A comparison of failure modes of radiotherapy Linear Accelerators

Laurence Wroe & Remigio Makufa

The current-generation sophisticated linear accelerators in use in upper-income countries often do not function well in the adverse conditions encountered in LMICs. In addition to

Treatment, Not Terror: Time for Unique Problem-Solving Partnerships for Cancer Care in Resource-Challenged Environments

C. Norman Coleman et al

Journal of Global Oncology 2017; 3: 687-91

cancer treatment capacity can be met. There is a need to accelerate the adoption and deployment of new technologies that meet the contextual needs of low-income and middle-income countries, which can have regular interruptions to energy supply, lack of air temperature control in buildings, and weak health systems. For example, an environmentally friendly radiotherapy accelerator that consumes little power on standby and has reduced heat production, low instantaneous power demand, and local power storage would reduce reliance on the electricity grid (especially if it could be solar powered) and is in development.

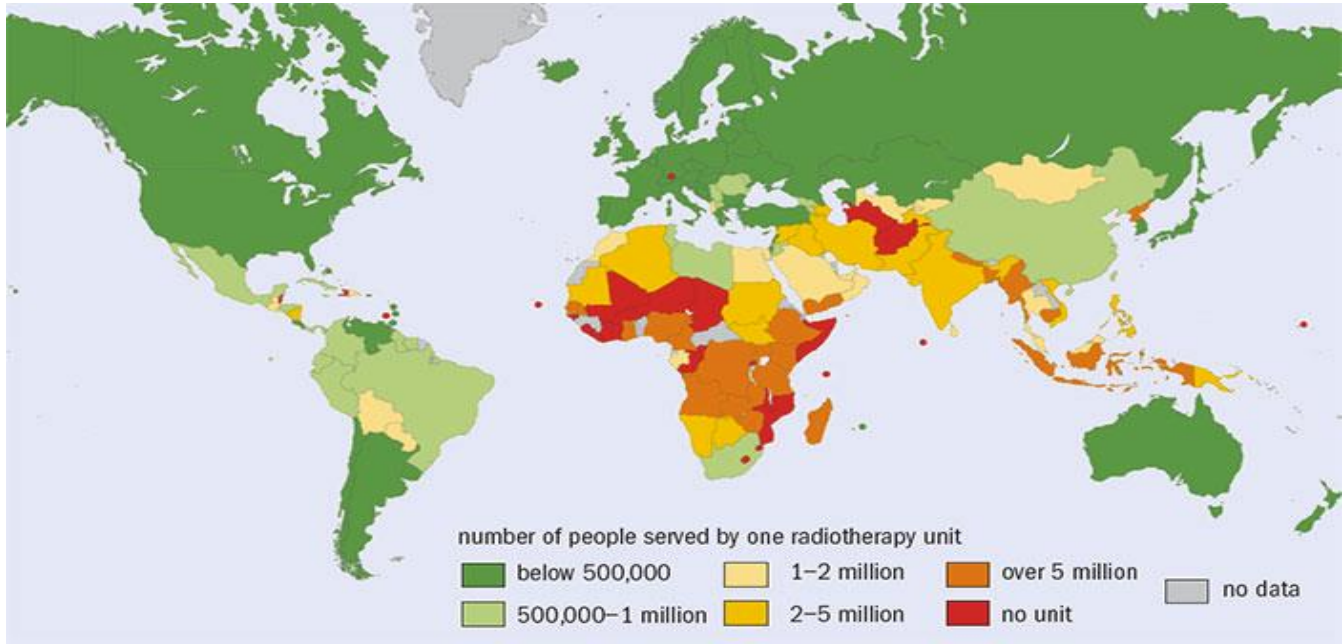
Expanding global access to radiotherapy

R. Atun et al

Lancet Oncol 2015; 16: 1153–86

Aims

- Determine **what** fails (LINAC subsystem)
- Determine **why** it fails (failure mode)
- **Are there any differences in the above in HICs and LMICs?**
- To our knowledge, first comparative study between different environments



https://cerncourier.com/developing-medical-linacs-for-challenging-regions/

Details of the Centres…

	Location	Model	Additional Features	Installation Date	Data From	End Date	Local Engineers
Nigeria	Abuja	Elekta Precise		1999	2008	2017	2-3
	Abuja	Elekta Synergy	MLC	2017	2017	-	2-3
	Benin	Elekta Precise		2011	2011	-	1-2
	Enugu	Elekta Precise		2009	2009	-	1-2
	Lagos	Elekta Precise		2013	2013	-	1-2
	Sokoto	Elekta Precise		2009	2009	-	1-2
Botswana	Gaborone	Elekta Precise		2001	2001	2014	1-2
	Gaborone	Elekta VersaHD	MLC, Intellimax	2015	2015	-	1-2
UK	Oxford	Varian iX2100	MLC, OBI, RPM	2007	2011	-	4
	Oxford	Varian iX2100	MLC, OBI, Rapid Arc, RPM	2007	2011	-	
	Oxford	Varian iX2100	MLC, RPM	2007	2011	-	
	Oxford	Varian iX2100	MLC, Rapid Arc, RPM	2007	2011	-	
	Oxford	Varian iX2100	MLC, Exactrac, OBI, Rapid Arc	2007	2011	-	
	Oxford	Varian iX2100	MLC, RPM	2007	2011	-	

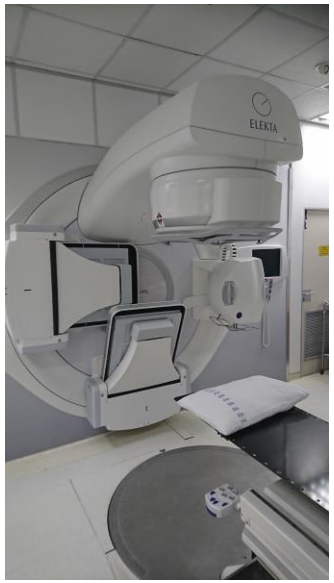
How to compare the LINAC data between environments?

- The LINACs studied do not record or log their own performance
  - Data recorded externally by radiotherapy personnel
- So, analysed paper and electronic log books as well as databases

Abuja: 2017

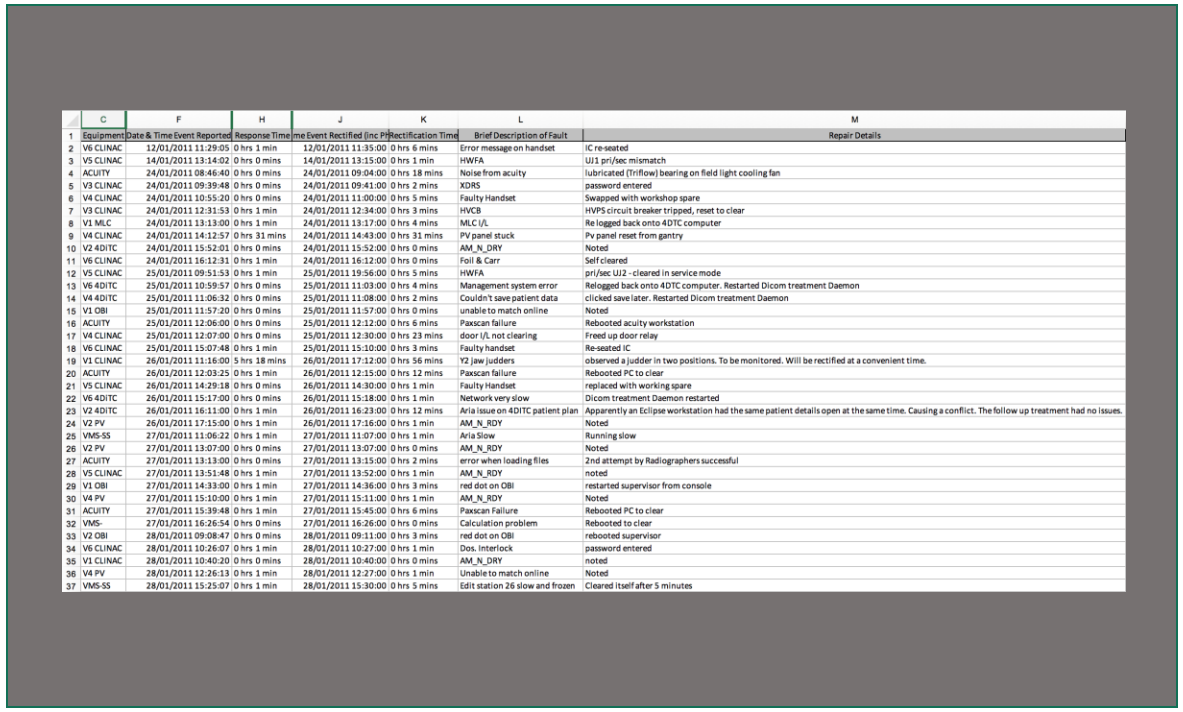
Abuja: Commissioned

Enugu



Gaborone: 2015

Example data available: Oxford, database

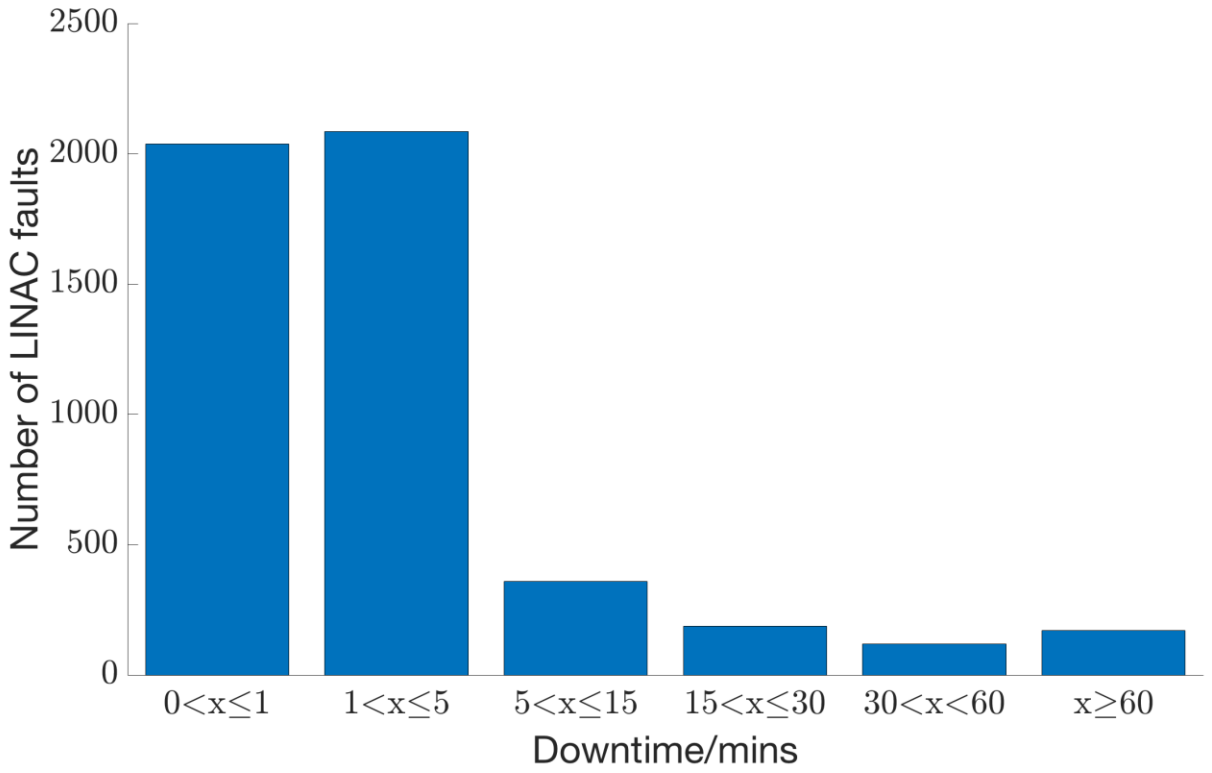


	C	F	H	J	K	L	M
1	Equipment	Date & Time Event Reported	Response Time	me Event Rectified (inc Pr	Rectification Time	Brief Description of Fault	Repair Details
2	V6 CLINAC	12/01/2011 11:29:05	0 hrs 1 min	12/01/2011 11:35:00	0 hrs 6 mins	Error message on handset	IC re-seated
3	V5 CLINAC	14/01/2011 13:14:02	0 hrs 0 mins	14/01/2011 13:15:00	0 hrs 1 min	HWFA	U1 pri/sec mismatch
4	ACUITY	24/01/2011 08:46:40	0 hrs 0 mins	24/01/2011 09:04:00	0 hrs 18 mins	Noise from acuity	lubricated (Triflow) bearing on field light cooling fan
5	V3 CLINAC	24/01/2011 09:39:48	0 hrs 0 mins	24/01/2011 09:41:00	0 hrs 2 mins	XDRS	password entered
6	V4 CLINAC	24/01/2011 10:55:20	0 hrs 0 mins	24/01/2011 11:00:00	0 hrs 5 mins	Faulty Handset	Swapped with workshop spare
7	V3 CLINAC	24/01/2011 12:31:53	0 hrs 1 min	24/01/2011 12:34:00	0 hrs 3 mins	HVCB	HVPS circuit breaker tripped, reset to clear
8	V1 MLC	24/01/2011 13:13:00	0 hrs 1 min	24/01/2011 13:17:00	0 hrs 4 mins	MLC I/L	Re logged back onto 4DTC computer
9	V4 CLINAC	24/01/2011 14:12:57	0 hrs 31 mins	24/01/2011 14:43:00	0 hrs 31 mins	PV panel stuck	Pv panel reset from gantry
10	V2 4DITC	24/01/2011 15:52:01	0 hrs 0 mins	24/01/2011 15:52:00	0 hrs 0 mins	AM_N_DRY	Noted
11	V6 CLINAC	24/01/2011 16:12:31	0 hrs 1 min	24/01/2011 16:12:00	0 hrs 0 mins	Foil & Carr	Self cleared
12	V5 CLINAC	25/01/2011 09:51:53	0 hrs 1 min	25/01/2011 19:56:00	0 hrs 5 mins	HWFA	pri/sec U12 - cleared in service mode
13	V6 4DITC	25/01/2011 10:59:57	0 hrs 0 mins	25/01/2011 11:03:00	0 hrs 4 mins	Management system error	Relogged back onto 4DTC computer. Restarted Dicom treatment Daemon
14	V4 4DITC	25/01/2011 11:06:32	0 hrs 0 mins	25/01/2011 11:08:00	0 hrs 2 mins	Couldn't save patient data	clicked save later. Restarted Dicom treatment Daemon
15	V1 OBI	25/01/2011 11:57:20	0 hrs 0 mins	25/01/2011 11:57:00	0 hrs 0 mins	unable to match online	Noted
16	ACUITY	25/01/2011 12:06:00	0 hrs 0 mins	25/01/2011 12:12:00	0 hrs 6 mins	Paxscan failure	Rebooted acuity workstation
17	V4 CLINAC	25/01/2011 12:07:00	0 hrs 0 mins	25/01/2011 12:30:00	0 hrs 23 mins	door I/L not clearing	Freed up door relay
18	V6 CLINAC	25/01/2011 15:07:48	0 hrs 1 min	25/01/2011 15:10:00	0 hrs 3 mins	Faulty handset	Re-seated IC
19	V1 CLINAC	26/01/2011 11:16:00	5 hrs 18 mins	26/01/2011 17:12:00	0 hrs 56 mins	Y2 jaw judders	observed a judder in two positions. To be monitored. Will be rectified at a convenient time.
20	ACUITY	26/01/2011 12:03:25	0 hrs 1 min	26/01/2011 12:15:00	0 hrs 12 mins	Paxscan failure	Rebooted PC to clear
21	V5 CLINAC	26/01/2011 14:29:18	0 hrs 0 mins	26/01/2011 14:30:00	0 hrs 1 min	Faulty Handset	replaced with working spare
22	V6 4DITC	26/01/2011 15:17:00	0 hrs 0 mins	26/01/2011 15:18:00	0 hrs 1 min	Network very slow	Dicom treatment Daemon restarted
23	V2 4DITC	26/01/2011 16:11:00	0 hrs 1 min	26/01/2011 16:23:00	0 hrs 12 mins	Aria issue on 4DITC patient plan	Apparently an Eclipse workstation had the same patient details open at the same time. Causing a conflict. The follow up treatment had no issues.
24	V2 PV	26/01/2011 17:15:00	0 hrs 1 min	26/01/2011 17:16:00	0 hrs 1 min	AM_N_RDY	Noted
25	VMS-S5	27/01/2011 11:06:22	0 hrs 1 min	27/01/2011 11:07:00	0 hrs 1 min	Aria Slow	Running slow
26	V2 PV	27/01/2011 13:07:00	0 hrs 0 mins	27/01/2011 13:07:00	0 hrs 0 mins	AM_N_RDY	Noted
27	ACUITY	27/01/2011 13:13:00	0 hrs 0 mins	27/01/2011 13:15:00	0 hrs 2 mins	error when loading files	2nd attempt by Radiographers succesful
28	V5 CLINAC	27/01/2011 13:51:48	0 hrs 1 min	27/01/2011 13:52:00	0 hrs 1 min	AM_N_RDY	noted
29	V1 OBI	27/01/2011 14:33:00	0 hrs 1 min	27/01/2011 14:36:00	0 hrs 3 mins	red dot on OBI	restarted supervisor from console
30	V4 PV	27/01/2011 15:10:00	0 hrs 1 min	27/01/2011 15:11:00	0 hrs 1 min	AM_N_RDY	Noted
31	ACUITY	27/01/2011 15:39:48	0 hrs 1 min	27/01/2011 15:45:00	0 hrs 6 mins	Paxscan Failure	Rebooted PC to clear
32	VMS-	27/01/2011 16:26:54	0 hrs 0 mins	27/01/2011 16:26:00	0 hrs 0 mins	Calculation problem	Rebooted to clear
33	V2 OBI	28/01/2011 09:08:47	0 hrs 0 mins	28/01/2011 09:11:00	0 hrs 3 mins	red dot on OBI	rebooted supervisor
34	V6 CLINAC	28/01/2011 10:26:07	0 hrs 1 min	28/01/2011 10:27:00	0 hrs 1 min	Dos. Interlock	password entered
35	V1 CLINAC	28/01/2011 10:40:20	0 hrs 0 mins	28/01/2011 10:40:00	0 hrs 0 mins	AM_N_DRY	noted
36	V4 PV	28/01/2011 12:26:13	0 hrs 1 min	28/01/2011 12:27:00	0 hrs 1 min	Unable to match online	Noted
37	VMS-S5	28/01/2011 15:25:07	0 hrs 1 min	28/01/2011 15:30:00	0 hrs 5 mins	Edit station 26 slow and frozen	Cleared itself after 5 minutes

- Equipment
- Time reported
- Response time of engineers
- Time rectified
- Rectification time (taken to be downtime)
- Fault description
- Repair details

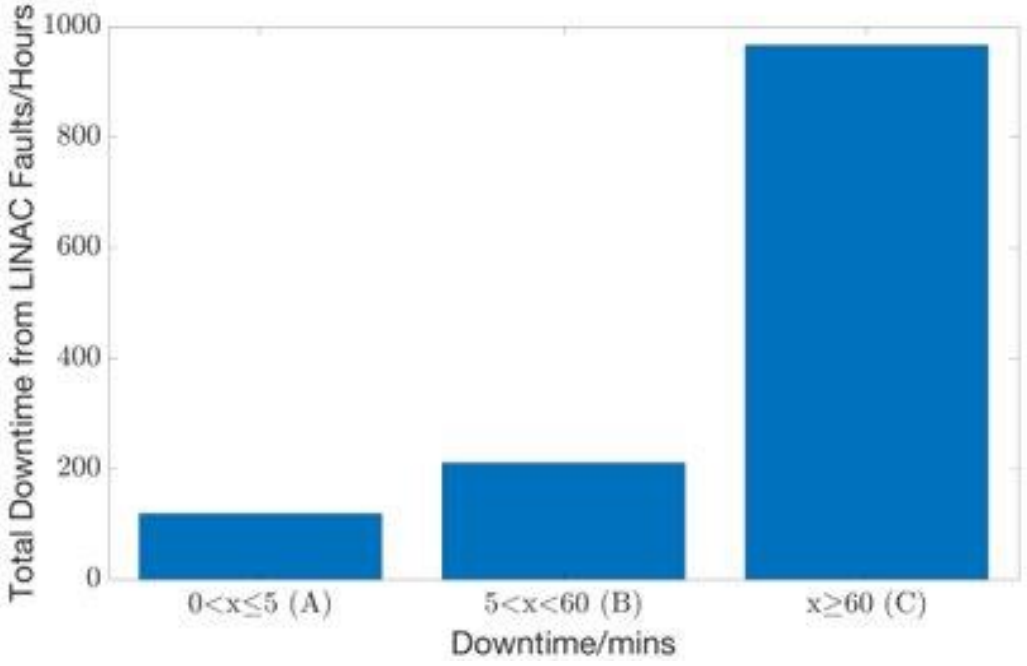
How can we analyse this?

- 12000 data entries cannot be manually analysed...
- Firstly, we look only at the 'CLINAC' system (I.e. ignore all extras) to approximately half faults



Categorisation of faults

- **A = Minor fault:** < 5 mins
- **B = Minor investigative fault**: > 5 mins and < 60 mins
- **C = Major fault**: > 60 mins



Category A

Mean = 2.2 mins, Median = 2 mins, Faults = **4122**

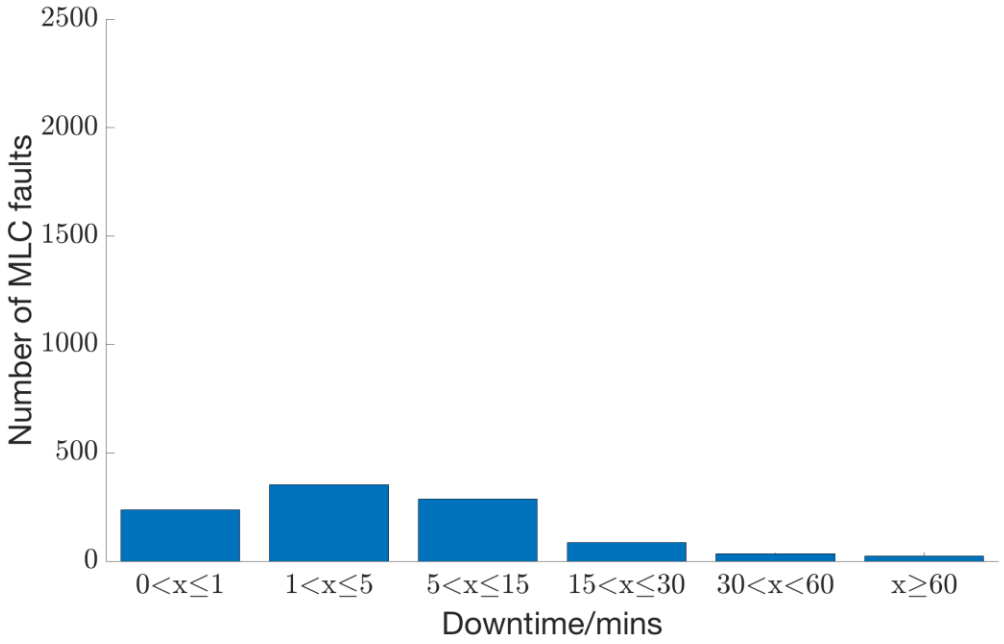
Category B

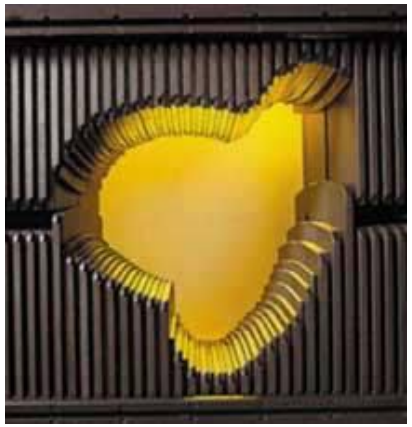
Mean = 14.2 mins, Median = 9 mins, Faults = **666**

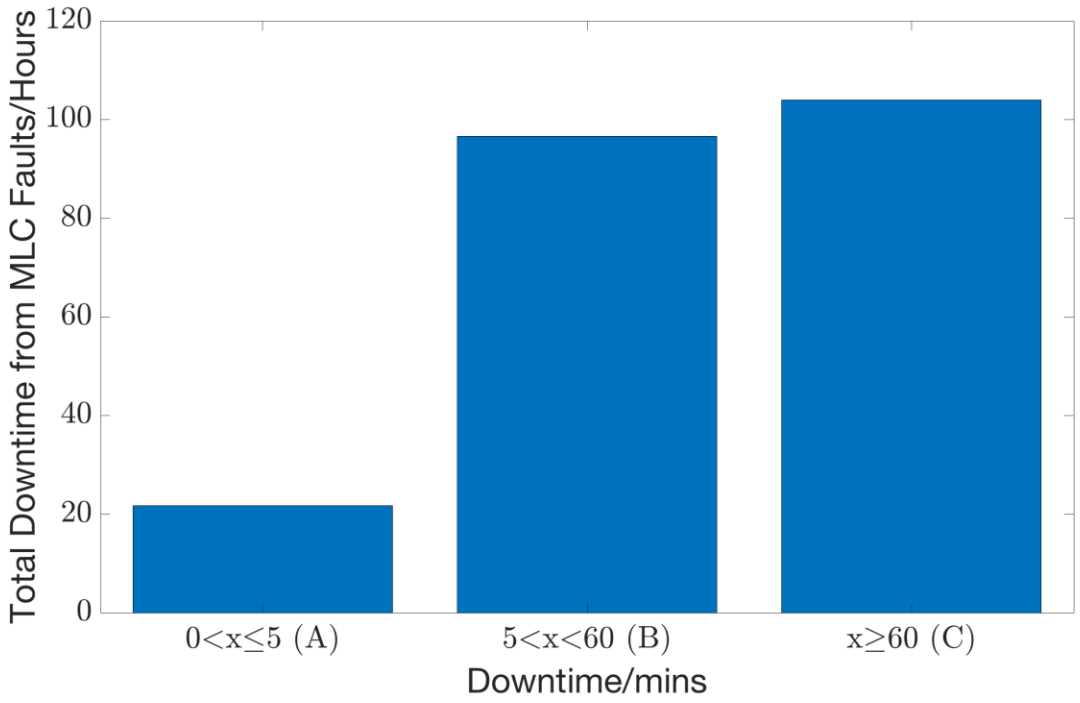
Category C

Mean = 271.3 mins, Median = 90 mins, Faults = **171**

Aside: MLC Fault Distribution

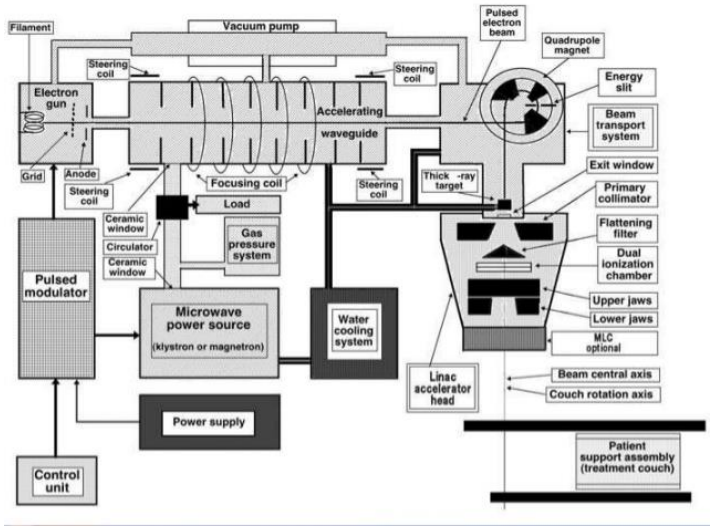






LINAC Subsystems

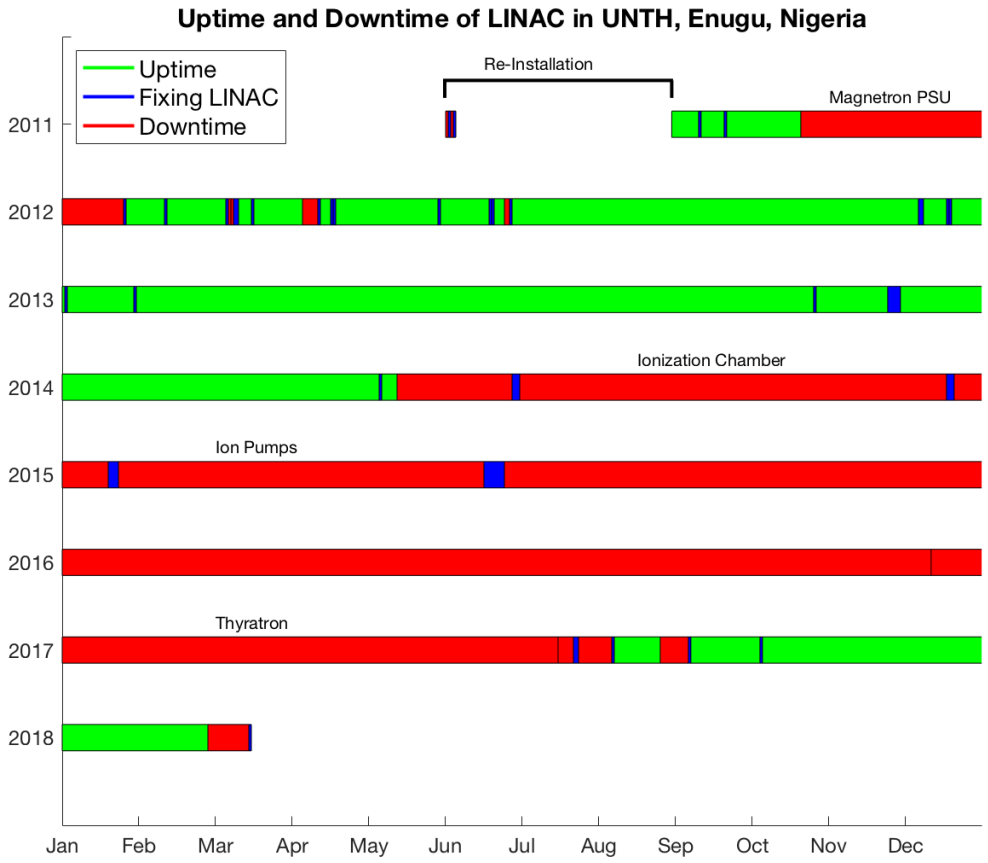
Subsystem	Examples
Air, Cooling and Generator	Generators, compressors, internal pipes, external chillers
Beam	Beam energy, symmetry
Computing	Monitors, keyboards, mice. (Does not include DICOM issues)
Couch and External Door	Couch, tabletop, hand-pendant, external door for shielding
Diagnostics	Ionisation chamber
Gantry	Gantry timing belt, gantry bearings
Gun	Gun death, gun current issues, gun PSU issues
MLC	MLC motors, MLC reflectors
Positioning	Lasers, field lamps, position read outs (PROs), encoders
RF Power	Thyratron, klystron/magnetron, power cables
Shaping	Collimators, touch guard, carousel
Vacuum	Vacuum pumps

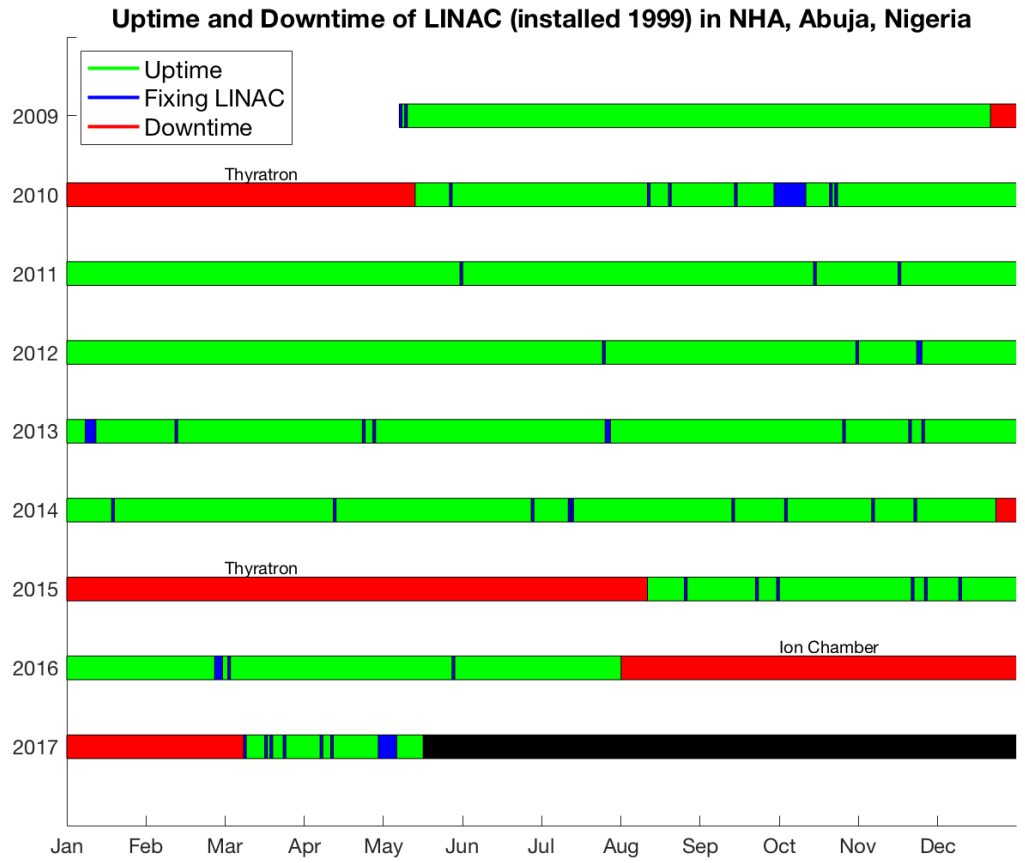


Fault Cause

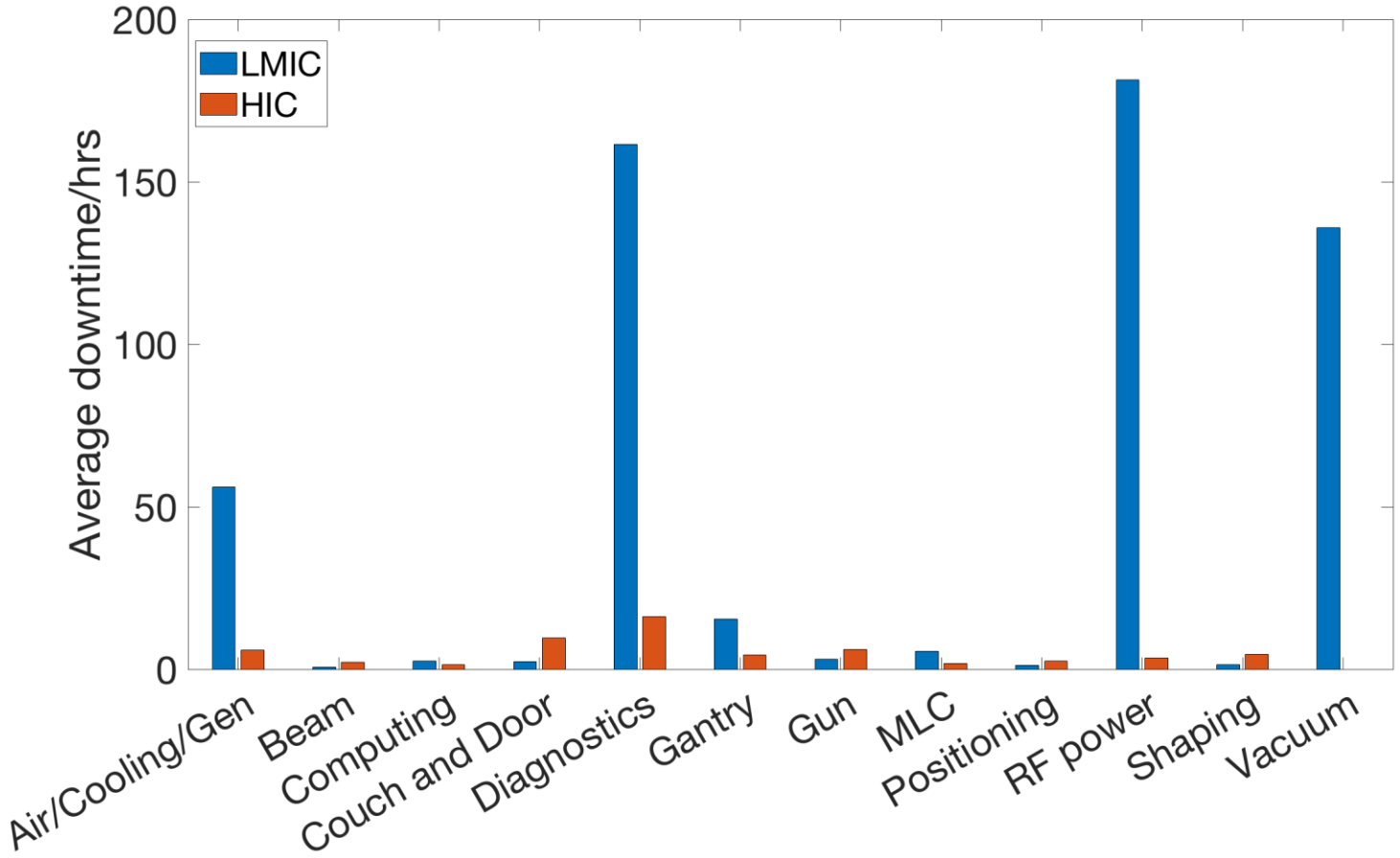
Fault Cause	Examples
Mechanical	Switches, gearboxes, bearings, PROs, pipes
Electrical	Thyratron, fuses, poor electrical connections, internal wires
Power	Power supply units, tripped circuit breakers, UPS
Board	PCBs, PSU boards, chips
Cabling	Power cables, signal cables
External	Generators, chillers, compressors, shielding door
Drift	Retuning of the beam

Downtime in Enugu and Abuja



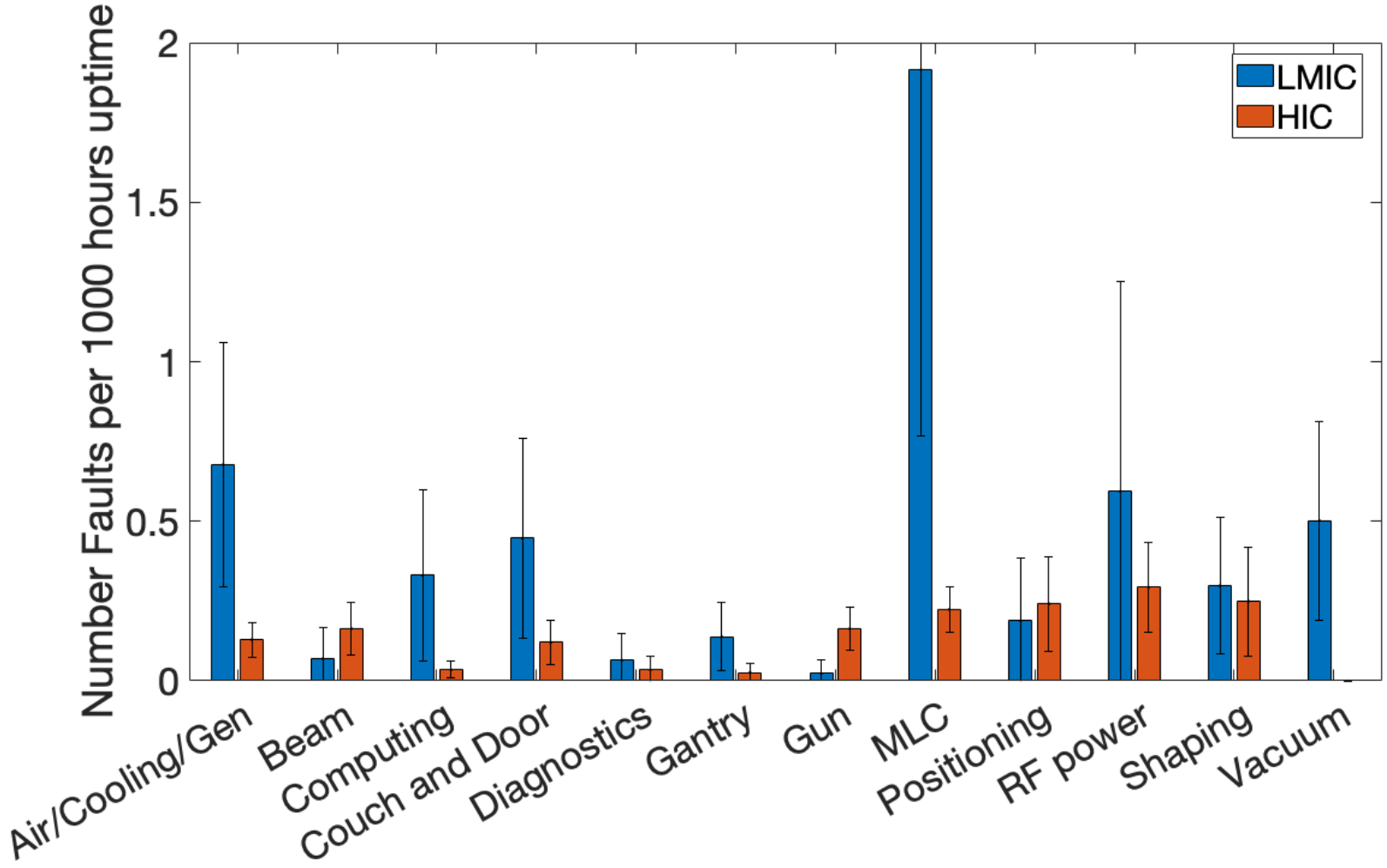


Average downtime for faults in LMIC and HIC

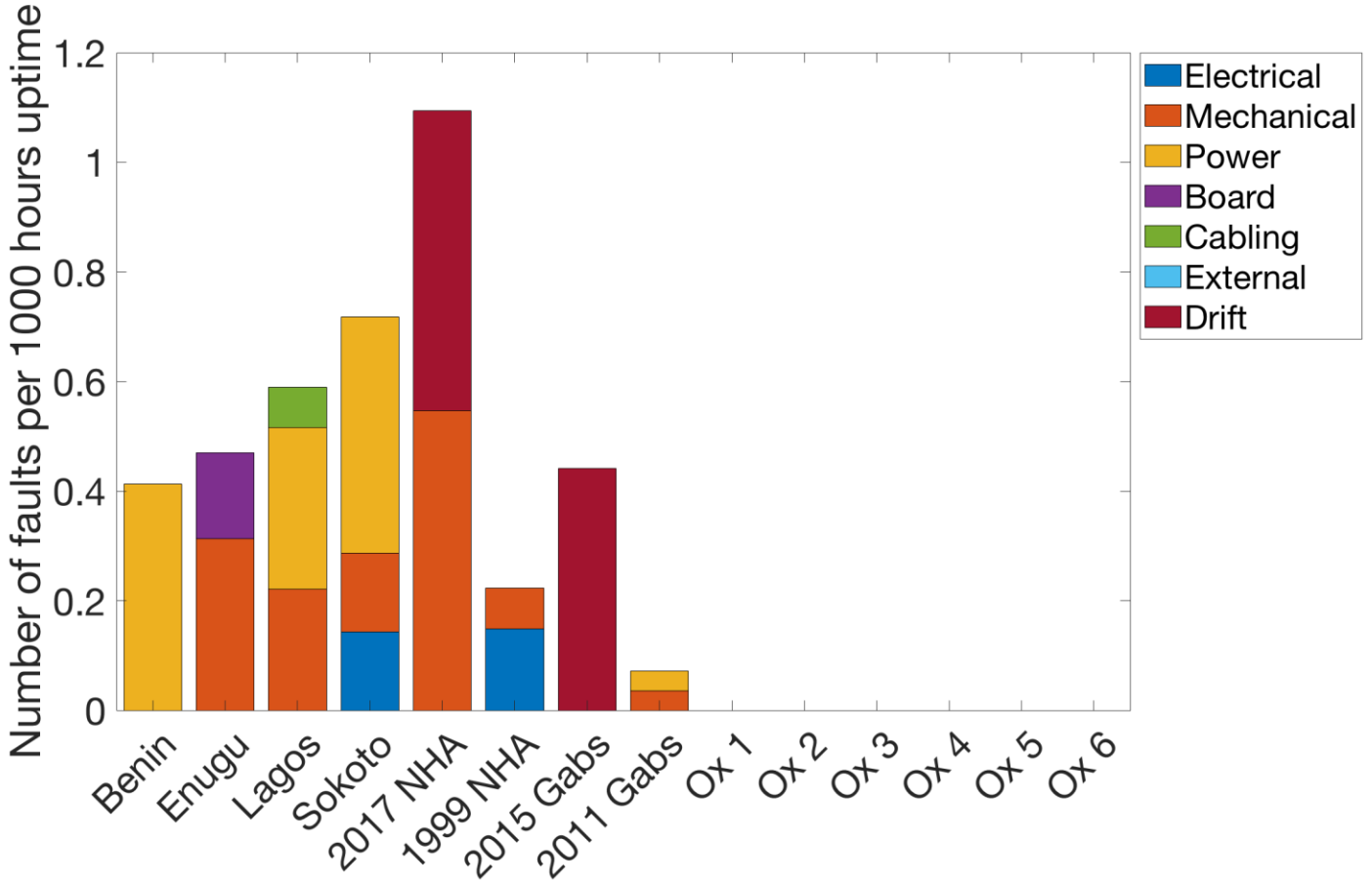


Does this actually represent the problem we want to solve in this study??

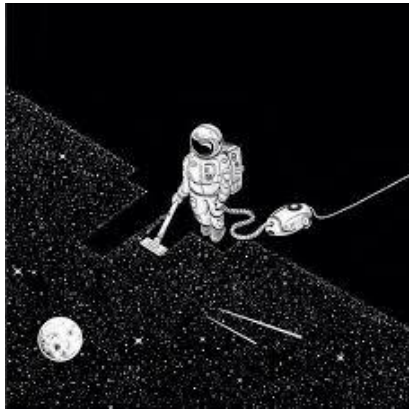
Frequency of fault comparison of LMIC to HIC

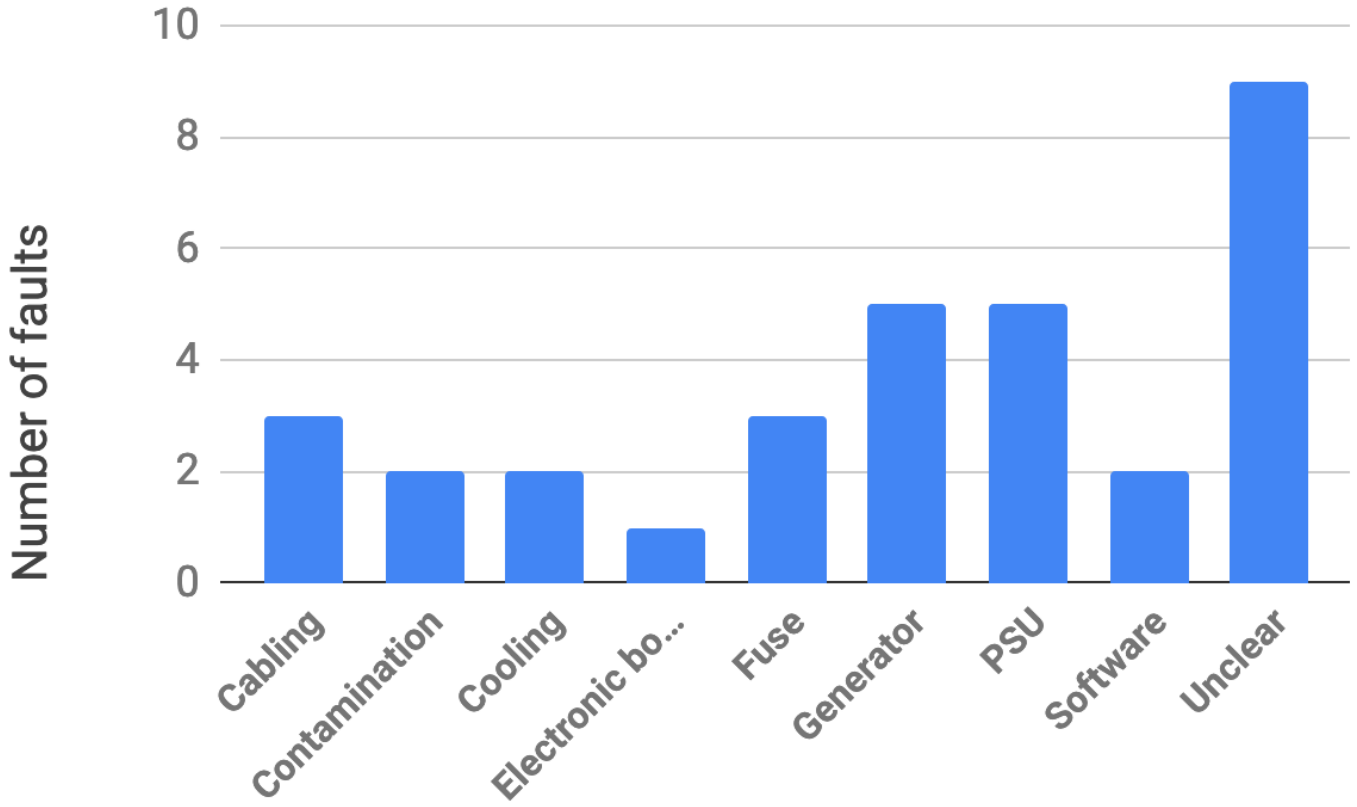


Vacuum Faults

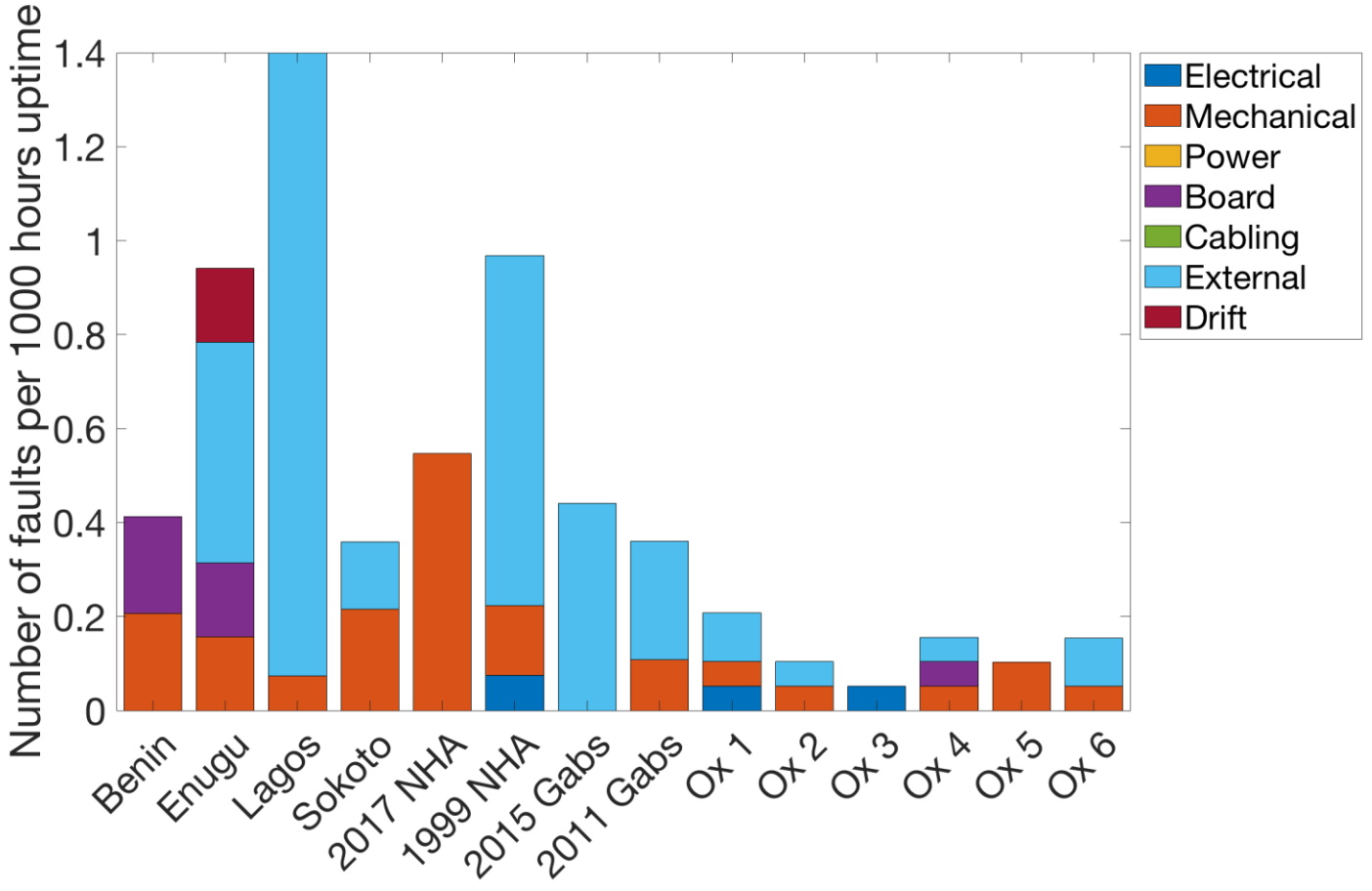


Breakdown on Vacuum faults

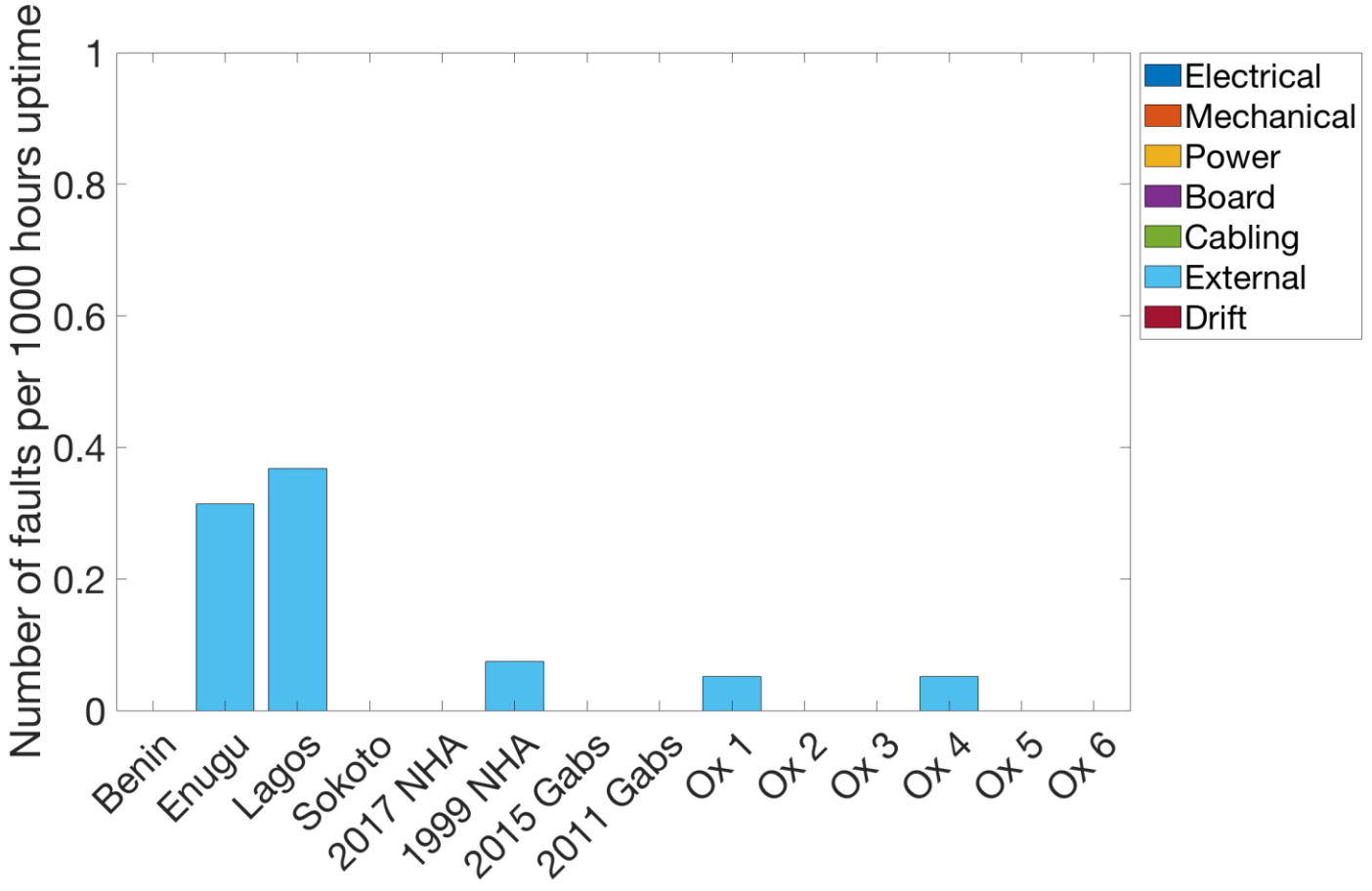




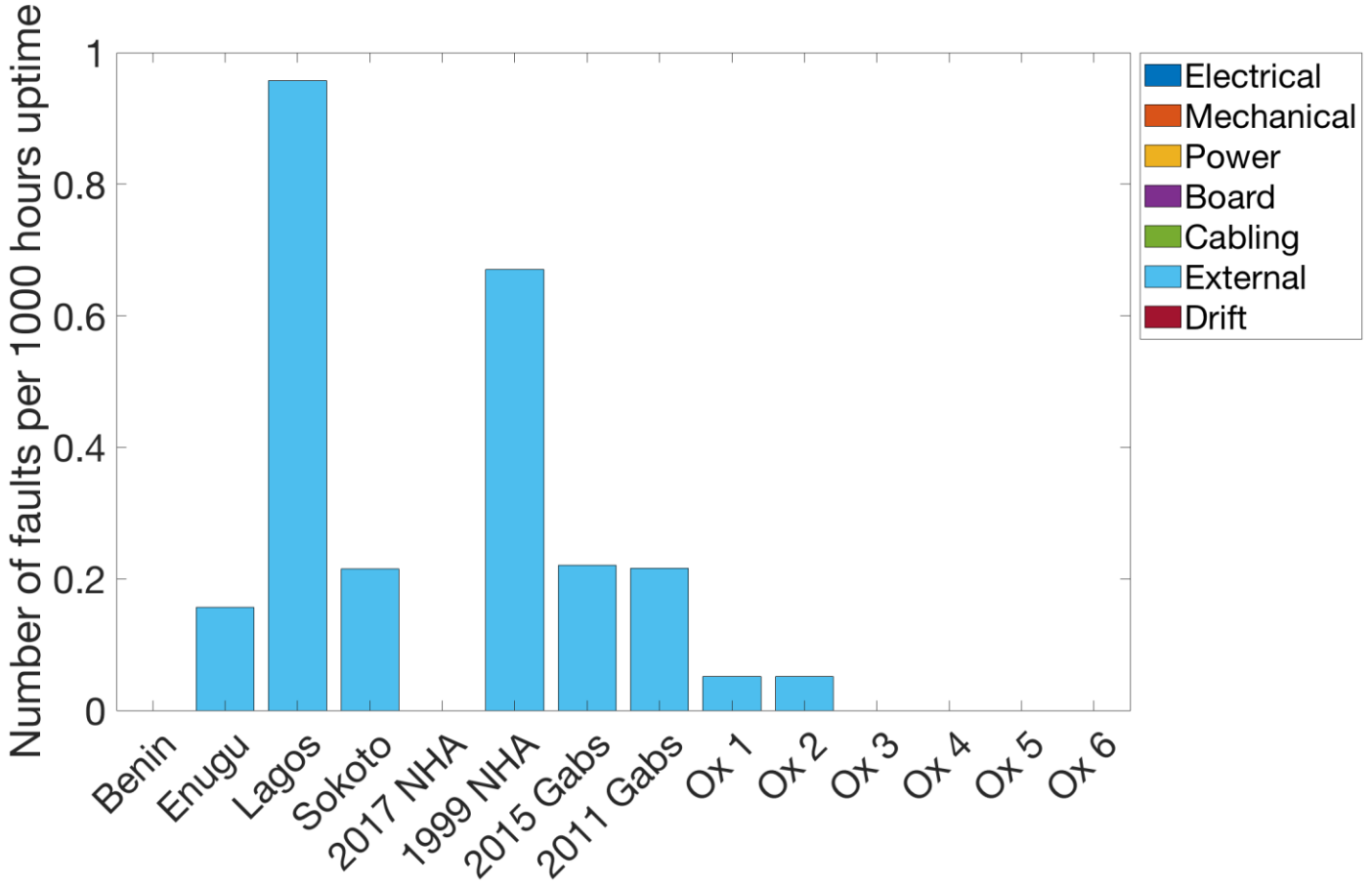
Air, Cooling and Generator Faults



Generator Faults



Cooling system and chiller Faults



Conclusions…

- Data agrees with qualitative statements
- Study of vacuum/interlocks and ion pump
  - Safe shut down/start up, better vacuum sustainment, better back up supply, alternative energy supply?
- Maintenance of chillers and generators
- Power regulation – prevent surges
- Easy identification and replacement of fuses
- Maintanence of water/gas pressure
- Gun – why does Oxford gun fail more than LMIC?

Recommendations

- More data! Look at LICs as well as LMICs
- Can a study of ‘A’ and ‘B’ faults indicate likelihood of ‘C’ occurring?
- Can we make collection of data systematic? Standardised database?

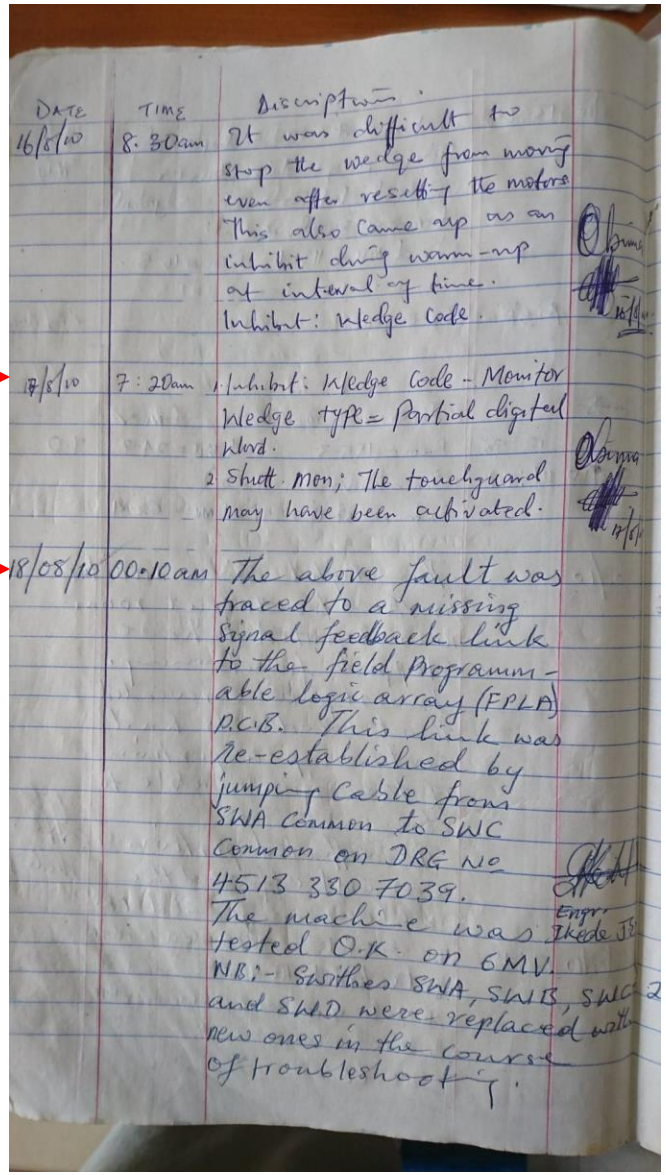
Journal paper coming out…

Comparative analysis of radiotherapy LINAC downtime and failure modes in the UK, Nigeria and Botswana

L. M. Wroe[a], T. A. Ige, O. C. Asogwa, C. S. Aruah[b], S. Grover[c], R. Makufa[d], S. L. Sheehy[a], on behalf of the CERN-ICEC-STFC Medical LINAC collaboration

[a]*Department of Physics, University of Oxford*
[b]*National Hospital Abuja (NHA), Nigeria*
[c]*Department of Radiation Oncology, University of Pennsylvania. Botswana-UPENN Partnership*
[d]*Life Gaborone Private Hospital (GPH), Botswana*

In the final stages of being submitted to the journal *Clinical Oncology*



DATE	TIME	Description.
16/8/10	8.30am	It was difficult to stop the wedge from moving even after resetting the motors. This also came up as an inhibit during warm-up at interval of time. Inhibit: Wedge Code.
17/8/10	7:20am	1. Inhibit: Wedge Code - Monitor Wedge type = Partial digital Hard. 2 Shutt Mon; The touchguard may have been activated.
18/08/10	00:10am	The above fault was traced to a missing signal feedback link to the field Programmable logic array (FPLA) P.C.B. This link was re-established by jumping cable from SWA common to SWC common on DRG No 4513 330 7039. The machine was tested O.K on 6MV. NB:- Switches SWA, SWB, SWC and SWD were replaced with new ones in the course of troubleshooting. Engr. Ikede J.

24/10/2009	Blank screen on LCS monitor	Faulty LCS mother board
24/12/2009	Vacuum failure	Small generator break down. Speed sensor failure
5/09/2010	X2 is out of Calibration limit	Diaphragm out of calibration The unit is recalibrated.
21/09/2010	Unusual vacuum readings T(-5.81) G(-6.56)	Power supply failure
15/11/2010	Vacuum trip	Ion pump Power supply cables short circuited
7/03/2011	Vacuum readings drift so much that it was advised by Elekta to be shutdown	Ion pump becomes too hot due to contamination
4/4/2011	Flight tube leaking vacuum and required replacement	Faulty electron window
20/06/2011	Table clutch and Interlock HTB	Emergency button on treatment couch de-activated
21/06/2011	Low water pressure	A Switch plug on the pump motor is loosed
6/07/2011	R.H.S laser miss alignment	Laser realigned
15/08/2011	Room door 1 Inhibit	Door 1 interlock switch misalignment
20/10/2011	Longitudinal movement out of calibration limits	The Table longitudinal Movement recalibrated
24/10/2011	Checking the integrity of Emergency switches	Found to be perfectly ok
2/02/2012	Table not making specification movement	Table shocks were replaced
23/03/2012	Blank screen on the LCS monitor	Faulty connector
4/4/2012	Table clutch, Touch guard (No any movement on the table)	Touch guard switches misalign.
25/4/2012	No good cooling in the bunker	Chiller was faulty,

25—08—2017

On this day, we were faced with another inhibit on the LINAC machine called "Pressure Diff" inhibit.

INHIBIT ⟹ "PRESSURE DIFF".

Machine displays on the inhibit page thus:

Description: The difference b/w the 2 dosimetry pressure sensors has exceeded 3 milibar.

Action: Recalibrate item 558 "pressure 1" and item 559 "pressure 2" using Calibrated barometer.

Engr Austine sent us the procedure for the calibration but it does not work.

07—09—2017

Engr Austine came for calibration of the LINAC pressure re the inhibit "pressure Diff".

He re-calibrated the pressure sensors and the inhibit disappeared. The steps/procedures for the calibration are as listed below:

Date	Time	Description	Remarks
21/12/09	7:45am	Inhibit: Thy. Grid	H. Umoden
13/04/10	08:34am	Dose Rate Error occured for 15MV Photon Energy. Uniformity and 2T Error occured for 18MeV Electron Energy.	
14/04/10	10.00hrs	Following the above complains I have carried out gun servo Setup fo 15mV. The dose rate for this energy is now O-K.	

Gathering additional data….

- Now we have done initial study, we would like to collect more data to provide:
  - Better statistics for analysis
  - Wider variety of countries and environments
  - Average out differences between vendors

- Ideally, we will 'automate' this data collection soon by providing a cloud-based logbook that collaborators can use to record down time and faults to assist the study (and their own knowledge of downtime!)

- It would be great to gather additional data from Indonesian hospitals! As well as the 'log book' data, would be good to also record:
  - Which type of LINACs are used?
  - Do they have service contracts or local engineers?
  - We also would like 'context' data i.e. challenges that led to significant down time (availability of spare parts, difficulty in procurement, politics etc…)

FAILURE MODE & DATA

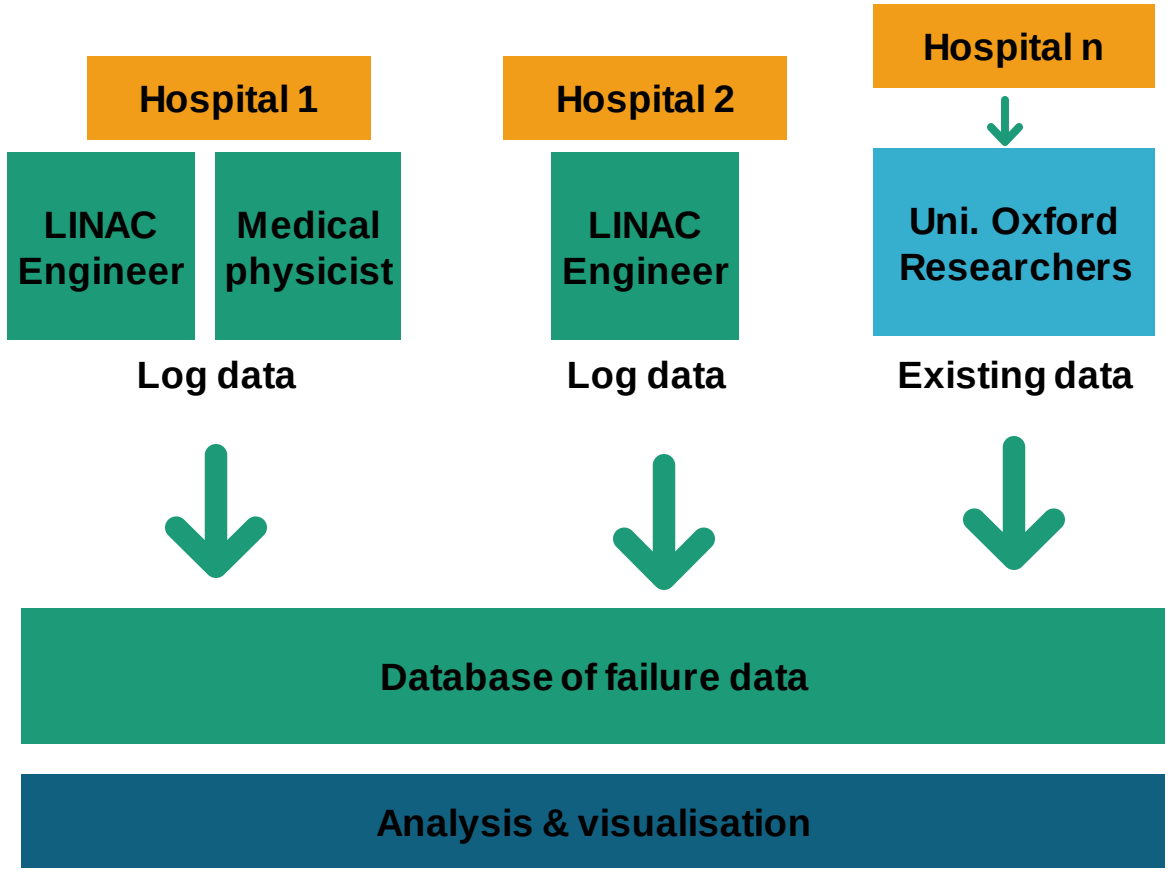
- Developing methodology to expand data collection:
  - Indonesia (Jan & June 2019) and other hospitals in Nigeria (TBC)
  - Later: cloud-based database system
- Have developed a simple tool to analyse availability based on MTTF & other data
- Planning for reliability/availability studies throughout project life

LINAC Availability			**86%**											
LINAC Unavailability			**14%**											
Subsystem	**General Power**		**Air Conditioning**	**Chilled Water**	**Vacuum**	**Gantry**	**RF Source**	**RF Power Control**	**Electron Gun**	**Accelerator Guide**	**Bend Magnet**	**X-ray Target**	**Control System Electronics**	**Collimator**
Subsystem Availability	100.00%		94.37%	90.91%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Subsystem Unavailability	0.00%		5.63%	9.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Mains	Backup												
Module Availability	99.99%	94.37%	94.37%	90.91%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Prob Stock sufficient		84%	84%											
Stockout Risk		16%	16%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
(Assume Stockout occurs 1/no of spares+1 through period)														
Number of Modules Installed		1	1	1	1	1	1	1	1	1	1	1	1	1
Number of Modules Required		1	1	1	1	1	1	1	1	1	1	1	1	1
Number of Modules Normally Running		1	1	1	1	1	1	1	1	1	1	1	1	1
MTBF (hours whilst running)	8760	1000	1000	1000	10000000000	10000000000	10000000000	10000000000	10000000000	10000000000	10000000000	10000000000	10000000000	10000000000
MTBF due to start up failures														
MTBF (hours, inc fails to start)		1000	1000	1000	10000000000	10000000000	10000000000	10000000000	10000000000	10000000000	10000000000	10000000000	10000000000	10000000000
Mean Downtime (assuming spares available)	0.5	1	1	100	1	1	1	1	1	1	1	1	1	1
Mean Downtime (allowing for stockout)		59.60300311	59.60300311	100	1	1	1	1	1	1	1	1	1	1
Probability of Failure on Start-Up		0	0	0	0	0	0	0	0	0	0	0	0	0
Average daily running hours		10	10	10	10	10	10	10	10	10	10	10	10	10
Number of Spares		1	1	1	1	1	1	1	1	1	1	1	1	1
% failures requiring spare to be used		100%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
No of Modules normally running		1	1	1	1	1	1	1	1	1	1	1	1	1
Mean Time Between Calls for a Spare		1000	1000											
Restocking Time (days)		30	30	30	30	30	30	30	30	30	30	30	30	30
(hrs)		720	720	720	720	720	720	720	720	720	720	720	720	720

Egerton Consulting, UK

The vision: database of LINAC downtime/failure mode data

- Can work to input data offline
- Upload or send regularly
- View own data & export
- User can have different levels of access to database
- Ability to import data from xls or text file



- Database can be amended/updated
- Analysis layer can be developed over time

Uni. Oxford Researchers

Iterate

- Guide analysis and iterations
- Bring in new hospitals/locations
- Report/input to accelerator study

CERN-ICEC-STFC Collaboration

Thanks!

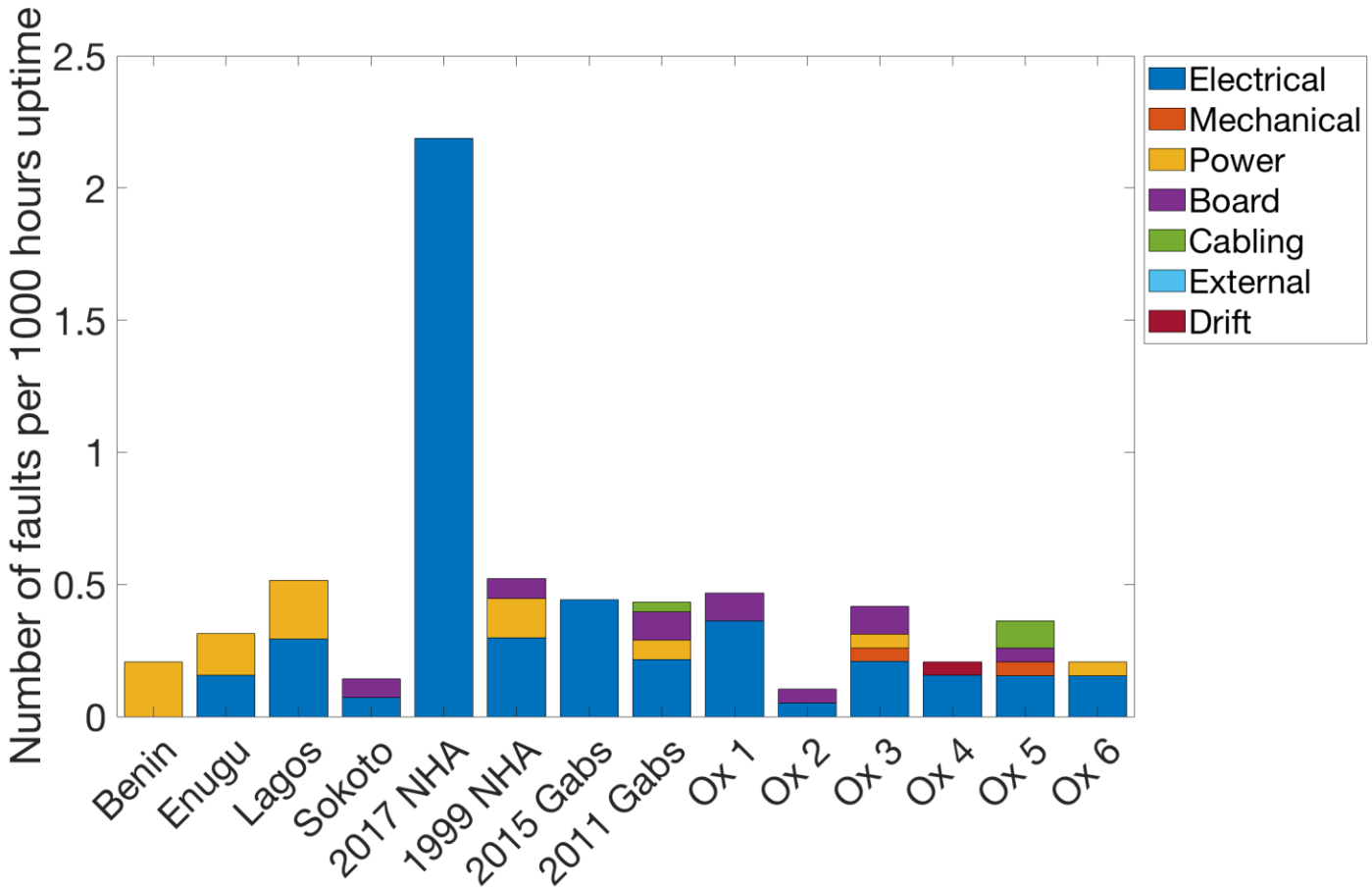
- Dr Aruah, Dr Ige, Mr Asogwaa at National Hospital Abuja
- Dr Grover and Mr Makufa at Life Gaborone Private Hospital
- Dr Sheehy at University of Oxford

Questions....

Back Up Slides

- Calculate downtime for each centre
- Can use this to normalise failure rates
  - In the following graphs: <u>Number of 'C' faults per 1000 hours of uptime</u> (Alternative representation of a mean time between failures graph)

	Location	Downtime	Power System	Hours of Data Estimate
Nigeria	Abuja	22.7%	Grid (back up gen)	17377
	Abuja	4.2%	Grid (back up gen)	1909
	Benin	14.2%	Generator	5640
	Enugu	54.7%	Generator	14080
	Lagos	18.8%	Generator	16720
	Sokoto	20.0%	Generator	17423
Botswana	Gaborone	1.3%	Grid	28343
	Gaborone	1.3%	Grid	4583
UK	Oxford	1.3%	Grid	19536
	Oxford	0.7%	Grid	19536
	Oxford	1.7%	Grid	19536
	Oxford	1.4%	Grid	19536
	Oxford	1.0%	Grid	19536
	Oxford	0.7%	Grid	19536


Number of faults per 1000 hours uptime
2.5
2
1.5
1
0.5
0
Benin
Enugu
Lagos
Sokoto
2017 NHA
1999 NHA
2015 Gabs
2011 Gabs
Ox 1
Ox 2
Ox 3
Ox 4
Ox 5
Ox 6
Electrical
Mechanical
Power
Board
Cabling
External
Drift

Example Categorisation for Oxford data

Fault Details	Repair Details	Downtime	Subsystem	Why	Fix	What
In Room Monitor	In Room monitor not working - VGA cable in ceiling loose. Refitted. Monitor working	2	Computing	Cabling	Repair	Cable
HWFA Y2 jaw	Physics Checks	2	Shaping	Mechanical	QA	Y2 Jaw
faulty handset	Reseated main IC	92	Couch	Board	Repair	Main IC
DS12 & outputs need adjusting	Outputs adjusted	3	Shaping	Electrical	Adjusted	NaN
Collimator stuck	Collimator rotation motor and gearbox ordered at 15 40 and replaced on arrival followi	9	Shaping	Mechanical	Replaced	Motor
Collimator Stuck	Pinched cable freed off	2	Shaping	Cabling	Repaired	NaN
Watlow temperature monitor failed	Replacement required	23	Air/Cooling/	Mechanical	Replaced	Temperatur
Door Interlock not working	Infra red barrier at fault. RHS relay not making connection. Changed to spare on PCB. Al	4	Couch	Electrical	Replaced	Relay
Targ interlock	6MV S1 interlock switch replaced in target system.	2	Beam	Electrical	Replaced	Switch
15MV Symmetry adjustment required	15MV R & T adjustment made	1	Beam	Drift	Adjusted	NaN
V2 overheating	Air con failed. Currently running machine on city water. Air con engineer on site 10/02/1	1	Air/Cooling/	Mechanical	Repaired	Air con
GFIL	replaced Gun filament PSU in gun hot deck. Outputs checks OK.	1	Gun	Board	Replaced	Gun filamer
6MV Symmetry adjustments required	Adjustments made (QA).	1	Beam	Drift	Adjusted	NaN
Low dose 16meV	Unable to tune 16meV after service. Varian Engineer on site 25/06/14. Dave Holten adj	1	Gun	Electrical	Repaired	NaN
HWFA	y1 spro replaced. X1 pro replaced. Colimator chain torque set	1	Positioning	Mechanical	Replaced	SPRO
GFIL	cold deck PSU dropping out intermittently. PSU replaced	1	RFPower	Board	Replaced	Cold deck PS
HWFA	W14A replaced	2	Shaping	Cabling	Replaced	W14a
Foil & Carr	Locking pin uswitch failed. Replaced and ok for use	1	Shaping	Mechanical	Replaced	Pin uswitch
Y2 Jaw issue	w14b ordered to be fitted 27th.	12	Shaping	Cabling	Replaced	NaN
HVOC intlk	Thyratron failure. replaced ok	1	RFPower	Electrical	Replaced	Thyratron
Gfill interlock	Hot deck filament power supply changed	80	Gun	Electrical	Replaced	Hot deck fila
GFIL	Fault found with gun deck. hot deck power supply. Awaiting part. Hot deck backplane re	15	Gun	Electrical	Replaced	Hot deck fila
MLC fault	Leaf A25 not clearing IMRT checks. Lead screw and T-nut replaced. Target side A softpo	4	MLC	Mechanical	Replaced	Softpot and
MLC interlock	A13 & A59 motor changed. A side iso softpot changed. A13 leadscrew & Tnut changed.	2	MLC	Mechanical	Replaced	Motor and s
MLC	bad comms with linac. Interface PCB in MLC controller replaced.	2	MLC	Board	Replaced	PCB
MLC fault	Cleared ok	8	MLC	Mechanical	Repaired	NaN

Categorisation of faults

- Similar definition to Korean study of LINAC failure modes!
  (*The Journal of the Korean Society for Therapeutic Radiology and Oncology 2005;23(3): 186-193*)
  - **A = Minor fault**: requires quick reset and no investigation (< 5 mins)
  - **B = Minor investigative fault**: (usually) requires engineer to look further into fault but little action or minor fix required (> 5 mins and < 60 mins)
  - **C = Major fault**: failure of a component/system that causes significant downtime and requires the engineer to investigate (>60 mins)

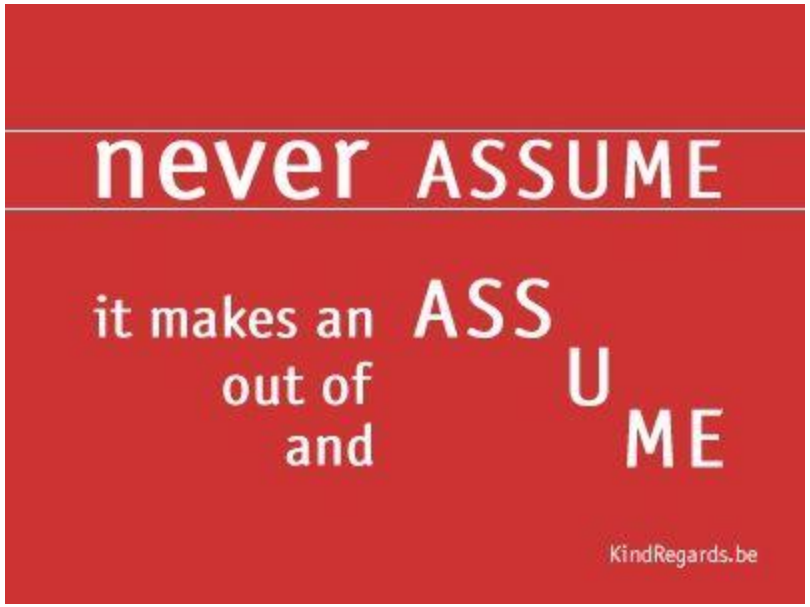
- In this analysis, we are exclusively looking at **LINAC** faults of **category C**

But….

- Recording of information differs between centres

- Requires **assumptions**…
  - All C faults are recorded
  - C faults are dominant
  - My categorization of faults is perfect (!)

- And estimations…
  - Some estimates of downtime



Categorisation in Korean LINAC Paper

- In order to briefly evaluate the effect of the equipment failure on the actual treatment work, the following can be investigated according to the severity of the failure
- In the event of a failure of the equipment, normal treatment is possible because the irradiation setting and treatment are not impaired. **(A)**
- Reduced ability to investigate: The basic ability of the equipment is temporarily deteriorated. However, if the equipment is rebooted or checked, it is possible to perform normal treatment by checking or replacing it. **(B)**
- Unable to investigate: If it is impossible to perform normal treatment due to equipment failure and it causes obstacle to the treatment of the patient (if repair is needed for a long time). **(C)**

장비 고장이 실제 치료 업무에 미친
평가하기 위해 고장을 경중에 따라 아래
조사능력저하, 조사불가능 등의 3단계로
다.

(1) 조사가능(이하 "(A)"로 표기): 장
했지만 방사선 조사 설정 및 치료에 장
상적인 치료가 가능한 상태

(2) 조사능력저하(이하 "(B)"로 표기):
력이 일시적으로 저하되어 있는 상태,
팅이나 간단한 점검, 교체 등으로 정상
상태 (1시간 이내 복구 가능한 경우)

(3) 조사불가능(이하 "(C)"로 표기):
으로 정상적인 치료가 불가능하여 환자
래하는 경우 (장시간의 수리를 요하는

Indonesia Collaboration

Collaboration with Universitas Indonesia, Jakarta (Prof. Supriyanto Pawiro) - connection facilitated by Dr. M. Kasim (Oxford).

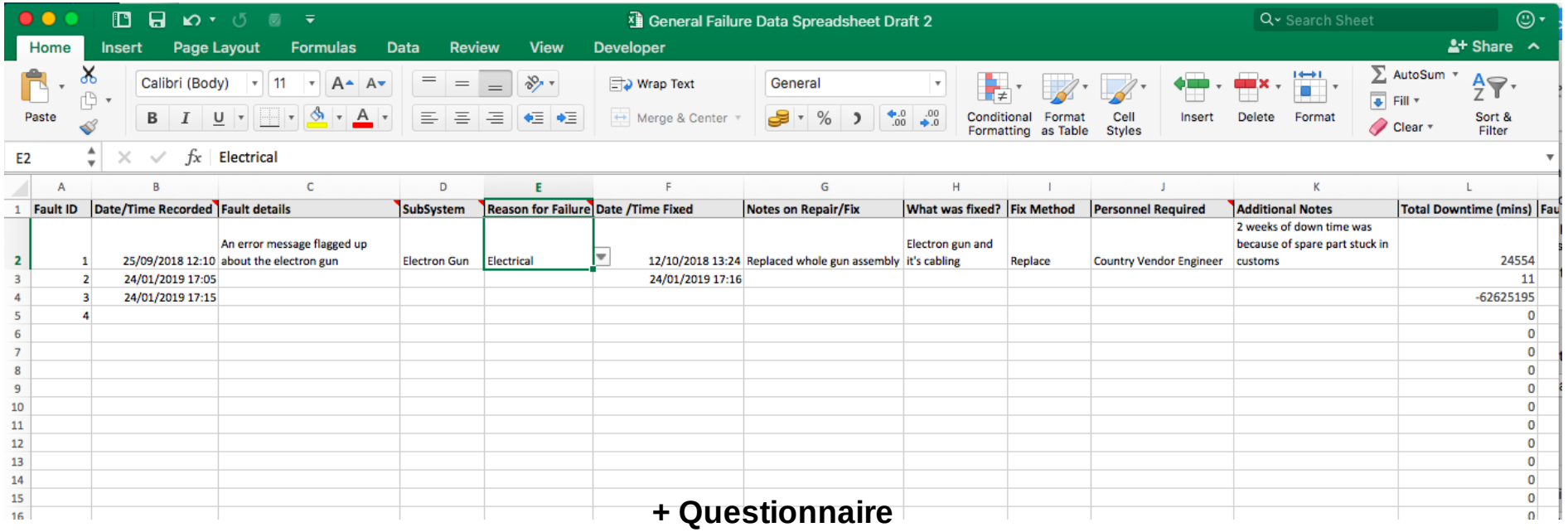
Ministry for Health is enabling our collaboration access to log book data from (all) the 15 hospitals with LINACs

Visited January 2019 to initiate collaboration, set up study & visit hospitals in Jakarta

Workshop ta), funded by Universi me). Will bring togethe ts who record ctise.

Visit to Cepto Hospital, Jakarta
(Private hospital with 3 LINACs)

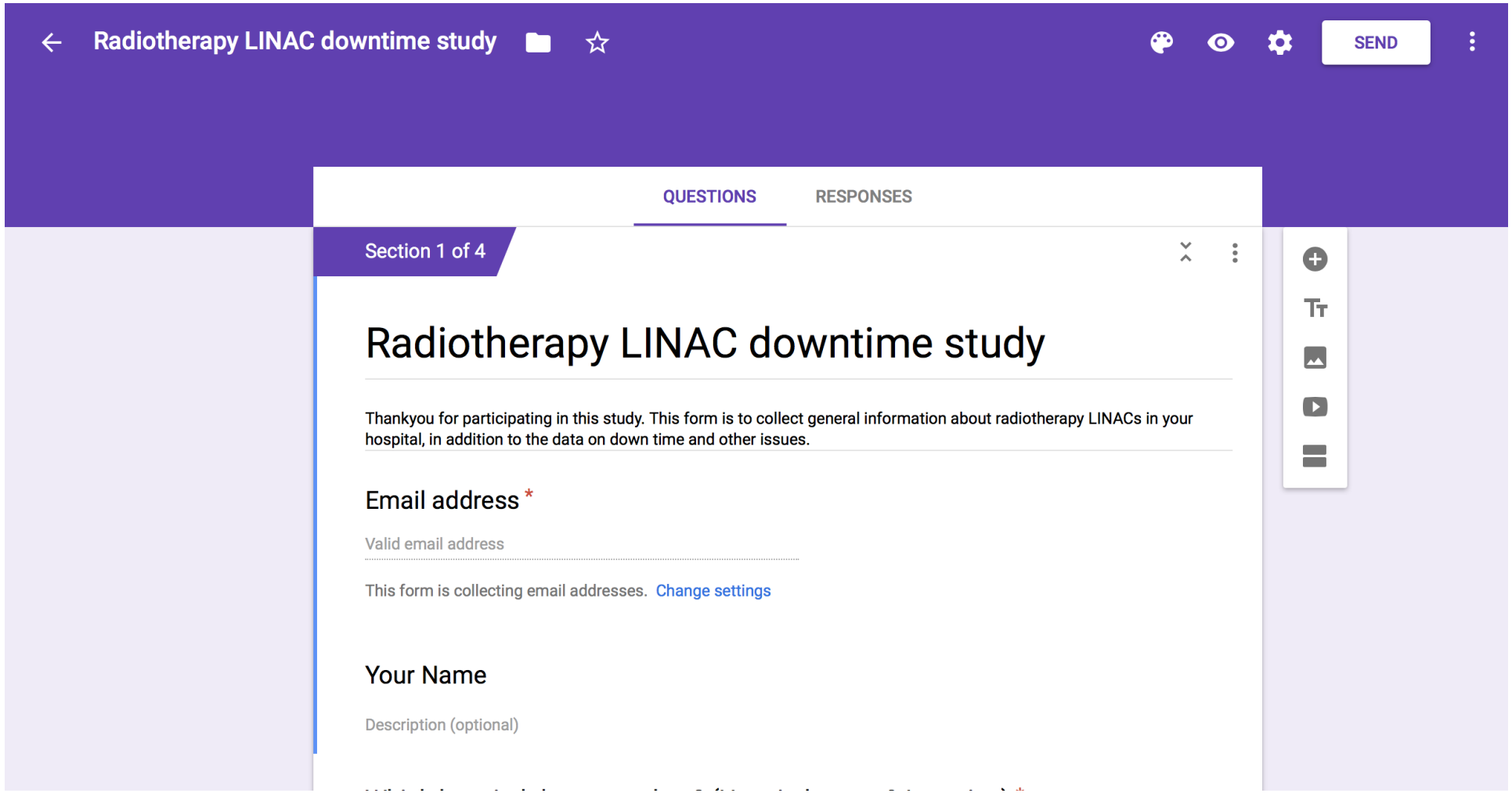
General spreadsheet for log data:



Fault ID	Date/Time Recorded	Fault details	SubSystem	Reason for Failure	Date /Time Fixed	Notes on Repair/Fix	What was fixed?	Fix Method	Personnel Required	Additional Notes	Total Downtime (mins)
1	25/09/2018 12:10	An error message flagged up about the electron gun	Electron Gun	Electrical	12/10/2018 13:24	Replaced whole gun assembly	Electron gun and it's cabling	Replace	Country Vendor Engineer	2 weeks of down time was because of spare part stuck in customs	24554
2	24/01/2019 17:05				24/01/2019 17:16						11
3	24/01/2019 17:15										-62625195
4											0

- As well as the ‘log book’ data, we want to record:
  - Which type of LINACs are used? Patients/day etc…
  - Service contracts or local engineers?
  - We also would like ‘context’ data i.e. challenges that led to significant down time (availability of spare parts, difficulty in procurement, politics etc…)

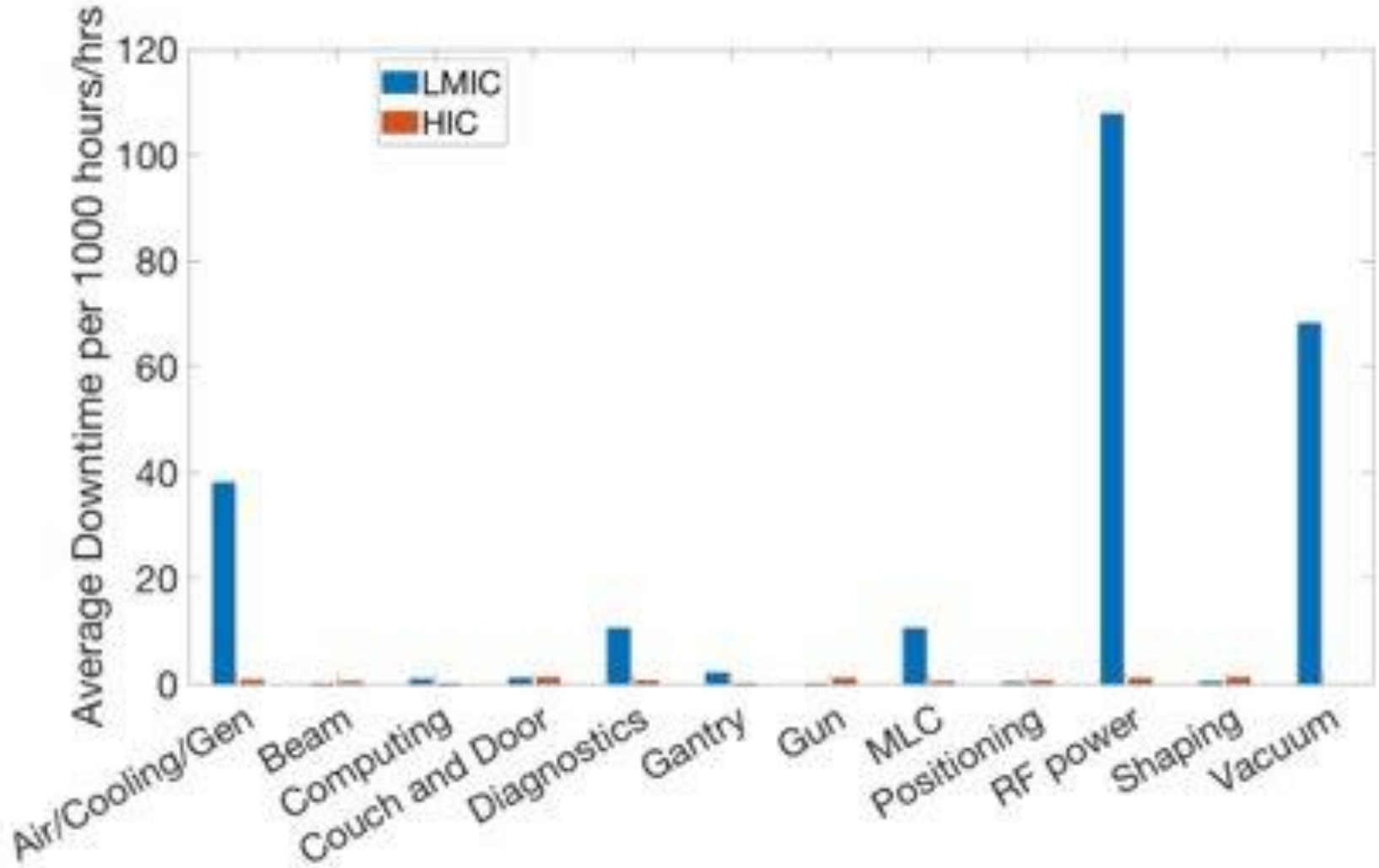
Google Forms Questionnaire:



Method so far

- Exclude data to **just C faults** (faults that take longer than 1 hour to fix)
- Exclude data to **only include the 'LINAC' and 'MLC' system**

- Now in order to compare, manually categorise the fault into the subsystem failed and the method of failure based on log book entry


Average Downtime per 1000 hours/hrs
120
100
80
60
40
20
0
LMIC
HIC
Air/Cooling/Gen
Beam
Computing
Couch and Door
Diagnostics
Gantry
Gun
MLC
Positioning
RF power
Shaping
Vacuum