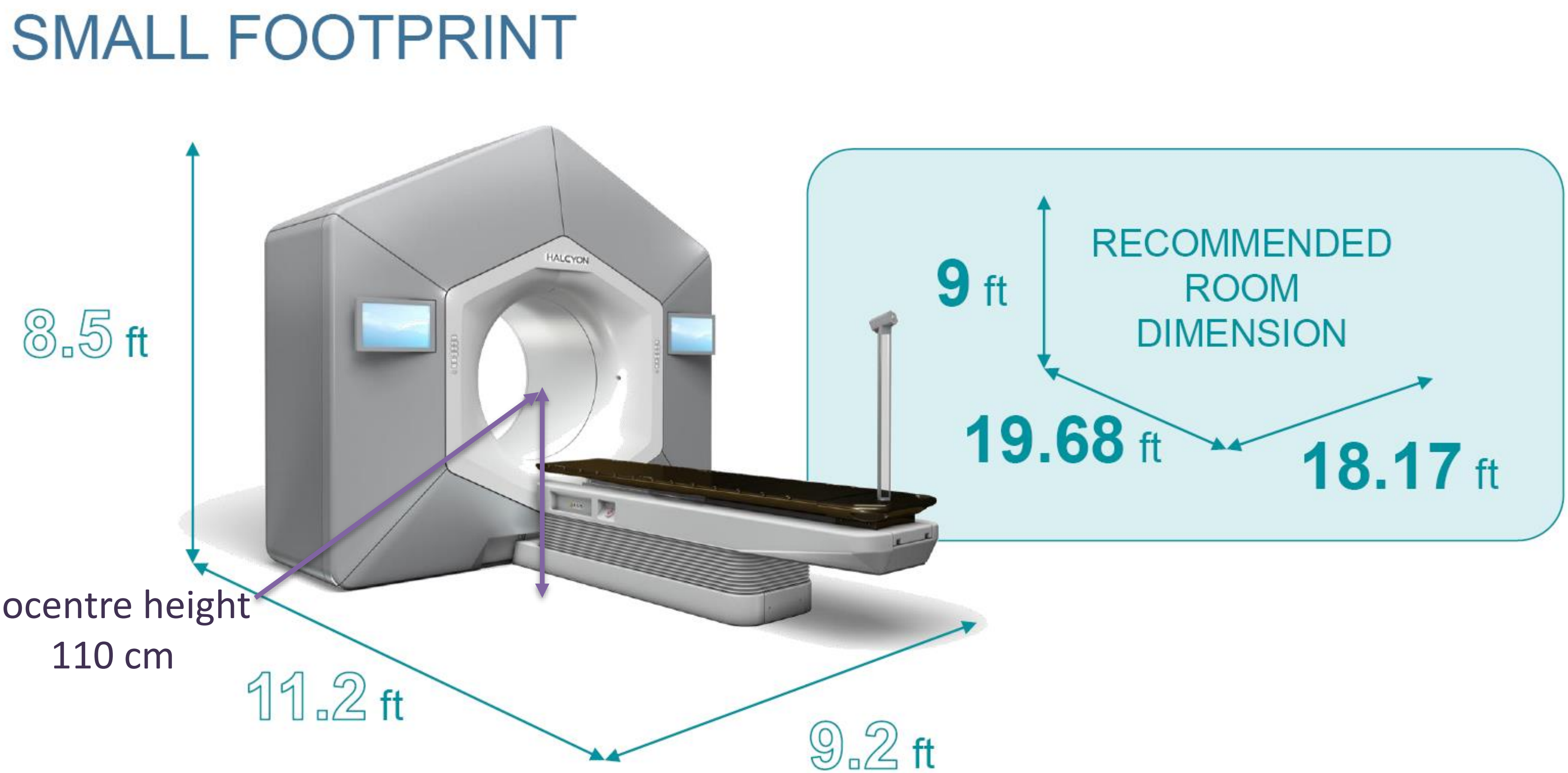
[1] Configuration depends on the country of use.

[2] Requires a transformer that will be included with the system.

Varian Halcyon … 2017

UC SD

Varian Halcyon … 2017

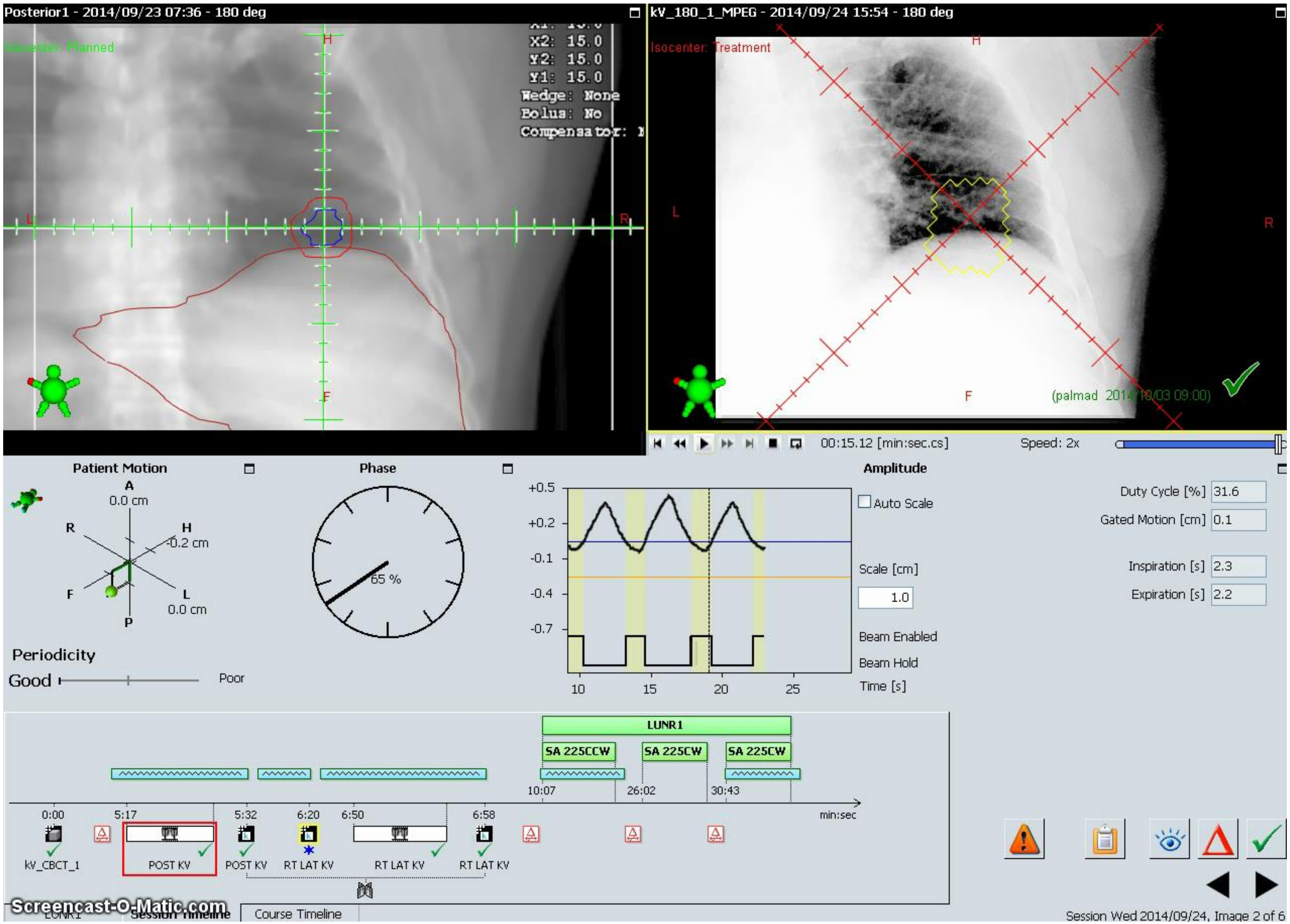


Isocentre height
110 cm

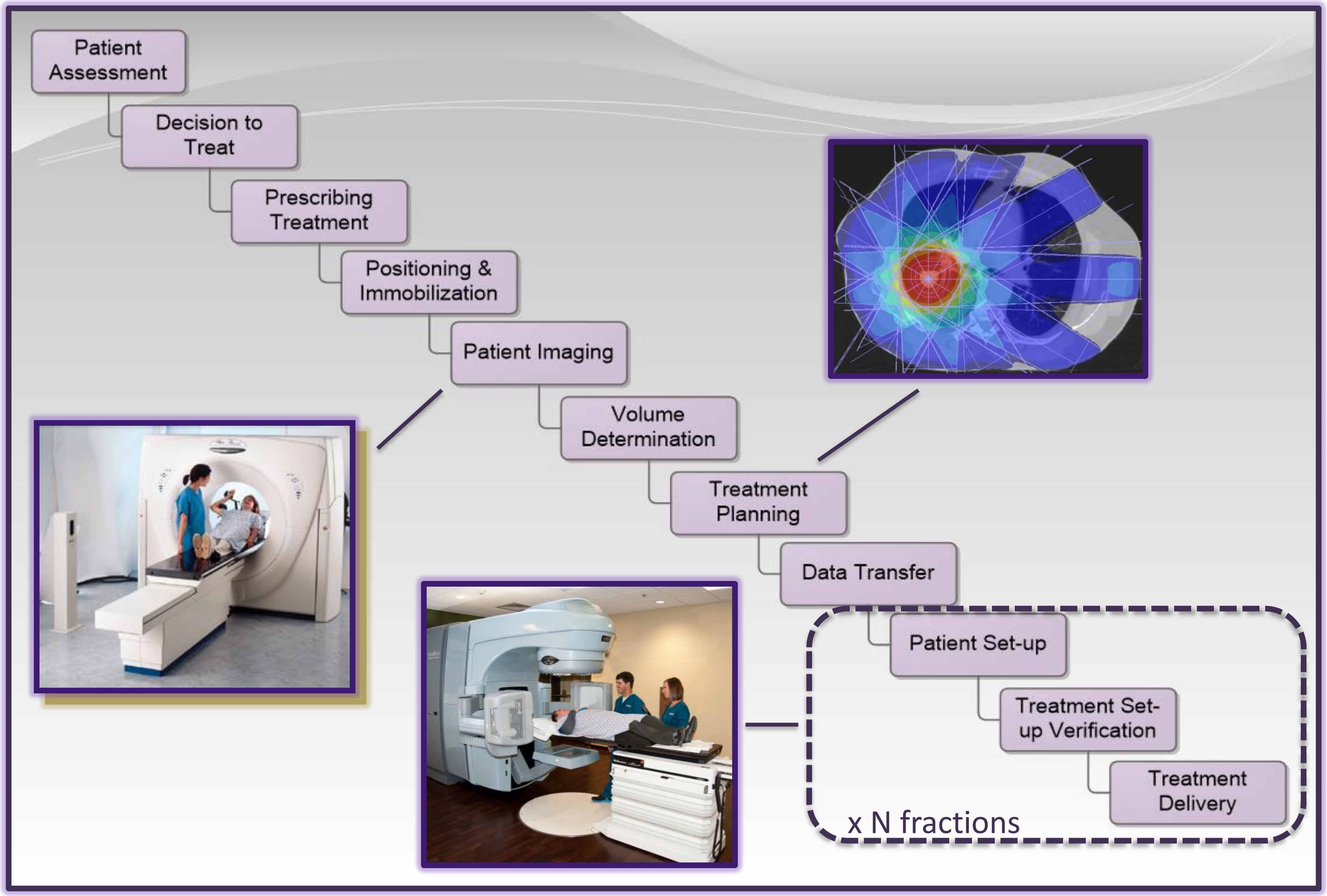
Bolted to floor, Pit dimensions
5’6” x 2’4.25” x 12” (W x L x D)

4D-CT based IGRT

Courtesy
Stewart Gaede



Stages in Radiation Treatment Process



Radiation Therapy Equipment

- Not only ‘treatment’ equipment, e.g., linacs
- Diagnostic equipment
- Patient immobilization
- CT-simulator
- Treatment planning system
- In-treatment room verification or image-guidance equipment
- Dosimetry and QA equipment

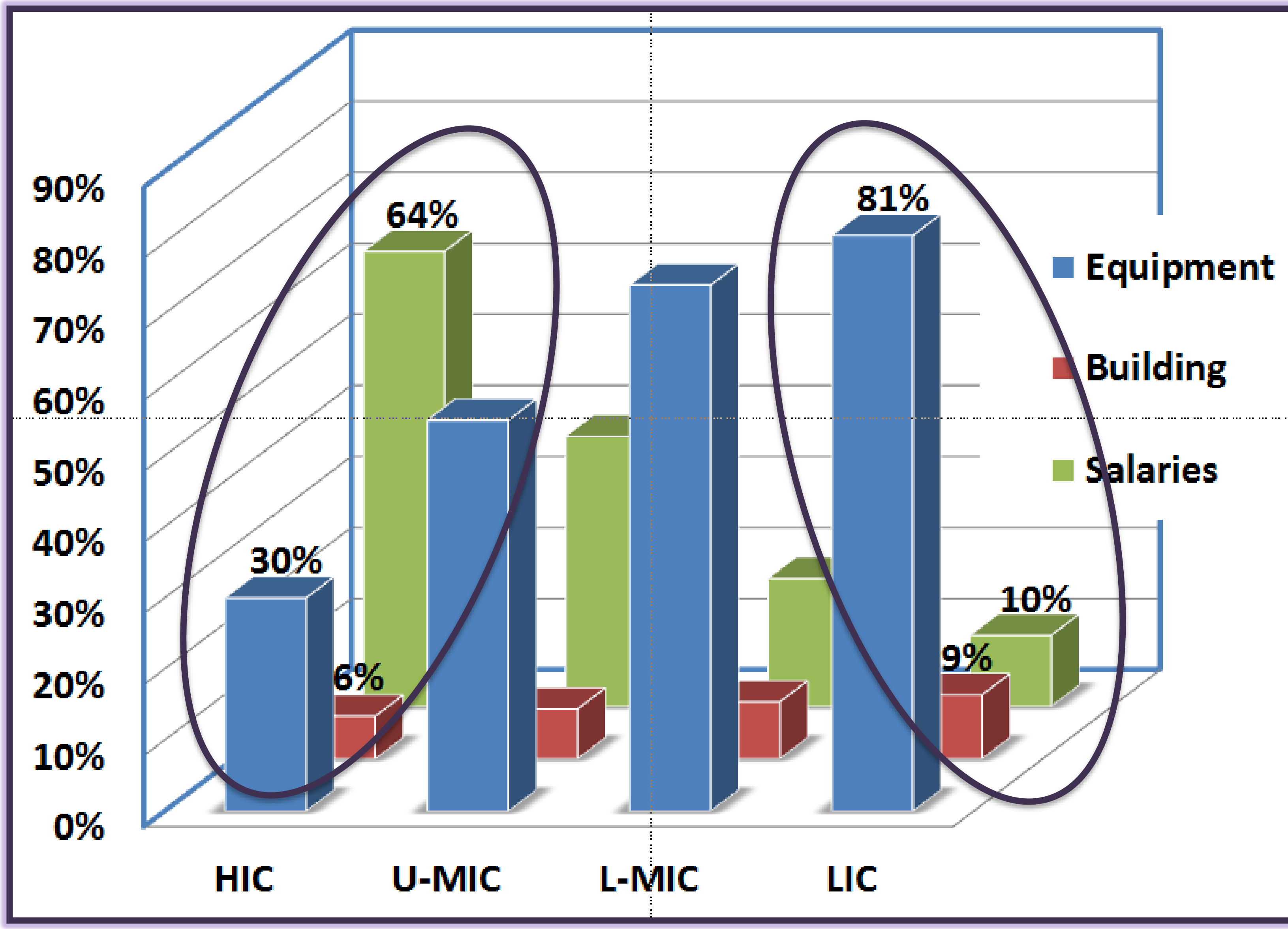
Cost Drivers

- Facilities

- Equipment

- Personnel

Relative Component Costs



Atun *et al*, Lancet Oncol 16: 1153-86; 2015

Trends Related to Technology Evolution

- Computer technology continues to evolve (>exponentially)
  - Daily imaging, real time optimization/adaptation, Monte Carlo dose calculations
  - More automated patient set-up/robotics
  - "Turnkey" installations
  - More hybrid, e.g., Linac + MR
  - Robust optimization accounting for uncertainties
  - More efficient commissioning & automated QC
  - More automated treatment planning
- Resource considerations and cost-benefit analysis
- Increased regulatory oversight … error reporting
- Increased use of radiobiological models
- Increased use of particle beams
- More hypofractionation (higher doses/fraction)