Technology Challenges of Commercial Medical Electron Accelerators

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Human Care Makes the Future Possible

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Aims of this talk

- Medical Radiotherapy is already a large and profitable business
- Well established as the standard of care, for certain cancers.
- New technology needs to prove itself against the successful history of improving practice.
- Challenges remain, but physics needs to reach across disciplines in order to displace establish clinical practice.

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The scale of medical accelerator business

- First systems date form the early 1950s
- Installed base of around ten thousand clinical accelerators.
- Roughly third of cancer patients treated with radiotherapy.
- Elekta treats around a third of these
- Elekta is a business with a turnover exceeding £1B.
- Both the need and the business case, require a global scale.

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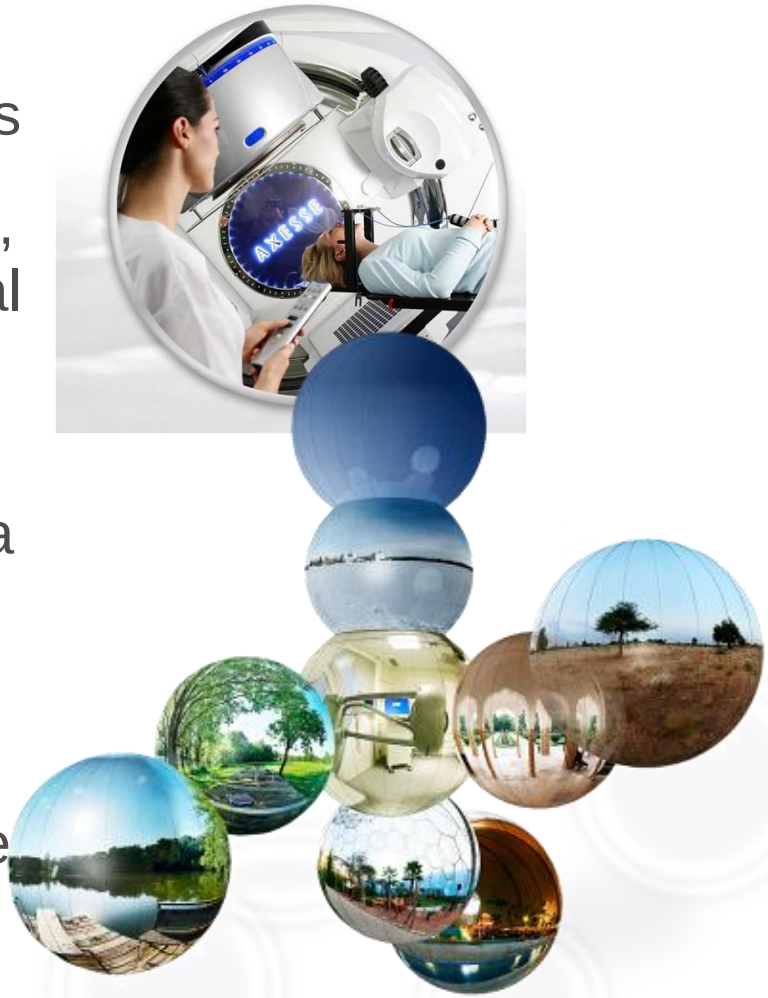
Why do will still have real technical demands?

- Accelerators require many disciplines
- Medical users, whilst knowledgeable, do not want exposure to the technical complexities
- Understanding both the domain and working across disciplines provides a constantly changing pallet of intellectual challenge
- Business success is clearly linked to innovation providing incentives to the owners to increase R&D funding



Key Requirements of Medical Linacs

- Small (i.e. fit though door) size
- Capable of producing X-rays between 4MV and 20MV
- Isocentric mounting
- Means of shaping the beam – MLC
- Accurate Dosimetry
- On-board Image guidance
- 10 - 15 year service life
- Reliable >98% uptime
- Safe for use on humans

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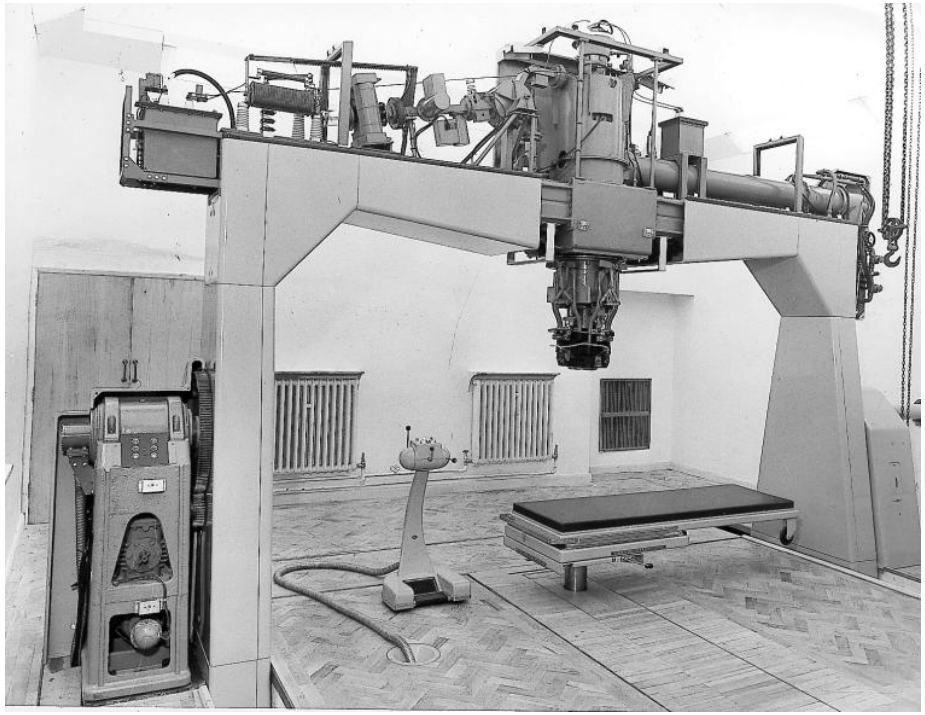
From Ising and Widerøe to an major business

- As physicists you all know the basis of particle accelerators

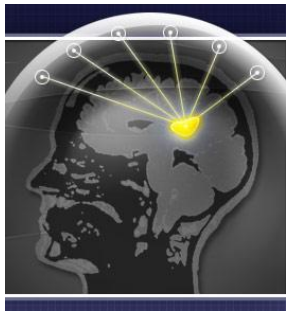
$$\mathbf{E} = -\nabla\phi - \frac{\partial}{\partial t}\mathbf{A}$$

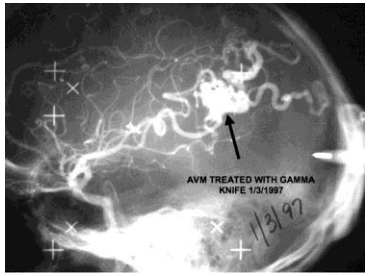


Although the physics has not changed the technology has been transformed

Reminder - Clinical basis of radiotherapy

- Radiotherapy is based on differential toxicity
  - Further enhanced by the development of fractionated radiotherapy
  - Typical of radiotherapy for cancer care
- Radiosurgery is based on the ablation of tissue.
  - Beams of radiation create a locally high dose of radiation.
  - Used as an alternative to surgery, not necessarily for cancer treatment.
    - E.g. AVM in brain
- The latest clinical techniques
  - based on some convergence in these two strands



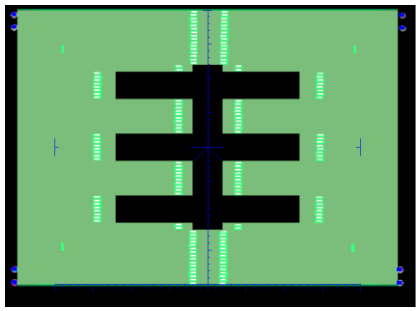


Translating the clinical need into product

- Fractionated radiotherapy
  - This requires a patient to attend daily for a few minutes of radiotherapy
  - This is very cost effective, as the patient can attend as an out patient
  - However 20 to 40 set ups place demands on workflow efficiency.
  - Managing 30 to 80 patients a day requires good organisation.
  - Software is key to managing this efficiently and safety.
- Hypo fractionated or single fraction radiosurgery.
  - Depends on the accurate targeting of tumour
  - Modern techniques have become ever more conformal
  - The key enable has been the multi-leaf collimator
  - As accuracy has increased so the for imaging to guide treatment has become vital.
  - Key success factors are dose escalation and controlling toxicity.

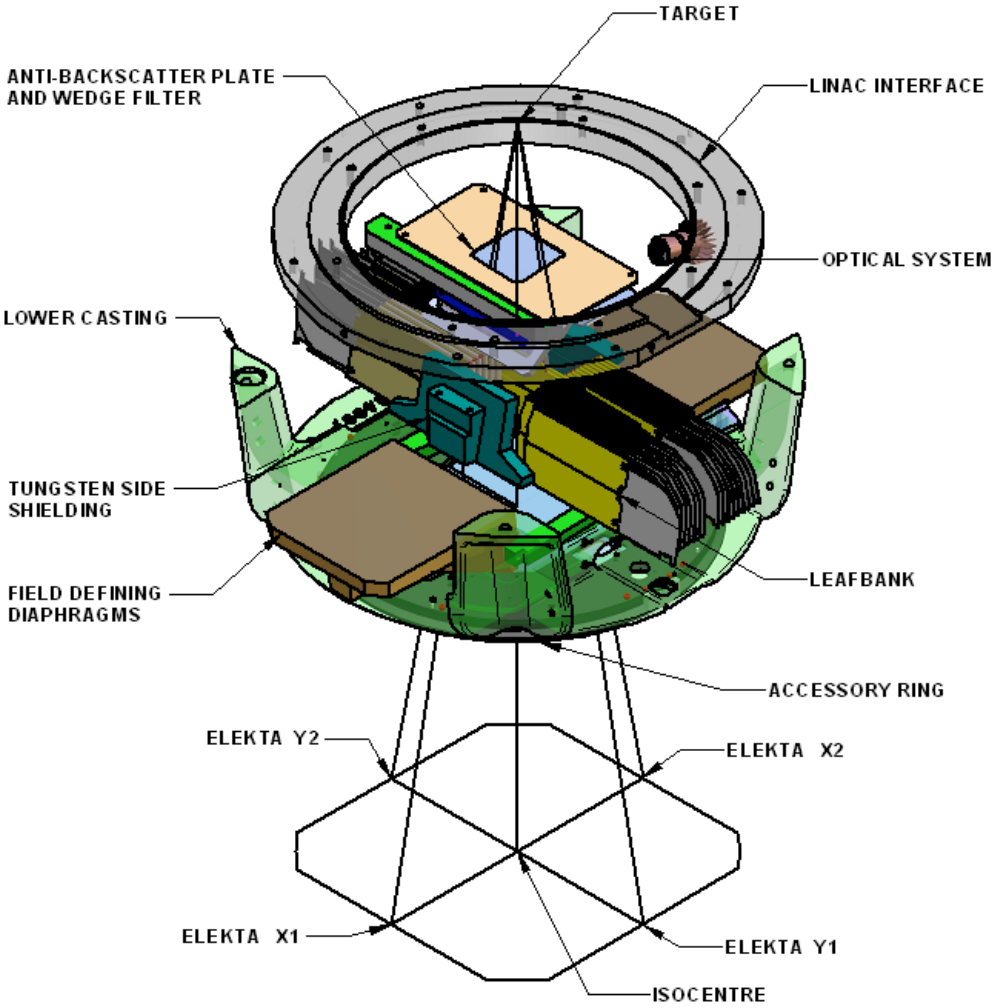
Why does radiotherapy require MLCs

- Multi-leaf collimator originated to replace metal blocks



- With computer technology the MLC leaves can be moved dynamically
- This allows much better dose distributions
- However the technology to do this is complex

Inside an MLC



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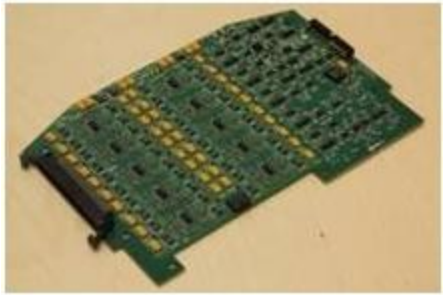
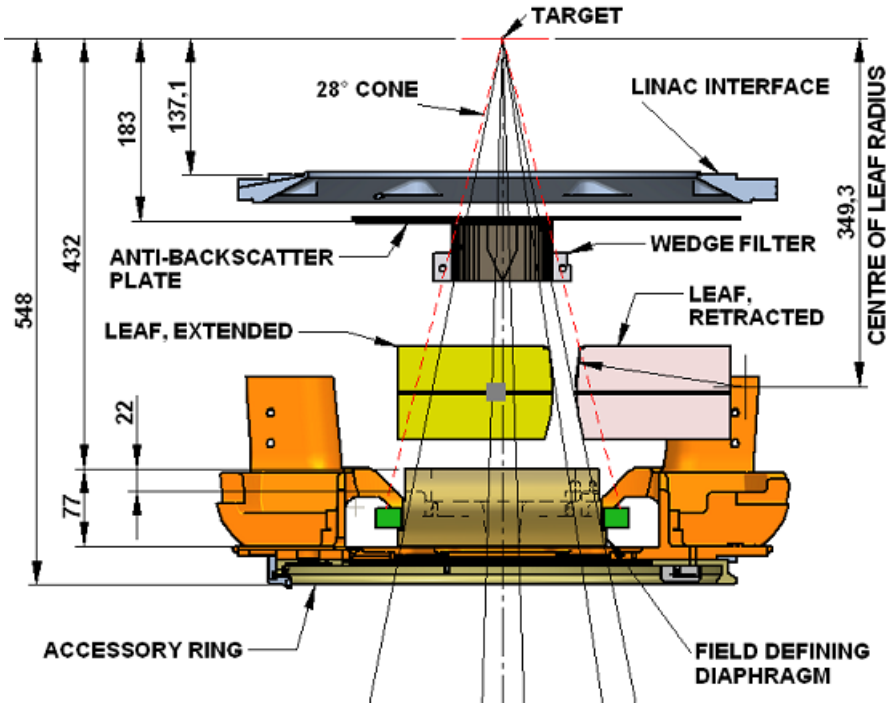
Technology Challenges

- 160 servo controlled motorised leaves
- Each servo motor drive need to fit on less than 8cm^2 of PCB
- Computer controlled, yet with safety critical software
- Developed with the rigor required for a medical device
- Radiation hard electronics
- Designed for manufacture more than 300 systems per year
  - Or nearly 50000 individual servo systems.



Agility geometry

- Leaves
  - 90 mm high, rounded leaves, offset focus
  - Move in conjunction with dynamic leaf guides (DLGs) to achieve 15 cm overtravel.
  - Interdigitation
  - Maximum speed of 6.5 cm/s (leaves (3.5) + DLG (3)).
  - Penumbra optimised for entire leaf travel



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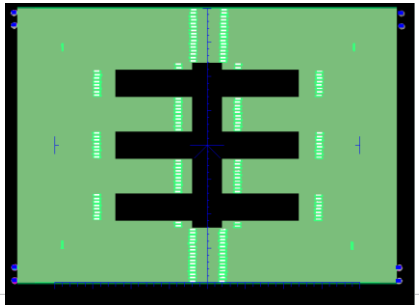
Optics based position control

- Using a single CCD camera it is possible to track all 160 leaves
- CCD sensitivity peaks at 1µm
- Reliable operation is achieved by illuminating the leave with UV light
- Small rubies on each leaf fluoresce in the infra-red and these show clearly on the CCD image.
- Design allows high contrast illumination without patient glare



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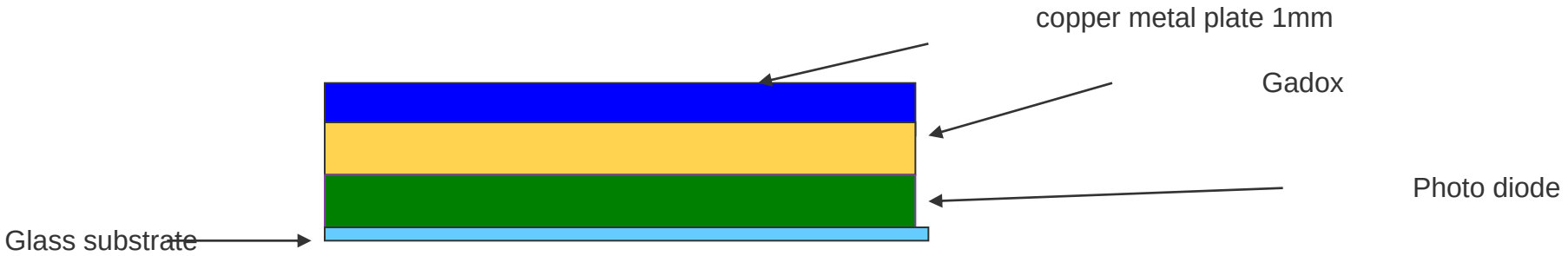
Imaging

- As treatments become more conformal the need “see” the target becomes more important.
- Key enabling technologies have been amorphous silicon flat panel imaging devices and software to perform cone beam 3D reconstruction from multiple 2D images.

Perkin-Elmer 1640AL AMSI Detector



AMSI Detector Electronics

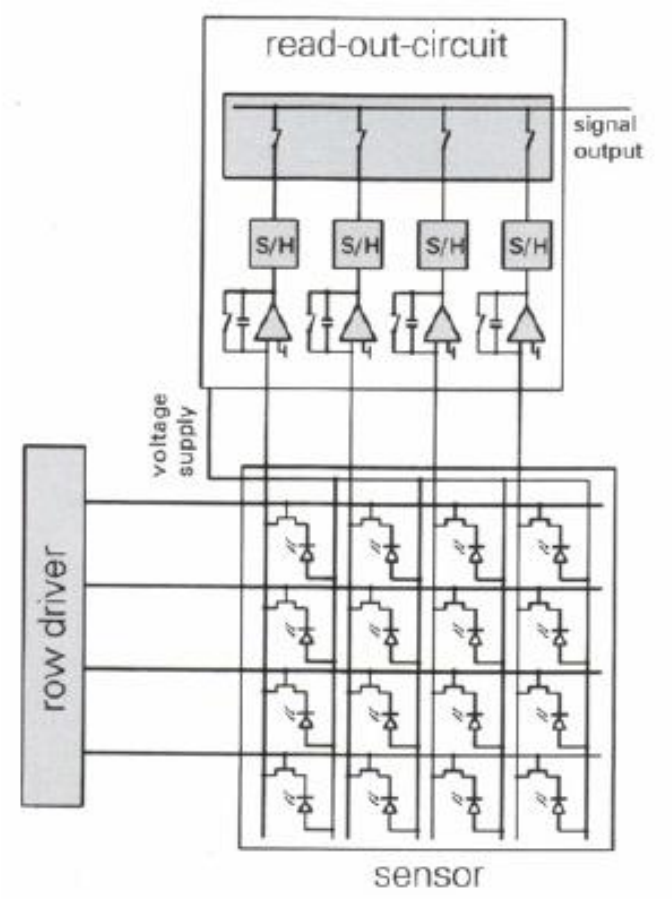
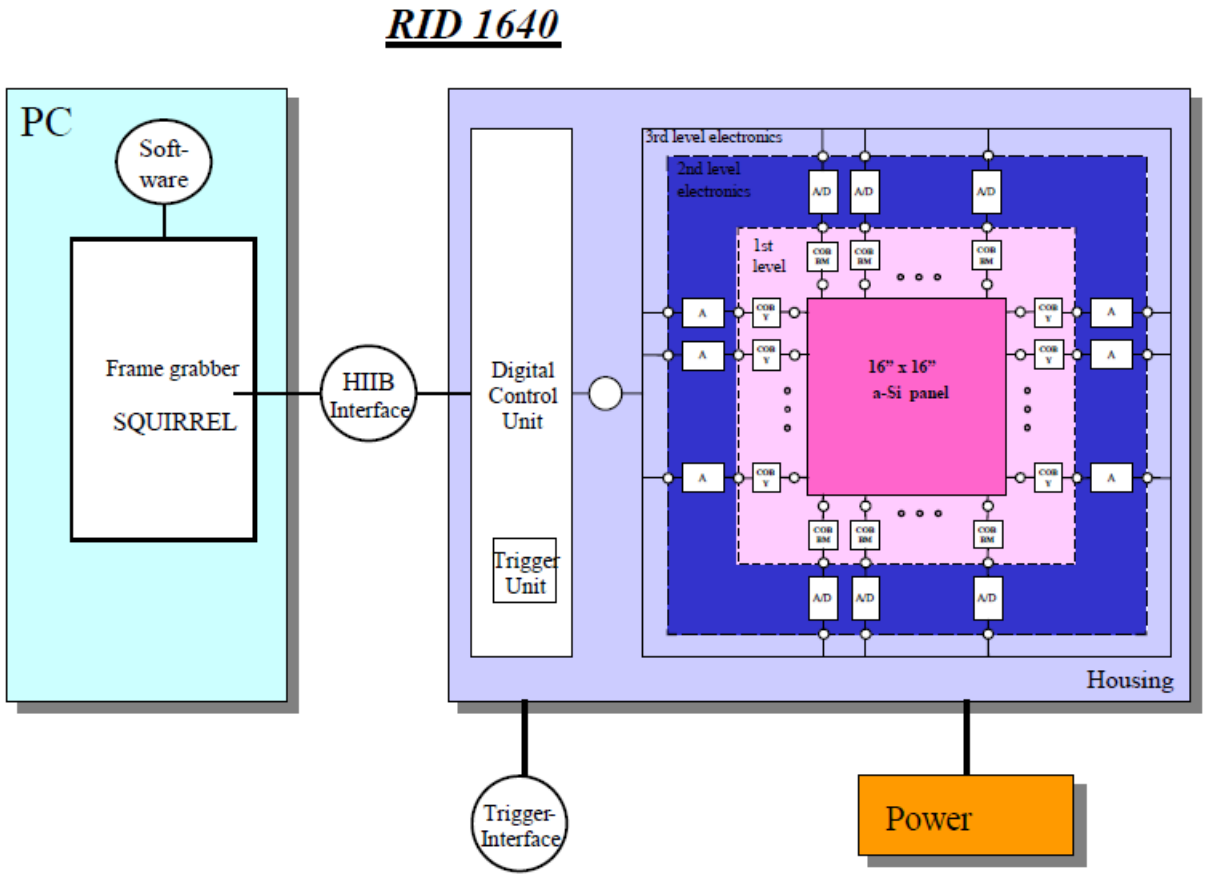


Fig. 1 Principle electronic arrangement of RID 1640

AMSI Panel Structure



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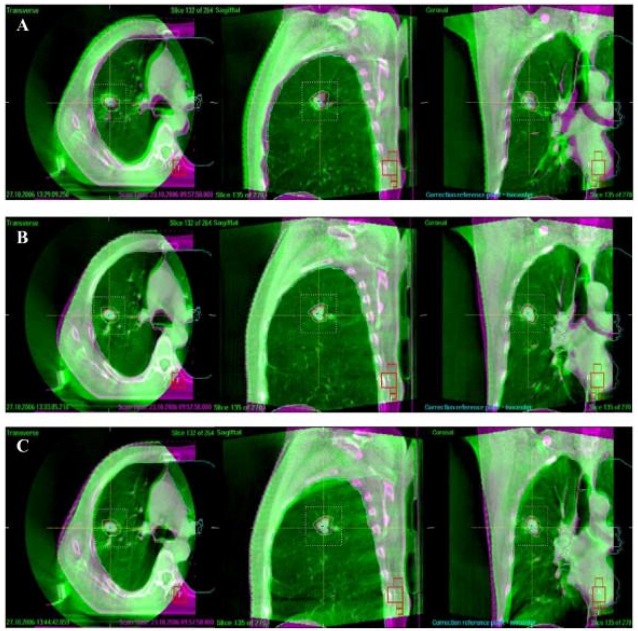
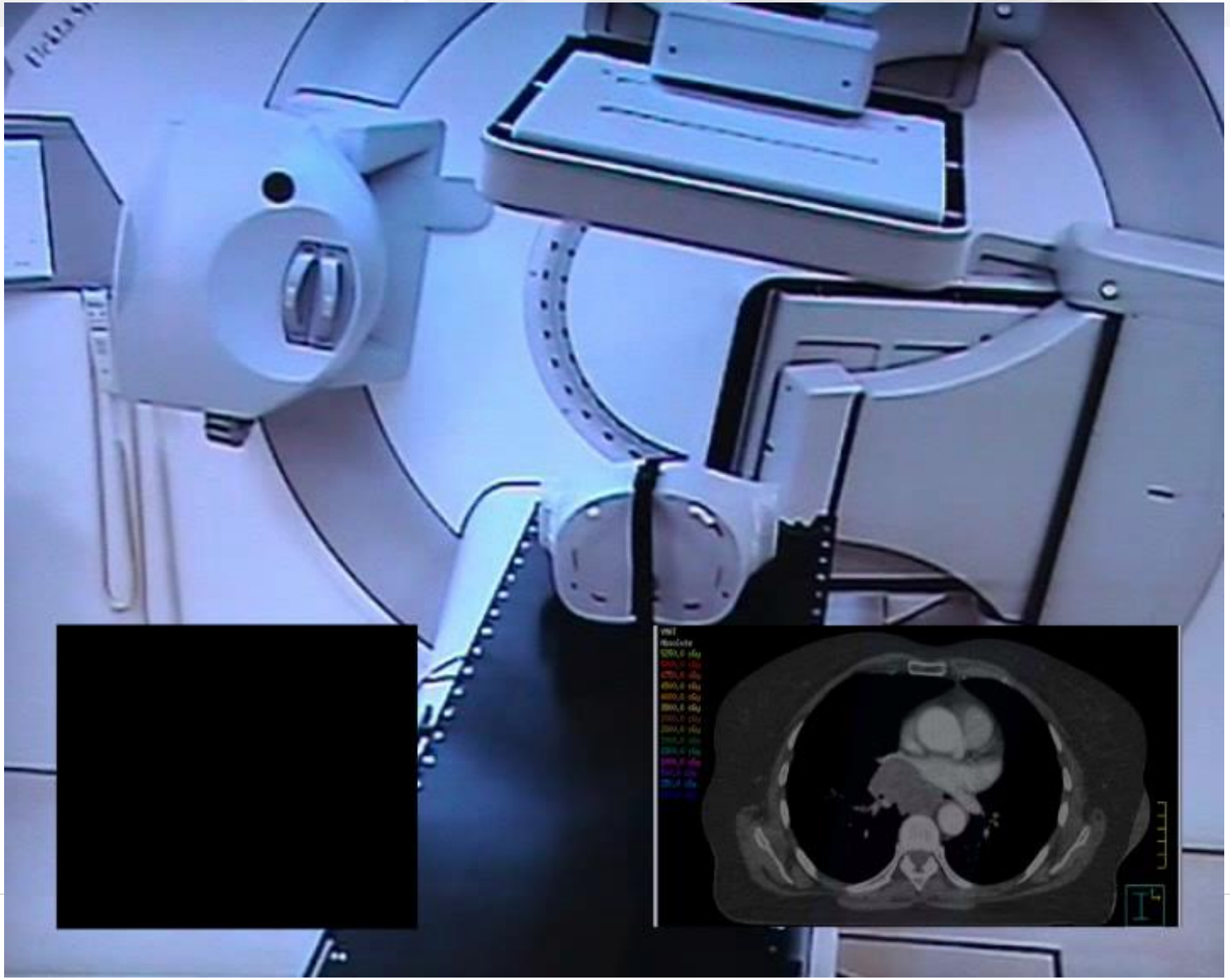
Imaging technology = IGRT of the last decade



- IGRT or image guided radiotherapy
- By taking images just before the radiotherapy can be directly guided by the patient’s anatomy
- The has already delivered real benefits to radiotherapy patients.

VMAT video



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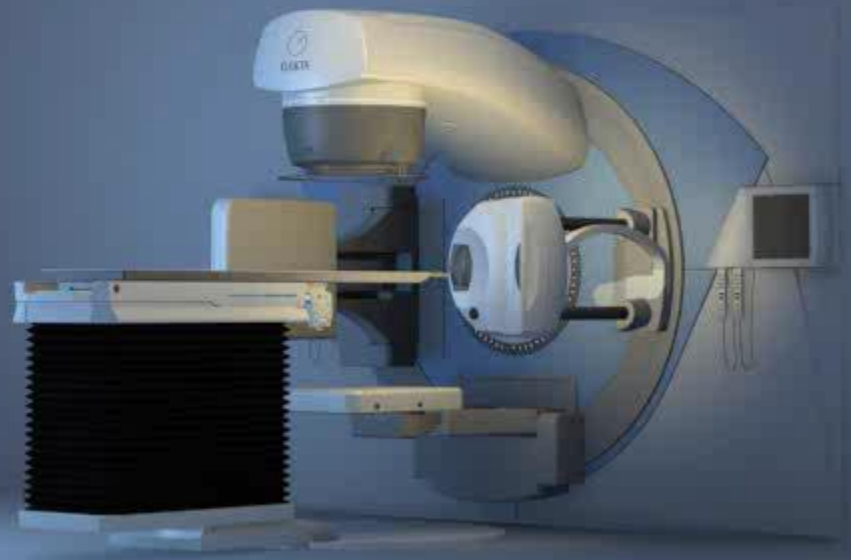

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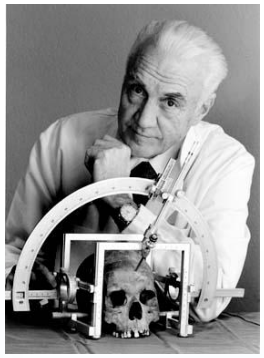
Efficiency

Elekta – technology is just a means not an end



Elekta Oncology

Elekta Software

Every year…

- Close to 1,000,000 patients receive treatment with radiation therapy and radiosurgery equipment from Elekta

Yet…

Yet radiotherapy is still massively under provisioned except in developed countries.

Every day…

- 100,000 patients receive diagnosis, treatment or follow-up that require Elekta's equipment.

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