Defining the challenges from the grass-roots perspective and delivering innovative Linac-based RT solutions

Taofeeq Ige and Manjit Dosanjh

27.04.2021

CERN

UNIVERSITY OF OXFORD

International Cancer Expert Corps
Partnering to transform global cancer care

UNIVERSITY OF ABUJA
FOR UNITY AND SCHOLARSHIP

NATIONAL HOSPITAL ABUJA

CANCER IS GROWING GLOBAL CHALLENGE

- Globally **18** million new cases per year diagnosed and **9.6** million deaths in **2018**
- Will increase to **27.5** million new cases per year and **16.3** million deaths by **2040**
- **70% of these deaths** will occur in low-and-middle-income countries (LMICs)

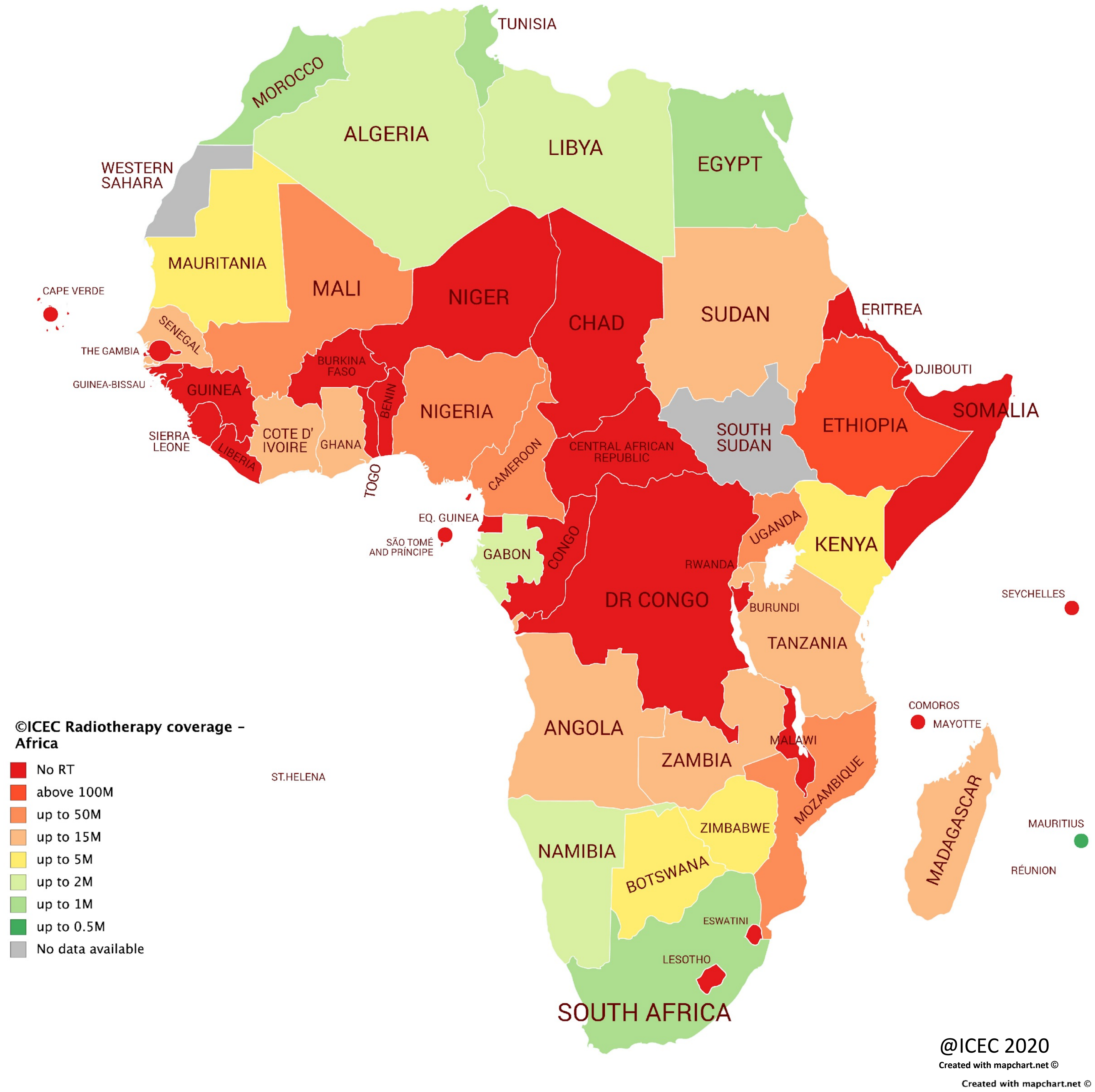
Radiation therapy is a key tool for treatment for over 50% patients and number of patients is increasing

LMICs have limited radiotherapy access: **Only 10% of patients in low-income** and **40% in middle-income countries have access to RT**

Map showing the number of people per functioning machine in countries in Africa

Dramatic Disparity in Access to LINACs

Country	LINACs	Population	People per LINAC
Ethiopia	1	115 M	115,000,000
Nigeria	7	206 M	29,400,000
Tanzania	5	59.7 M	11,900,000
Kenya	11	53.8 M	4,890,000
Morocco	42	36.9	880,000
South Africa	97	59M	608,000
UK	72	67.M	195,000
Switzerland	540	8.6 M	119,000
US	3827	331 M	87,000



- **28** countries have LINAC-RT facilities
- **12** countries only one facility
- **27** no LINACs for RT
- **385** RT-LINACs for > **1 billion** people
- **Nigeria** had 85 radiation and clinical oncologists and only a couple of trained linear accelerator maintenance engineers for its nearly 200 million people

CHALLENGES

- Acute Shortage of RT services both in quantity and quality in AFRICA especially in ECOWAS (15 Member States)
- Only 5 (+1) Member States (CIV, GHA, MLI, NIR , SEN) currently have RT machines. TOGO commissioned a new LINAC just last month in a Private facility.
- BKF and NIG have made progress with building (bunkers) infrastructures
- LINAC technology requires strong, robust and reliable infrastructure (power, clean water, supply chain etc.) to operate and often difficult to access.
- Paucity of properly trained personnel's – resulting in both internal and external brain drain.
- LINAC servicing can be slow and very expensive. Service contracts are expensive and often not always purchased – Long down times (months or more).

RECOMMENDATIONS

- Regional (AU – African Union) and Sub-regional entities like ECOWAS should play a catalytic function in addressing the cancer conundrum in Africa by harnessing and deploying resources in the establishment of RT and other ancillary infrastructures. Should also facilitate cross-border and seamless access to treatment facilities in the countries within the region.
- National Cancer Control Programmes should be instituted in the Member States that have none as this is a veritable metrics to monitor the progress or lack of it in the Cancer minimization and eradication efforts.
- Bilateral and Multilateral partnerships should be explored to fully or partially fund the purchase of equipment and training of all cadres of staff like the IAEA's counterpart funding scheme and the assistance of international NGO's like ICEC etc.

Current status

- The burden of cancer is increasing globally
- Large shortfall in LIC and LMIC RT systems that are needed for effective cancer care
- LINAC-based RT is the current technology of choice

But LINAC technology is **complex, labour intensive, and high cost** to acquire, install, operate and service.

Can we use technology developments to address the current challenges and make RT more widely available?

1st workshop on: “Design Characteristics of a Novel Linear Accelerator for Challenging Environments”

Norman Coleman(ICEC) David Pistenmaa (ICEC) Manjit Dosanjh (CERN)

http://indico.cern.ch/event/560969/

European Organization for Nuclear Research (CERN)
International Atomic Energy Agency (IAEA)
James Martin Center for Nonproliferation Studies (CNS)
National Aeronautics and Space Administration (NASA)
National Nuclear Security Administration (NNSA)

Medical Linacs for challenging environments

- 1^{st} Design Characteristics of a Novel Linear Accelerator for Challenging Environments, November 2016, CERN
- 2^{nd} Bridging the Gap Workshop, October 2017, CERN
- 3^{rd} Burying the Complexity Workshop, March 2018, Manchester

- 4^{th} Accelerating the Future Workshop, March 2019, Gaborone

CERN

International Cancer Expert Corps

Partnering to transform global cancer care

UKRI

Science and Technology Facilities Council

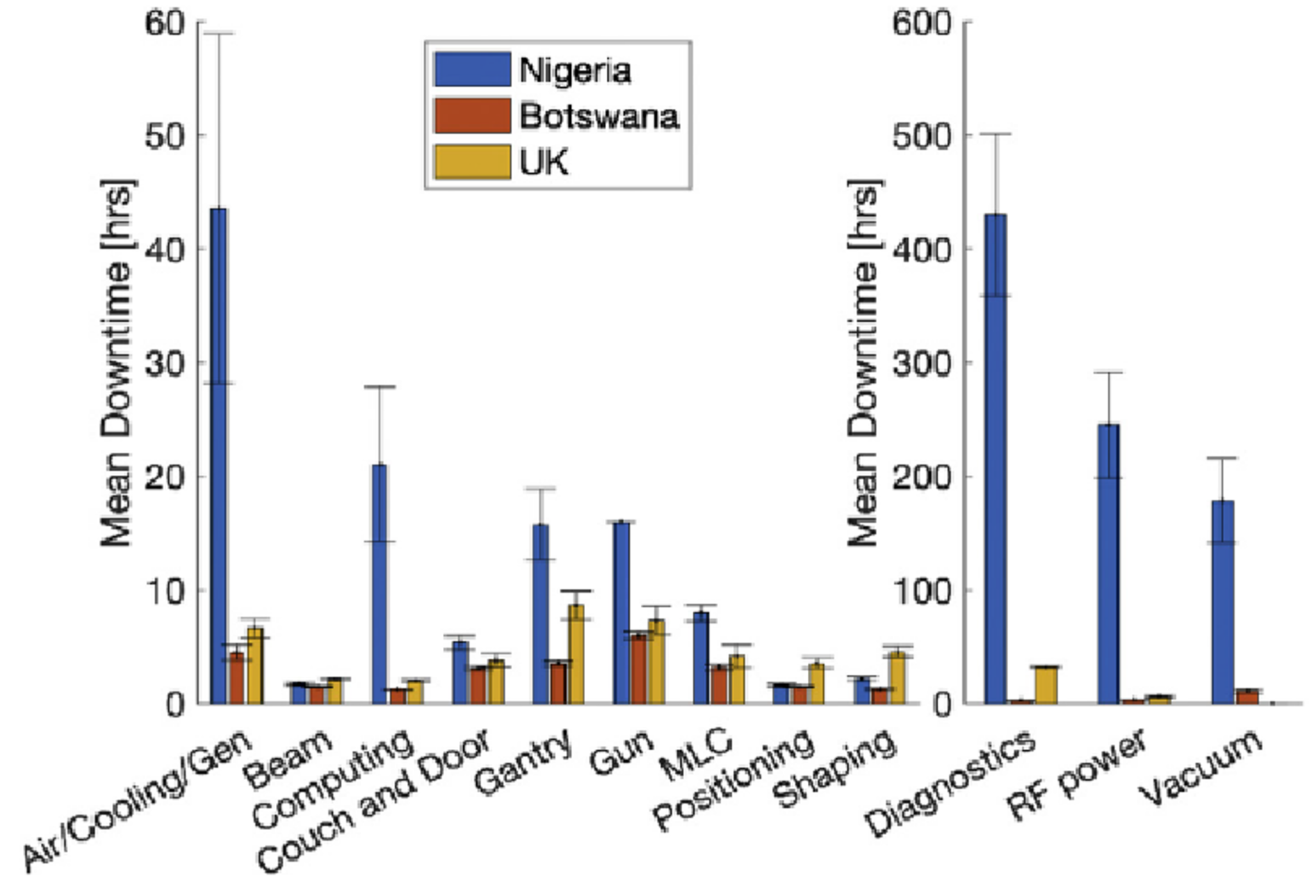
Project STELLA

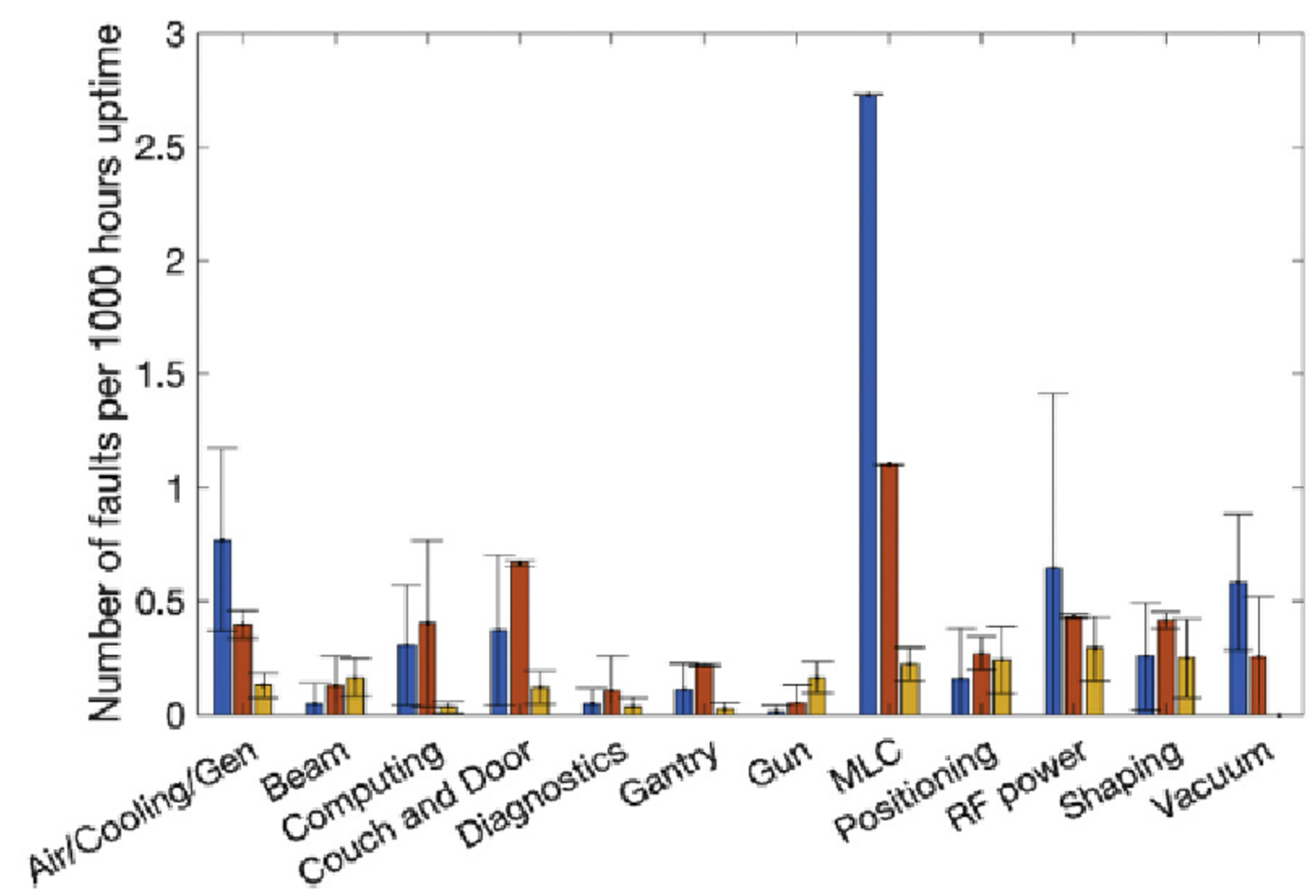
Smart **T**echnologies to **E**xtend **L**ives with **L**inear **A**ccelerators

Project STELLA is a unique global collaboration involving some of the **best physics** and **medical talent, expertise from leading laboratories in accelerator design** and, importantly, **input and collaboration** from users in **Africa, other LMICs** and **HICs.** The goal of this project is to design disruptive technology for the treatment of cancer patients with radiation therapy.

Initial Failure Report Gaborone (Botswana)-Abuja (Nigeria)-Oxford (UK) (Sheehy Melbourne/Oxford)

- Not all failures and repairs are created equal.
- Nigeria has far longer repair times than in the UK, the repair hub is normally in a different continent or South Africa and maintenance is often not to the same standard
- Interestingly Botswana which is a fairly affluent country and pays for manufacturer's warranty, service and repair has similar downtime with more faults
- MLC (multi-leaf collimator) has the most faults but diagnostics, RF and vacuum contribute to the longest downtime



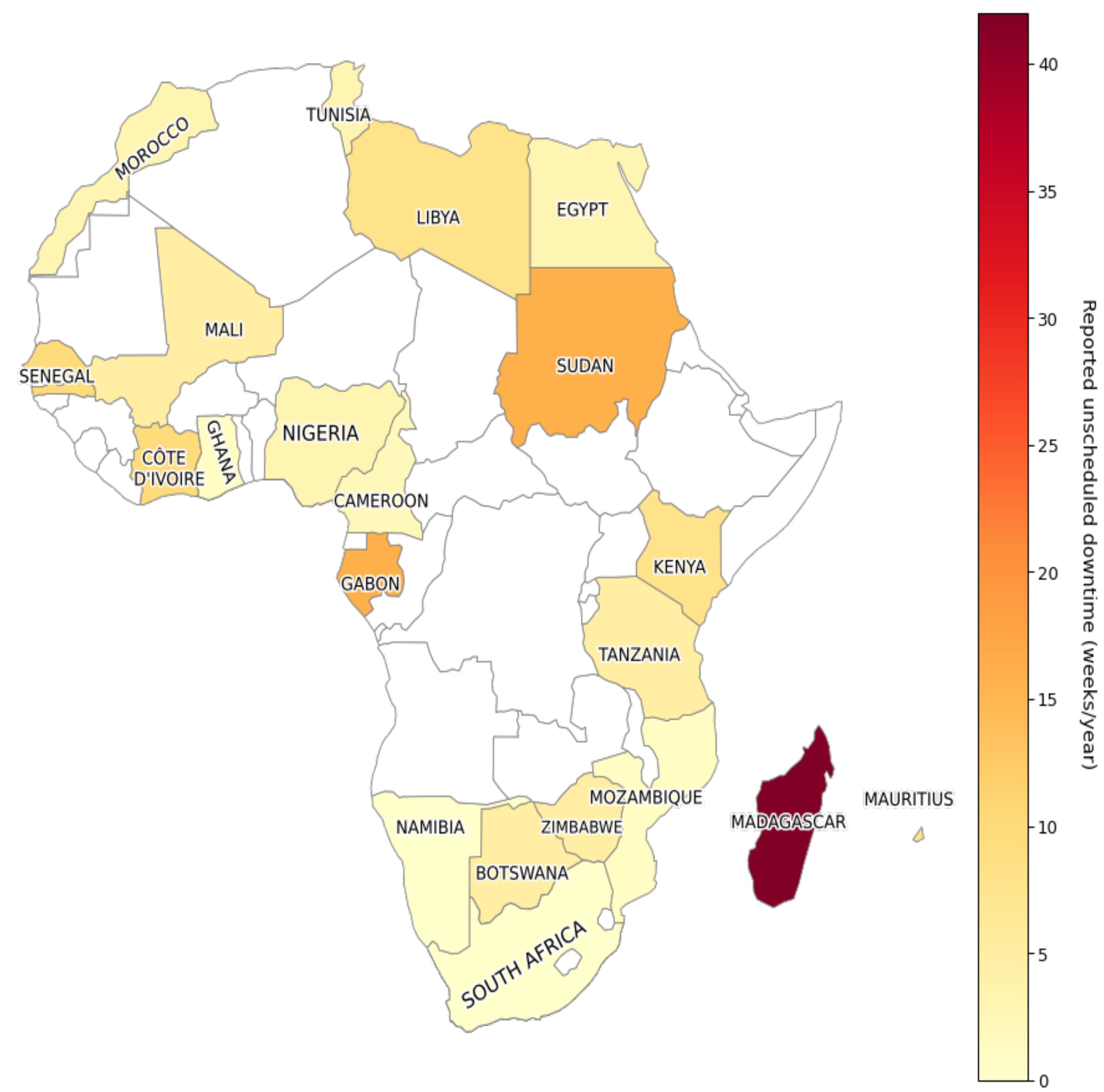


Innovative Technologies towards building Affordable and Equitable Global Radiotherapy (ITAR)

- **Gather information** from African hospitals/facilities regarding challenges faced in providing radiotherapy in Africa
- **Identify** the challenges with those who live with them day-to-day
- **Create design specifications** for a radiotherapy machine to meet these challenges for an improved design
- Assess applications of **ML, AI and use of cloud-computing** in African and LMIC settings
- **Technical design report** for a prototype

Survey to determine what causes downtime?

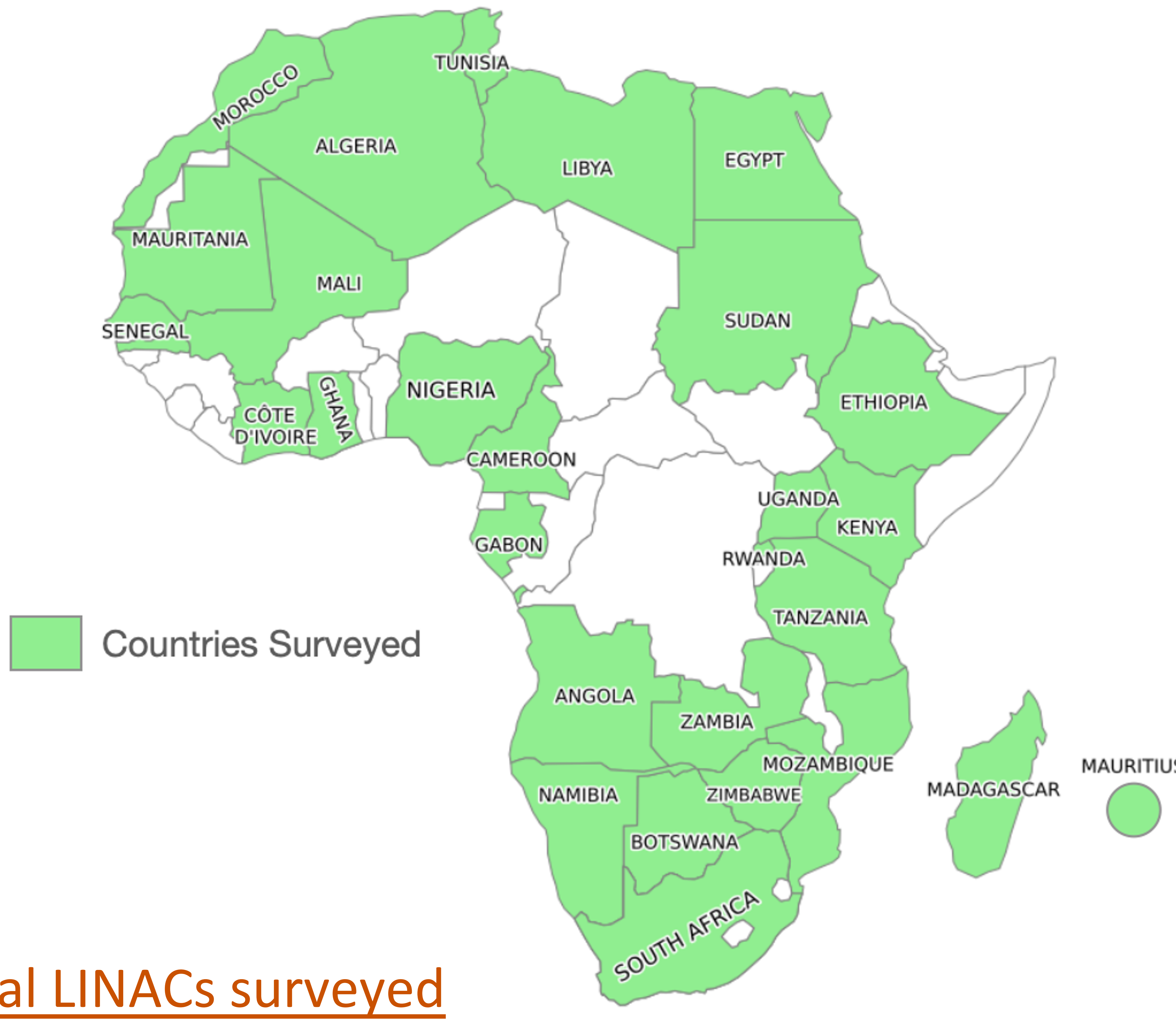
Focus	Questions
Model	What manufacturer and model? Year of installation?
	What number of treatments are performed per year on each machine?
Environment	What is the temperature and humidity in the area?
	What is the speed and availability of the internet connection?
	How reliable is the electricity supply?
	What is the floor area and ceiling height of the shielded area?
	What photon energy is your shielded area able to safely operate at?
Services	Do you have a service contract? Who provides it? What is the annual cost?
	How often does the machine have maintenance/tuning/calibration?
	What type of failures can you repair locally?
	Number of staff available for in-house repairs? Are staff formally trained?
Subsystems	How do you identify machine faults? Is it easy?
	Do you have problems with the vacuum system? How often?
	Do you have problems with the vacuum pump? Do you keep spares? Can you repair locally?
	Do you keep spare RF sources? Can you repair locally?
	Do you have problems with the MLC? Do you keep spares? Can you repair locally?
	Do you have problems with the electron gun? Do you keep spares? Can you repair locally?
	How much down-time do you experience?
	Do you have any software problems?
Treatment and Imaging	Does your hospital have diagnostic CT near the radiotherapy area?
	Do you use a tilting Couch? How important is this feature?
	How important is it for a LINAC to offer electron treatment mode?



Map showing breakdown time

Data African countries that have LINAC-based RTand from HICs

Country	Total number of LINACs surveyed
UK	25
USA	14
Canada	11
Switzerland	2
Jordan	1



Total LINACs surveyed

HICs: 52

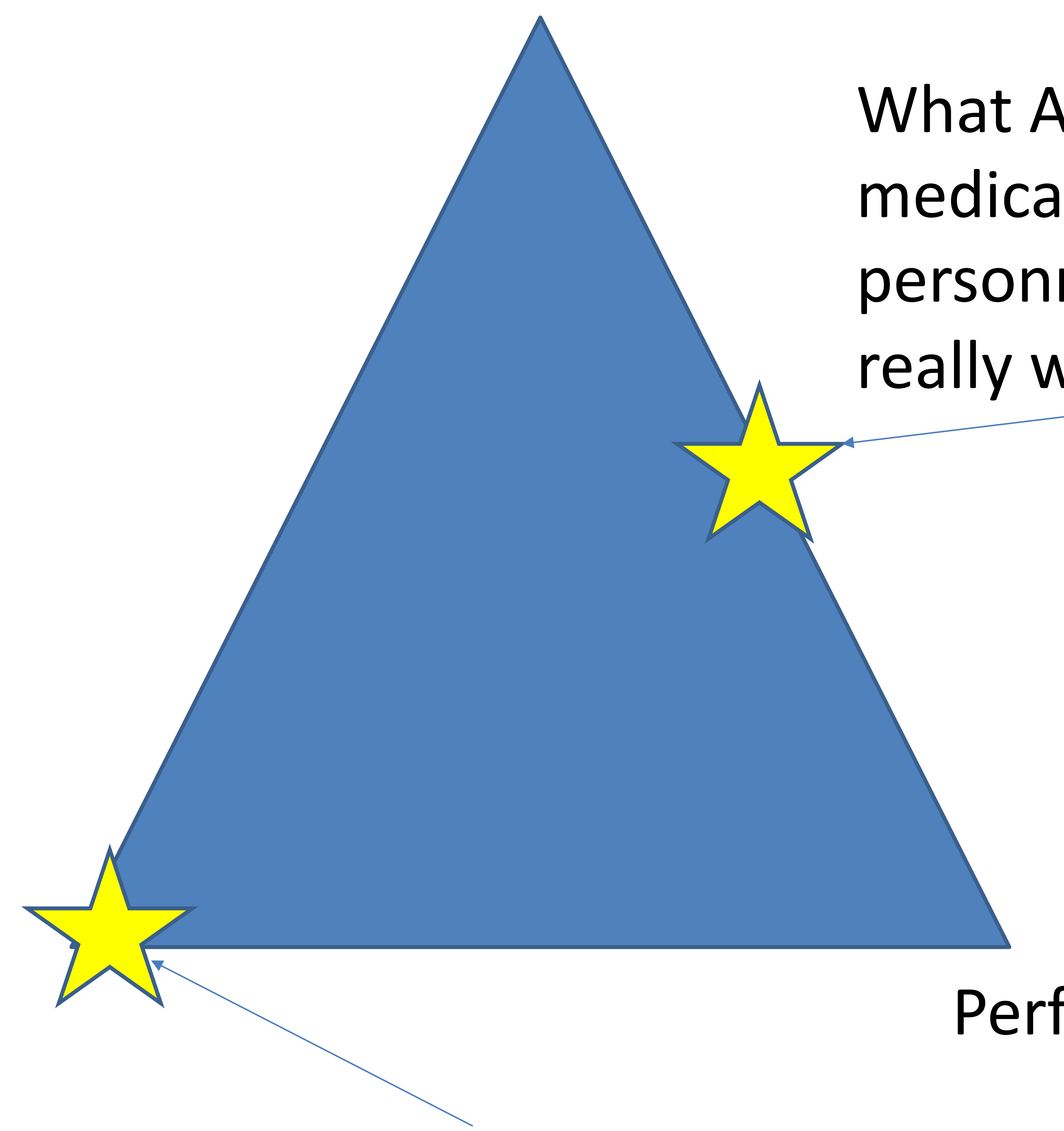
Africa: 59

Biggest issues in LMIC hospitals

Lancaster University

Graeme Burt

- Delays in repairs
- Lack of funds for regular maintenance
- Lack of trained engineers
- Fluctuating electrical supply
- Corruption



What isn't wanted

- Cheap, poorly made linacs and second-class treatments

Summary of current findings

- Local repair and access to parts significant factor determining downtime
- Software problems are a major contribution to downtime
- Frequency and voltage fluctuations also appear important
- Current data suggests- component importance on downtime: **Electron Gun**, **Vacuum Pump, MLC, RF source, Software, Power Fluctuation**

Analysis by Alexander Jenkins

ITAR Project Goals

- Key issues to tackle and goals in order of priority created from reviewing the various surveys, data gathering exercises, failure mode data and a workshop
- It was clear that not everything the survey respondents wanted can be realised in a single machine.
- High Priority:
  - staff training and skills requirements to run a radiotherapy machine,
  - the difficulties/technical failures and cost of repairing them
  - frequency of failures (i.e. component lifetime).
- Medium Priority:
  - making the electrical system robust to fluctuations and minimising the power requirements
  - Delivering higher dose rates
  - the cost of spare parts
  - initial capital cost
  - robustness to temperature fluctuations and dust.
- Low priority:
  - size of the machine.
  - total machine lifetime (as opposed to component lifetime)
  - easily upgradable.

Key design choices (ITAR) and studies

- Key goal is higher availability!
- Repairs are difficult & reduce availability - prefer components that are less likely to break or can be repaired in house with cheap spares
  - improve the lifetime of components
  - AI/ML systems to predict faults in advance and the cause
- Beam
  - use a standard compact radiotherapy specification of a 6 MeV single energy electron beam with photons for treatment
  - improve the efficiency of beam delivery
- Impact of linac parameters on X-ray beam parameters studied in detail

Ultimate Goal for STELLA

- Robust, modular, reliable and simple to use machines
- Are affordable
- with the aim to: **expand access to RT**

STELLA is looking at innovative design for reduction in acquisition and operating costs ensuring more improved LINAC access and a **mentoring and training program for a sustainable solution**

Such an ambitious project not be possible without ICEC, ITAR, STELLA teams and our colleagues from the grass-roots http://www.iceccancer.org/

This work would not be possible without the great collaborators:

- ICEC, ITAR, STELLA teams and our colleagues from the grass-roots
  http://www.iceccancer.org/

Thank you for listening