Robust Technologies for RT: Systems Thinking

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Objective: Bring safe, high quality radiotherapy to the 12.5M cancer patients that will need it by 2035.

- Cost – not a problem.
- Value – not a problem.
- Methods – a problem.

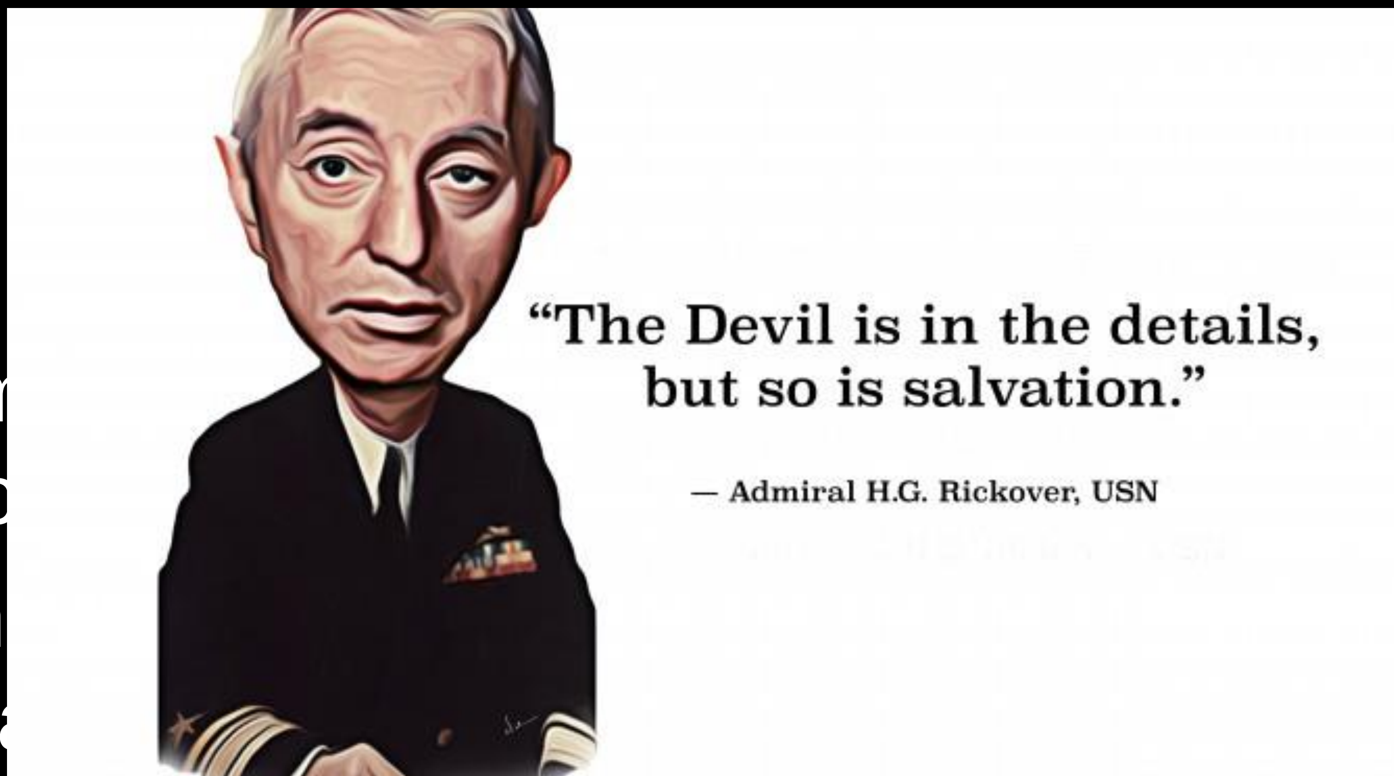
We know what we need to do,
we don't know how to do it.

The solution will require a diverse set of methods.

- Financial,
- social,
- and technological.

Encourage us to step back and take a ‘multi-scalar view’.

The design of a RT treatment machine affects the entire



- Em … s a glo…
- Th … he fina… derivatives wrt time).

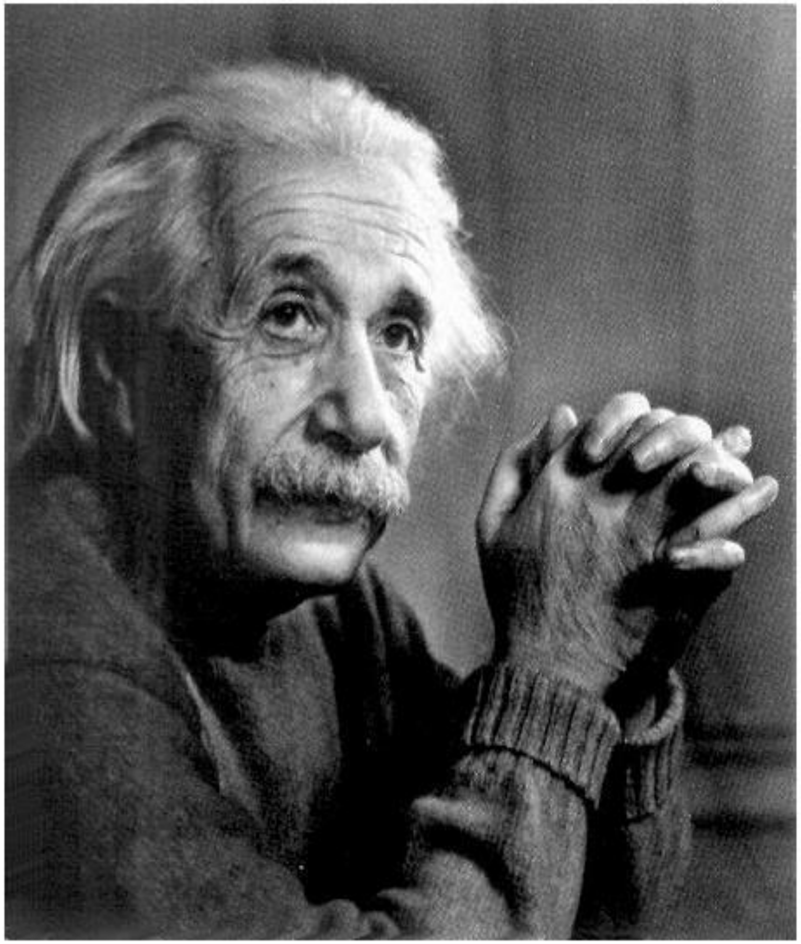
BOX 1.2 FOUR REVOLUTIONS THAT WILL TRANSFORM HEALTH AND HEALTH SYSTEMS

There are four revolutions currently underway that will transform health and health systems. These are the revolutions in: a) life sciences; b) information and communications technology; c) social justice and equity; and d) ***systems thinking to transcend complexity*.**

Source: *Frenk J. "Acknowledging the Past, Committing to the Future". Delivered September 5, 2008. Available at: http://www.hsph.harvard.edu/multimedia/JulioFrenk/FrenkRemarks.pdf*
Italics added for emphasis.

ed.: Don de Savigny and Taghreed Adam (2009).

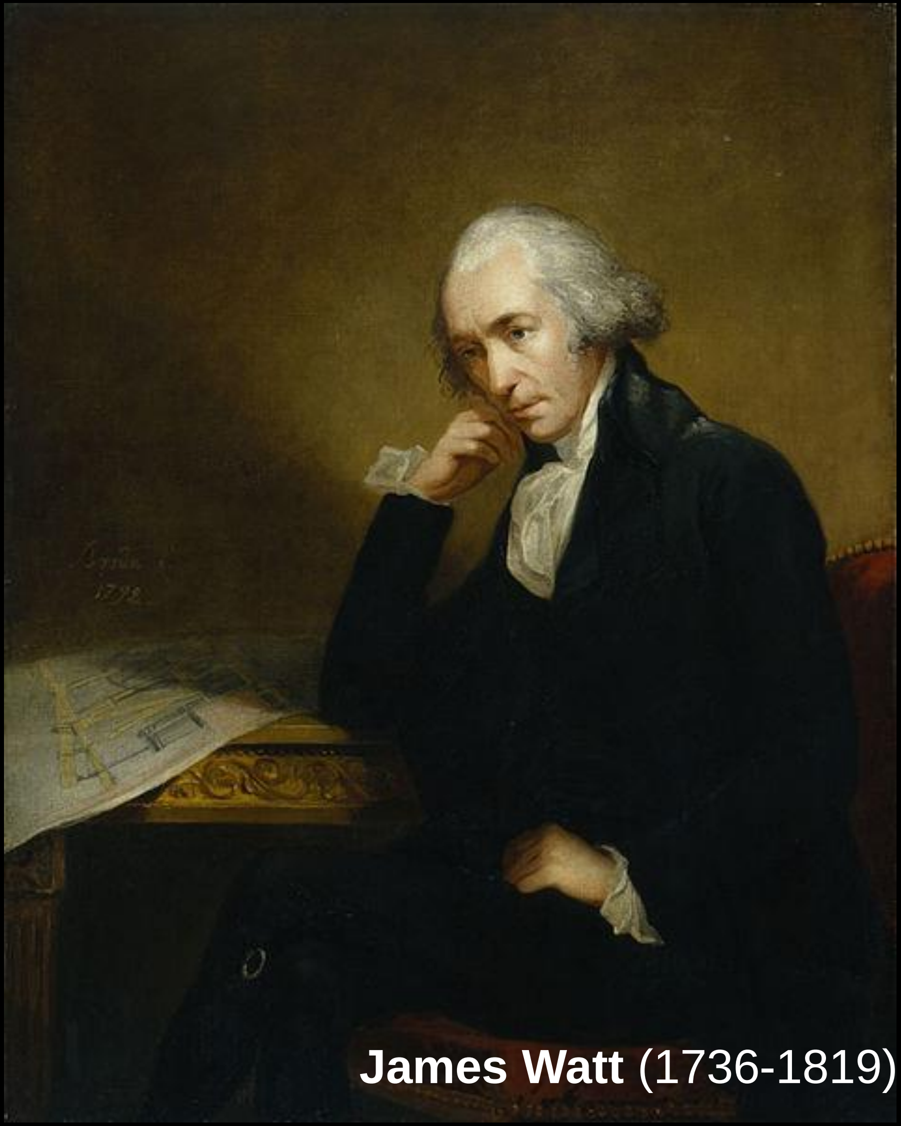
Burden of Complexity



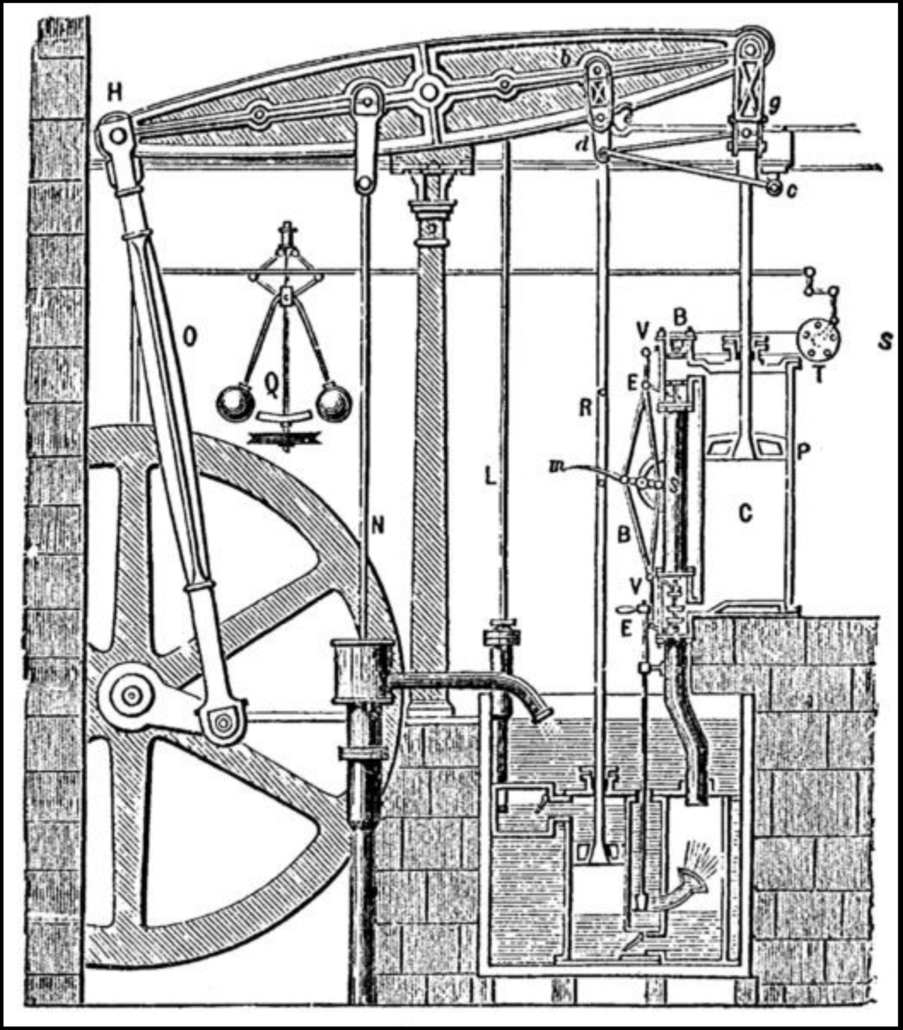
Things should
be made as simple as possible,
but not simpler.

Albert Einstein

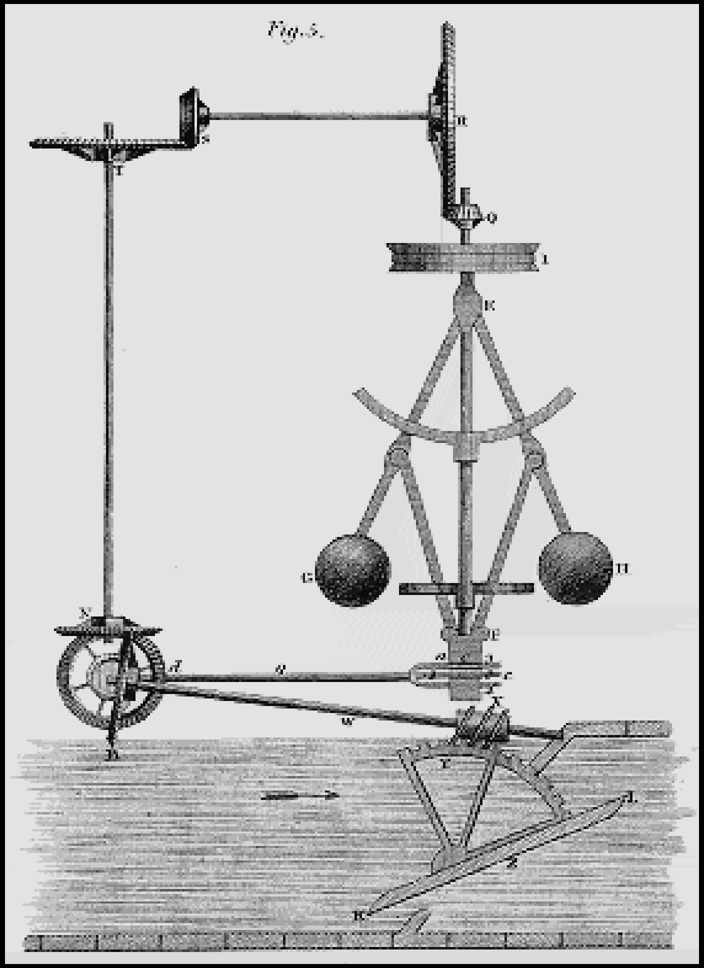
The Steam Engine



James Watt (1736-1819)



Complexity ‘Hide Thy Self’



Mr. Watt believed that throttling a steam valve by a human being was not the best way to maintain a constant speed of the steam engine.

The beginning of modern automatic control began, when James Watt in 1788 developed a mechanical device the flyball governor.

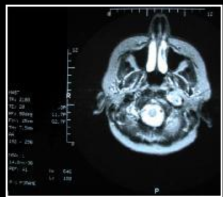
The flyball governor maintained the speed of the steam engine automatically by controlling the opening and closing of the steam valve.

Complexity Buried

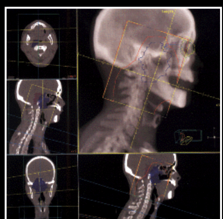
Objective: Bring safe, high quality radiotherapy to the 12.5M cancer patients that will need it by 2035.

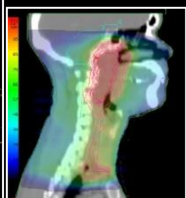
We will fail if we reduce this conversation to:
“How can we make a lower-cost linac?”

RT in Developed Nations is Very Complex



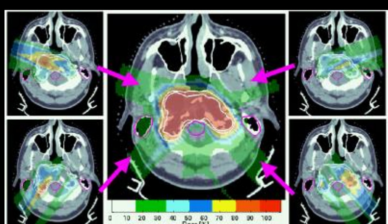
Diagnosis
Staging





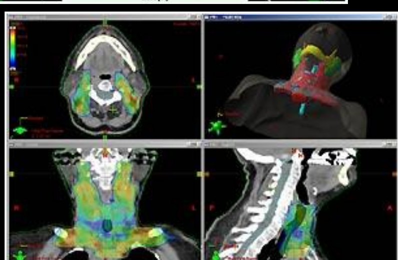
3D imaging
Target volume
Organ localization

Prescription
Segmentation

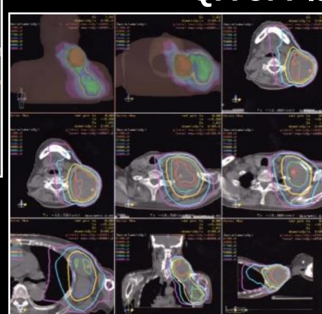


Dose calculation
Beam optimization

Beam shaping



QA of Plan



Plan Transfer

Treatment verification
Delivery

Monitoring
Clinical
Response

Follow-up

GTFRCC: Human resources to deliver RT the way we do it now.

2035	High-income countries	Upper-middle-income countries	Lower-middle-income countries	Low-income counties
Fractions	76 424 000	77 014 000	40 974 000	13 268 000
Radiotherapy departments	4600	3700	2000	600
Megavoltage machines	9200	7400	3900	1300
CT scanners	4600	3700	2000	600
Radiation oncologists to be trained	15 500	16 800	9900	3300
Medical physicists to be trained	17 200	12 500	7200	2400
Radiation technologists to be trained	51 900	45 300	24 900	8100

215,000 Radiation Therapy Professionals need to be trained by 2035.

Atun et al., Lancet Oncology 2015

GTFRCC: Key Assumption.

Infrastructure in place to support safe and effective RT technology deployment.

Including diagnostics, procurement, power, service, training, regulatory.

If we were going to a build a new machine, what could we include to address these assumptions and dependencies?

Principle #1: You can’t treat it if you can’t locate it.

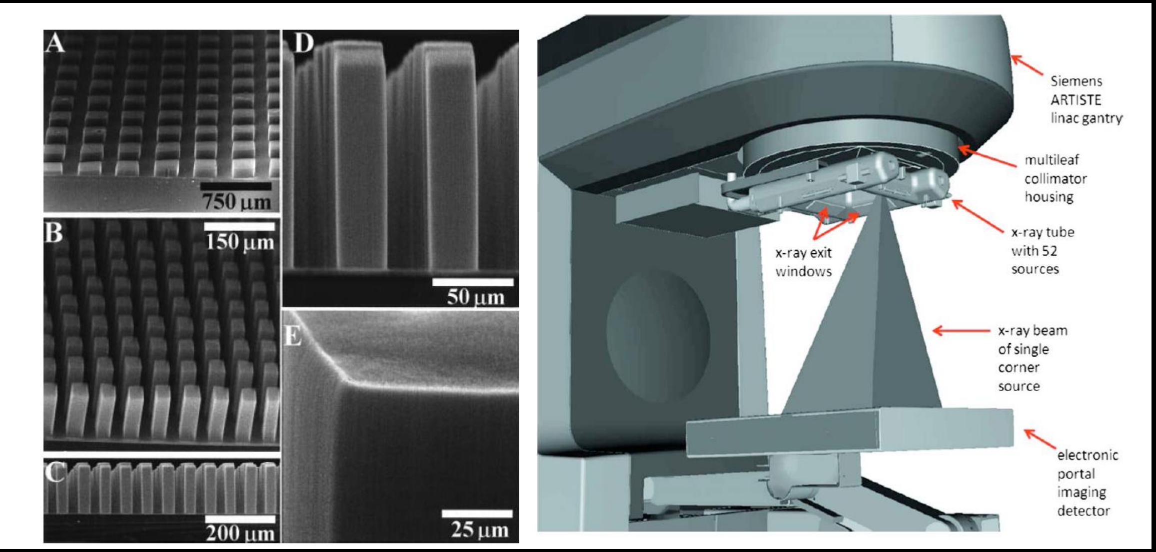
- Need to be able to diagnose and delineate the RT target and surrounding normal structures.

If you don’t get this right, the treatment will fail and waste precious time, money, and lives.

Technological Trends: Imaging

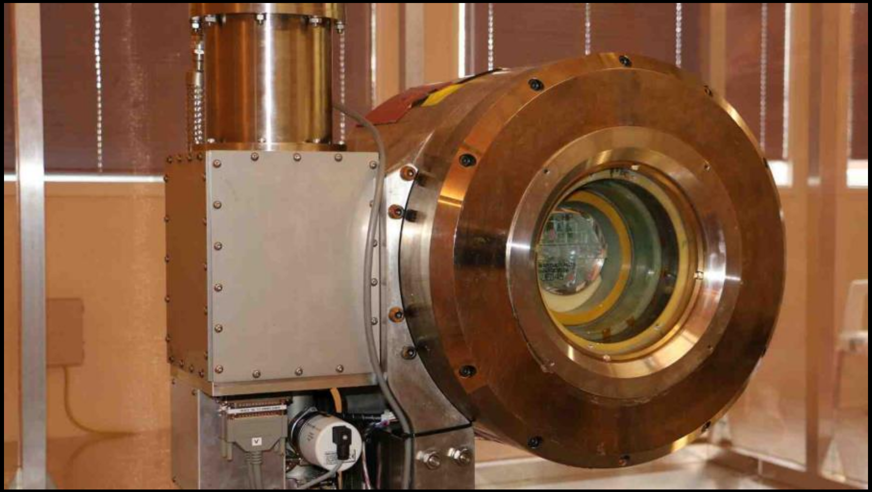
- Need: accurate geometry, reasonable cost, reliability, robust in environment, ease-of-use, automated, quality assured.
- Have:
  - Current CT: Too many moving parts; built for cardiac, sold for cancer; driven by marketing. Tube costs alone - $1/slice. Slip rings, air handling, compute resources – all for cardiac…
  - MR: Very simple technology – beautiful physics; made ugly by humans; made expensive by industry; need to address geometry

Example Technologies



No moving parts. Addressable x-rays sources: Carbon nanotube (CNT) field-emission electron source.

De Heer WA et al – Science 270 (1995)



Using a high temperature superconducting (HTS) magnet based on YBCO wire, and are currently researching opportunities for both higher field / smaller bore magnets and lower field / larger bore magnets utilising MgB2 and Nb3Sn.

http://www.victoria.ac.nz/robinson/research/magnet-systems

Principle #2: Treating poorly is worse than not treating it all.

- Radiation therapy is a balance of the ‘therapeutic ratio’ – it must operate within a tightly defined band of uncertainty.
- Else: severe side effects, loss of opportunity for cure.

If you don’t get this right, the treatment will fail and waste precious time, money, and lives.

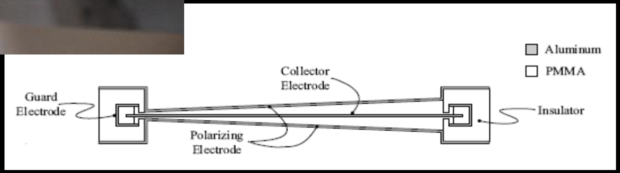
Technological Trends: Machines

- Need: dose control, spatial gradients, dose rates, depth penetration, cost, reliability, robust to environment, ease-of-use, automated, quality-assured.
- Have: Complex multi-purpose machines, unused features, wasteful power consumption (Bmag, water pumps, HT, inefficient, heat generating), not ‘smart’, over-built, dis-integrated safety systems.

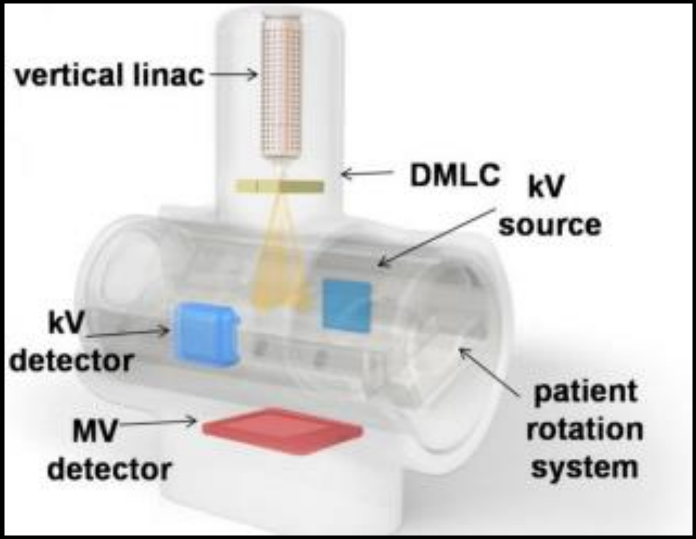
Could we put as much effort into making the systems robust, as we put into adding new features?

Example Technologies

Integrated energy fluence field monitoring system.
>Dosimetric checksum of dose and field shaping systems.



Islam et al. Med. Phys. 2011

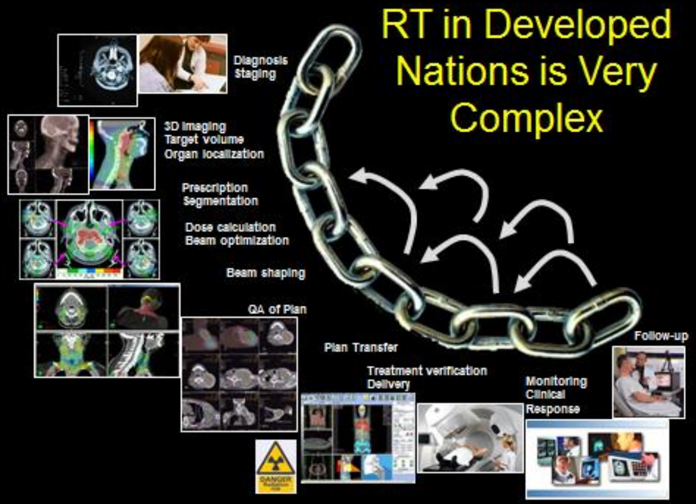


NanoX radiotherapy system design including fixed linac and patient rotation system.
>Significant construction cost savings.

Keall et al. http://dx.doi.org/10.1594/ranzcr2014/R-0142

Principle #3: Waste and errors are at the boundaries.

- Automation, integrated education tools, safety by design, bury the complexity.



If you don’t get this right, the treatment will fail and waste precious time, money, and lives.

Innovation for Efficiency: Technology, Processes, Purchasing

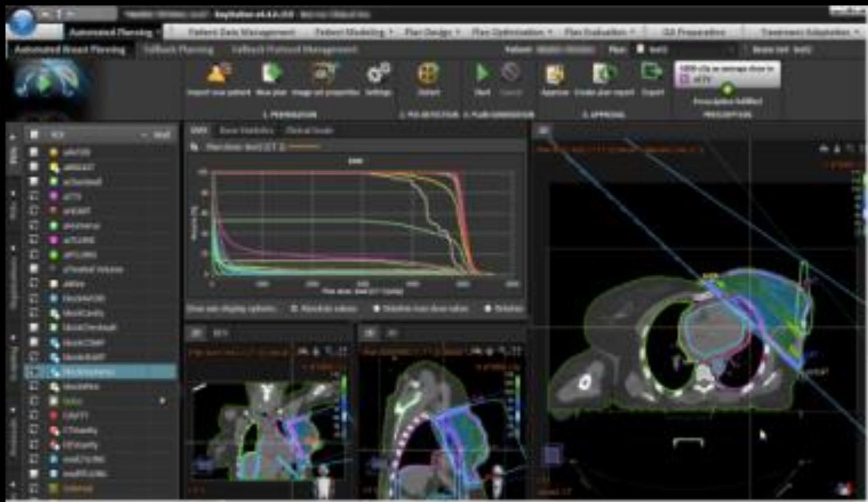
	Operating cost per fraction: sensitivity analysis			Cost savings relative to base scenario			
	Automation: efficiency	Longer hours	Bulk purchase	High-income countries	Upper-middle-income countries	Lower-middle-income countries	Low-income countries
Combination 1	X	..	..	25%	21%	21%	21%
Combination 2	..	X	..	13%	18%	23%	25%
Combination 3	..	..	X	8%	16%	21%	23%
Combination 4	X	X	..	33%	34%	39%	40%
Combination 5	..	X	X	19%	34%	38%	42%
Combination 6	X	..	X	31%	34%	38%	39%
Combination 7	X	X	X	37%	43%	51%	53%

The operating cost model allows for improved efficiency, longer treatment hours per day, and bulk purchasing savings. These factors can occur alone or in combination, resulting in seven different combinations. X shows the inclusion of a factor in the sensitivity analysis.

***Table 3*: Sensitivity analysis to determine operational costs**

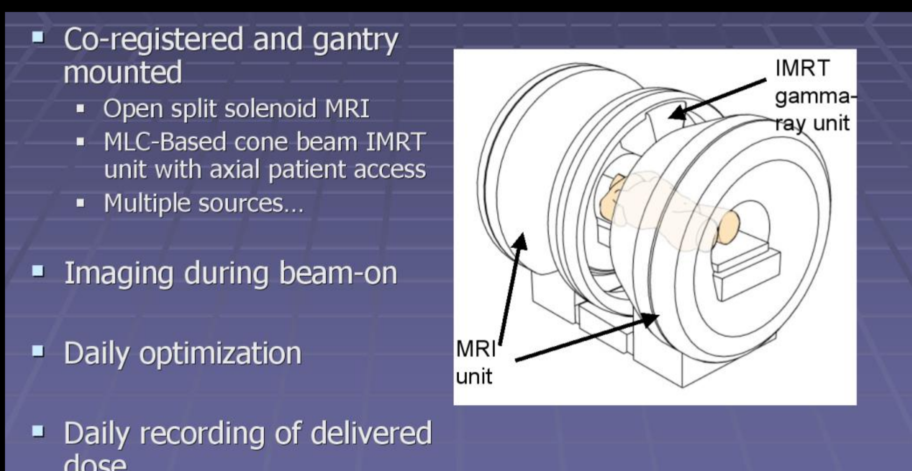
Capacity for significant savings while maintaining quality.

Example Technologies



Software systems that automate the treatment planning process AND improve plan quality.
>Planning from 4 hours to 4 min.

Purdie et al. - Int J Radiat Oncol Biol Phys. 2011



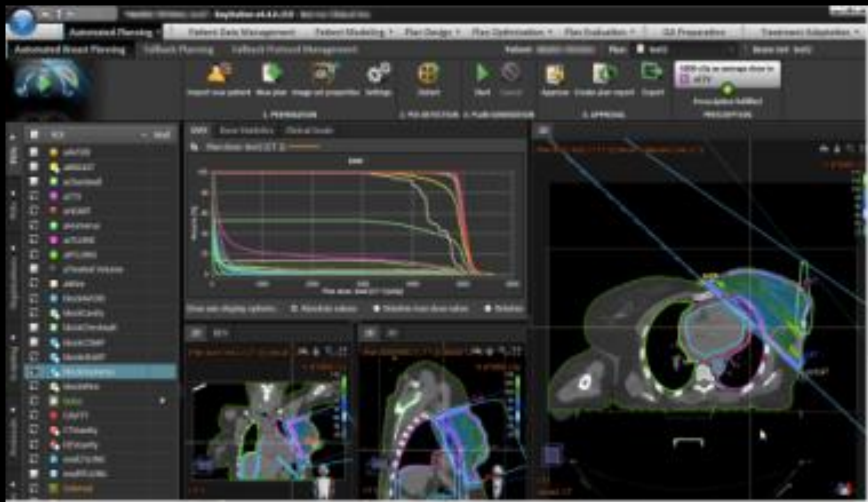
Integrated imaging, delivery, and fully automated planning/adaptation.

Dempsey et al. - Viewray Radiation Therapy Systems

Summary

- Need to consider the treatment device in context of the system.
- The scale of the problem should push us to pursue highly innovative and disruptive solutions that cross boundaries.
- Focus on the problem: Radiotherapy for 12.5M people by 2035.
- Think beyond the scaling of current solutions.

Example Technologies



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During the summer, the array's output will be more than the Radiation Oncology Centre needs to run its two linear accelerators, a large bore CT system and the clinic's IT technology, lighting and air-conditioning.

Lake Constance Radiation Oncology Centre (Germany)