



**The Clatterbridge  
Cancer Centre**  
NHS Foundation Trust

Extending the working life of a low-energy  
isochronous cyclotron for ocular proton therapy

## **Douglas Cyclotron Upgrades**

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Engineering manager

# Background

- Built in 1984 by Scanditronix for fast neutron therapy - 62MeV Adapted for treating eyes in 1989.
- Was also used for producing radioisotopes and for radiobiology research, but now completely dedicated to ocular proton beam therapy.
- Scanditronix fully supported the machine until around 1991, with “best efforts” provision for spare parts for some time afterwards.
- 2019 There was an expectation amongst staff & management that the service would close down imminently. Key staff gradually retired & not replaced.
- NHS had no plan for replacement of the service, and referring medics were worried.
- Alternative plan (to either terminating the service, or building a new machine) was put together.



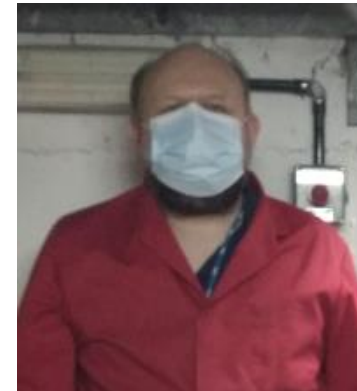
# The Plan

- Medium term plan (5 to 10 years after upgrade) to extend the life of the service to give NHS England some thinking time.
- Investment of approximately £2.5 million.
- Objectives :
  - Rejuvenate the team, particularly in engineering.
  - Modernise the most vulnerable parts of the accelerator.
  - Shore up spares holdings.
  - Where possible, bring the machine into compliance with modern standards



## Team

- Engineering team recruited new staff, expanded the involvement of existing radiotherapy technicians.
- Physics personnel now rotate through cyclotron so more variation in work, personnel less trapped in silos
- Radiographers rotate through cyclotron so greater pool of people available.



# Technical Cyclotron upgrades

- Cyclotron is an extremely complicated system.
- Can seem like an impossible task.
- How to we even go about upgrading?
- QUESTION :



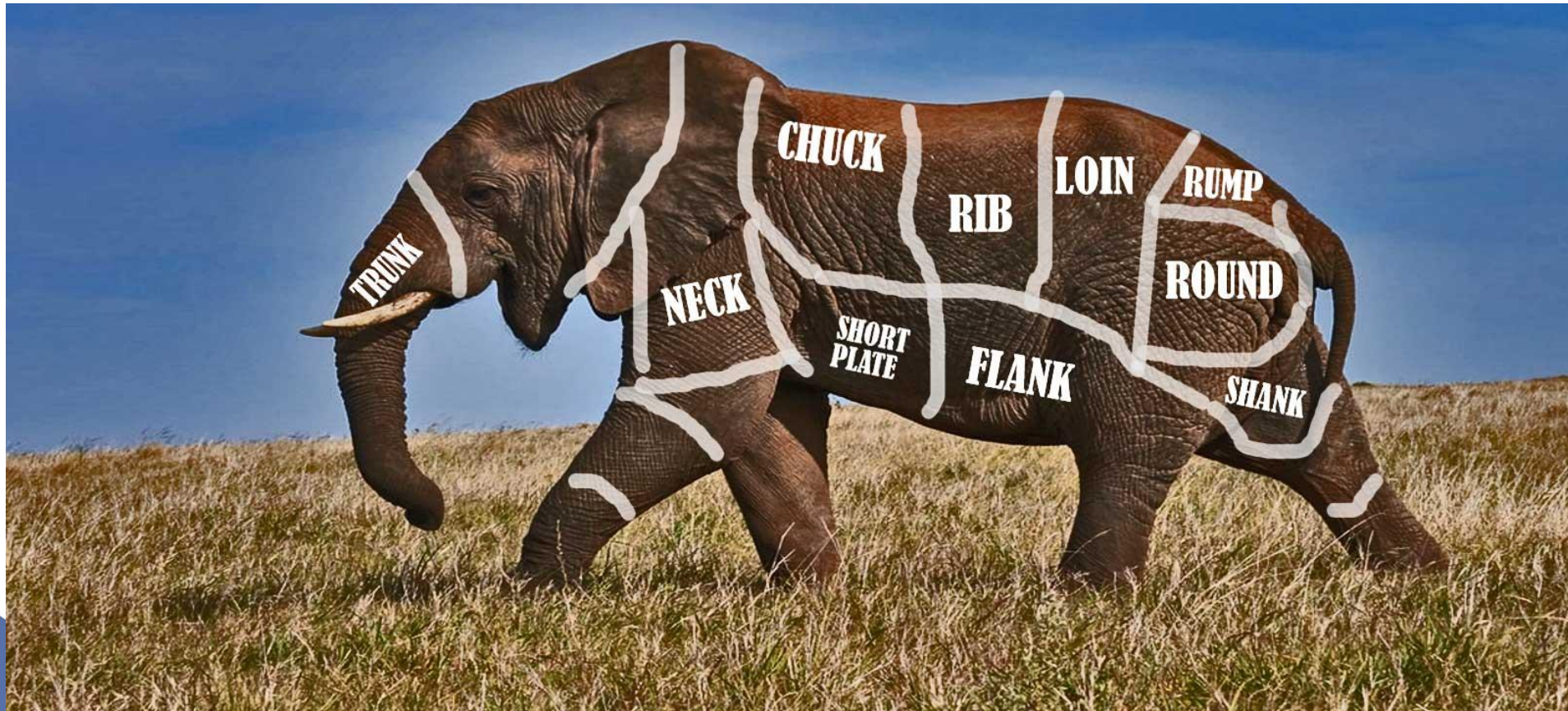
How do you  
eat an elephant?





# Cyclotron upgrades

- Answer : One bite at a time



# Cyclotron upgrades

- In Technical terms: **Systems engineering & project management**
  - Examination of cyclotron and split it into bite size subsystems.
  - Risk assessment of each subsystem
    - How intrinsically robust is it?
    - How often does it currently fail?
    - Do we hold spares / can we even buy a spare any more?
    - How long will the downtime be if it fails?
    - Is it unsafe at the moment?
  - Define what upgrades are possible
  - Prioritise that list based on risk / cost / benefit







## Smaller upgrades

- Upgrades we assess as being non-safety related.
- Managed according to a documented in-house ISO9000 process.
  - “Light touch”
  - Series of gateways
    - Justification/background
    - Conceptual design
    - Procurement
    - Detailed design
    - Implementation
    - Monitoring / sign off
  - Risk assessment at each stage
  - Sign off by an oversight committee,



# Major upgrades

- Safety related – their function directly affects patient safety, they are a medical device.
- **Main Control system**
- **Dose Monitor Controller**
- Being managed as full medical devices according to ISO13485 – for externally delivered projects
  - All documentation provided as if certification was being sought.
- For DMC, going through the same gateways as per smaller upgrades, but also applying ISO14971 for management of risk.



# Smaller upgrades completed so far

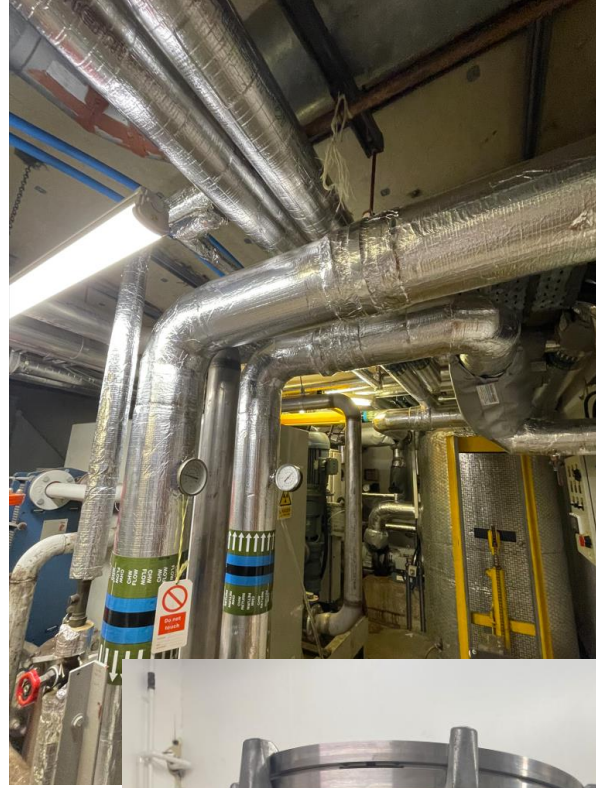
- Main vessel Vacuum Pump
- 7 x Circular correction power supplies
- 12 x Harmonic Power supplies
- Beam current measurement
- CCTV installation
- Network installation
- Deflector PSU





# Smaller upgrades completed so far

- Switch Magnet PSU
- 7 x Quadrupole Power supplies
- 8 x Steering power supplies
- Vacuum leak detection
- Cooling water pipework upgrade
- Treatment room HVAC
- New beam QA devices



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Minor Upgrades Milestones - allocated to individuals

	Priority	Responsible person	Start	Milestone						
				Justification	Specification	Ordering	Detailed design	Installation	Finish / sign off	
Vacuum PG2 diff pump upgrade	1	P.Corlett	01/07/2021	10/09/2021	10/09/2021	14/09/2021	22/10/2021	22/12/2021	10/01/2022	
Circular correction supplies	1	S.Elmer	13/09/2021	11/10/2021	11/10/2021	25/10/2021	29/11/2021	30/04/2022	28/02/2022	
Harmonic coil supplies	1	C.Davies	13/09/2021	11/10/2021	11/10/2021	01/11/2021	11/04/2022	31/05/2022	14/03/2022	
Beam QA Equipment	1	L.Mortimer	11/10/2021	29/11/2021	29/11/2021	16/05/2022	N/A	N/A	N/A	
F-Cup electronics	1	M.Talbot	11/10/2021	01/11/2021	01/11/2021	29/11/2021	27/12/2021	30/04/2022	20/04/2022	
DMC replacement	1	P.Corlett, S.Elmer	14/03/2022	06/05/2022	31/12/2023	05/05/2023	29/02/2024	24/06/2024	31/6/2024	
Switch Magnet Power supply	2	J.Lea	11/10/2021	01/11/2021	01/11/2021	29/11/2021	10/01/2022	18/04/2022	13/01/2023	
Main magnet supply	2	S.Elmer / P.Corlett	11/10/2021	01/11/2021	01/11/2021	20/06/2023	31/01/2024	18/03/2022	31/03/2024	
Hydrogen flow control system	2	S.Elmer / C.Davies	03/01/2022	24/01/2022	24/01/2022	02/02/2022	31/03/2024	15/07/2024	31/07/2024	
RF water Pipework	2	P.Pryce	11/10/2021	01/11/2021	01/11/2021	29/11/2021	N/A	N/A	14/02/2022	
EM Channel power supply	2	C.Davies, S.Elmer	03/01/2022	24/01/2022	24/01/2022	07/10/2022	13/04/2023	11/12/2023	31/12/2023	
RF grid Power supply x 2 (investigate remote control)	2	P.Corlett, S.Elmer	07/02/2022	07/03/2022	07/03/2022	28/09/2022	29/12/2023	29/02/2024	08/03/2024	
RF screen Supply x 2	2	P.Corlett, S.Elmer	07/02/2022	07/03/2022	07/03/2022	28/09/2022	30/12/2023	29/02/2024	08/03/2024	
Quad power supplies (follows on from Circular correctors)	2	M.Smith	10/01/2022	31/01/2022	31/01/2022	28/02/2022	28/03/2023	08/08/2023	15/08/2023	
XY steering supplies (follows on from CC & harmonic)	2	C.Davies, S.Elmer	18/04/2022	19/05/2022	19/05/2022	23/05/2022	20/06/2023	13/10/2023	17/10/2023	
Vacuum instrumentation	2	J.Lea, P.Corlett	17/01/2022	14/02/2022	14/02/2022	03/10/2022	31/03/2024	30/06/2024	30/06/2024	
Deflector 50kV supply (interim glassman supply)	2	P.Corlett	06/12/2021	24/01/2022	24/01/2022	14/02/2022	21/03/2022	30/05/2022	06/06/2022	
Deflector 50kV supply (permanent spellman supply)	2	P.Corlett	06/12/2021	24/01/2022	24/01/2022	14/02/2022	22/03/2022	29/02/2024	01/03/2024	
CCTV in vault	2	M.Smith	11/10/2021	01/11/2021	01/11/2021	29/11/2021	13/12/2021	18/07/2022	19/07/2022	
Vacuum leak detection	2	P.corlett	01/04/2022	08/04/2022	08/04/2022	18/08/2022	N/A	N/A	31/10/2023	
Pump room pipework	3	Propcare								
Air conditioning	3									



# Dose Monitor Controller Upgrade

- System which terminates the proton beam when the prescribed dose is reached.
- Collaboration with Pyramid Technical Consultants
- Pyramid provide the ion chambers & dose control electrometers
- Clatterbridge provide the integration & risk management
- Cosylab providing software code review



# Dose Monitor Controller





# Cosylab control system upgrade

- Existing computer control system is a PDP11 and original as built in 84.
  - A minor miracle it still operates!
- New system based upon Beckhoff industrial automation platforms.
- New signal IO hardware
- Make use of data interfacing where possible
- Produced to ISO13485
- Documented as medical device







### Clatterbridge Cancer Centre Accelerator Control System

Machine Overview > Vacuum

System State: SB1, SB2, Beam On, Beam Off

FC1 Current Roadback: 39.254 nA

RF Gun Voltage: 5000V V

RF Gun Voltage: 4000V V

RF Gun Voltage: 3000V V

RF Gun Voltage: 2000V V

RF Gun Voltage: 1000V V

RF Gun Voltage: 0V

Applied Parameter Set: Simulation Setpoints

User: \_SystemGuest

### Clatterbridge Cancer Centre Accelerator Control System

Machine Overview > Extraction

System State: SB1, SB2, Beam at TARGET, Beam Off

Cursor Setting: 1000 nA

Set Cursor

FC1 Current Roadback: 20.015 nA

RFAC

Selected Subsystem status: All Devices OK (Green), Fault (Red)

Subsystem	Status	Details
PSEMC	OK	
DECU	OK	
PSIX	OK	
Deflector Entry	OK	
Deflector Exit	OK	
EMC Exit	OK	
Deflector Probe	OK	
Main Beam Probe	OK	

Buttons: Details, Reset All, Turn On All, Turn Off All

### Clatterbridge Cancer Centre Accelerator Control System

Machine Overview > Extraction

System State: SB1, SB2, Beam at TARGET, Beam Off

Cursor Setting: 1000 nA

Set Cursor

FC1 Current Roadback: 23.111 nA

RFAC

## Conclusion & Future.....

- Cyclotron itself is largely untouched
- Extensive upgrades made to ancillary equipment & electronics
- Working according to appropriate quality management systems
  
- Once we do our planned upgrades, its not the end!
- Future work – slower time
  - RF system work
    - Redesign circuit boards
  - Servo controlled :
    - beam steering
    - dose rate
  
- Thank you!





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**Thanks**

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**Extra slides**



# Regulatory issues

- Our cyclotron pre-dates any standards on proton therapy.
- It is NOT CE marked or built to any specific standard.
- Our “licence” to treat patients is based on the provenance of the machine being safe for 40 years. Clatterbridge assume all risk involved.
  
- As a hospital, we have no route to get anything CE marked as a medical device.
  - All upgrades are “in house developments” and Clatterbridge assume full responsibility.
  - Its our responsibility to document everything to an appropriate level.
  - We have had our minor upgrade programme examined as part of a BSI audit.

