A rethink of the linear accelerator for resource-limited environments

Manjit Dosanjh and Taofeeq Ige

AAPM Session on Affordable Cancer Care for All

UNIVERSITY OF OXFORD

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 and expand access globally?

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

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

- 4th 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.

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
- **Concept design report** for a prototype

STELLA questionnaire - data gathering

Overview

We asked a range of questions shown in the table to at least one facility in all African countries with RT access.

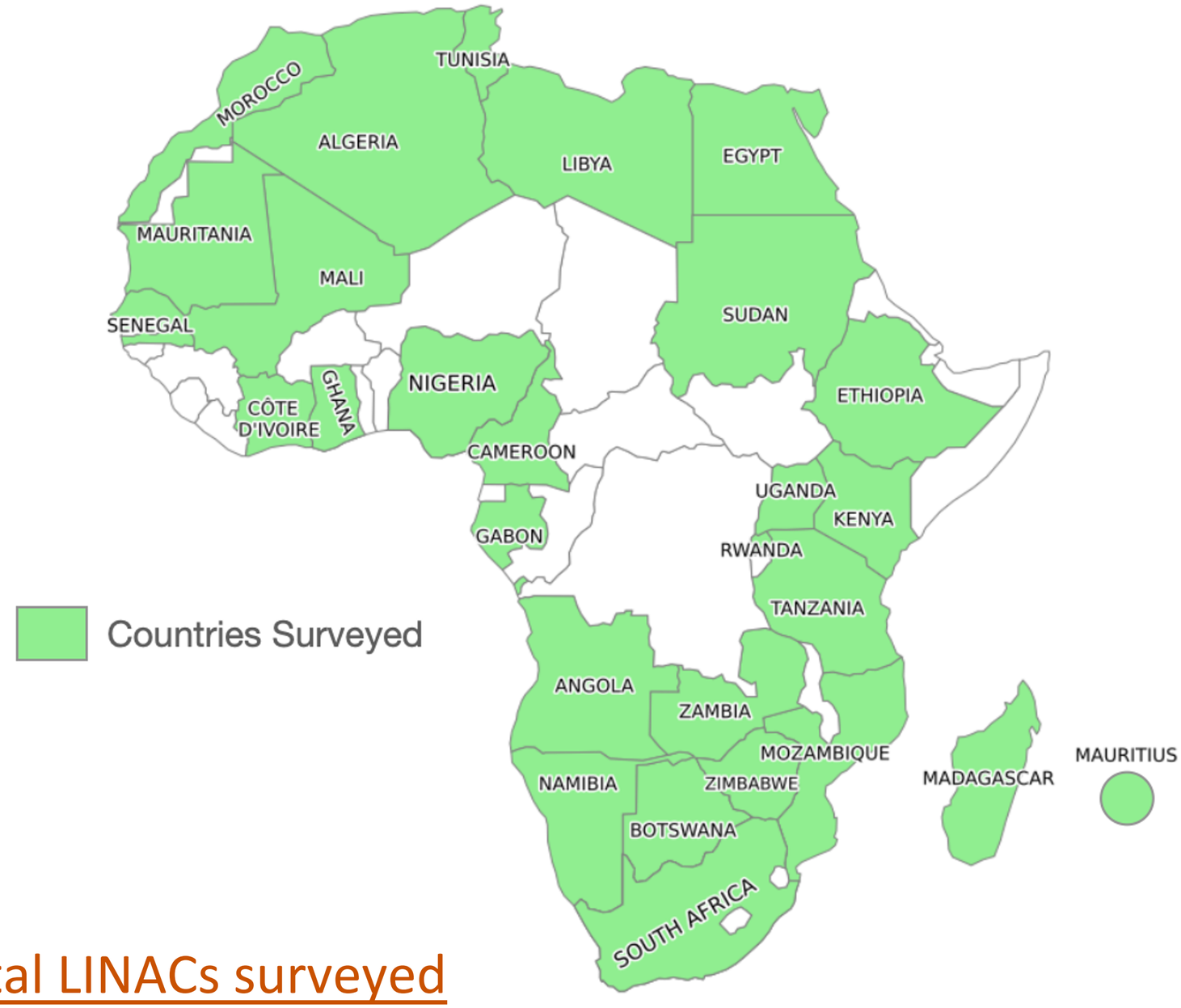
We examined: the LINAC model, environment, services, subsystems, treatment and imaging.

Also sent the survey to facilities in the UK, Canada and the USA, for comparison.

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?

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

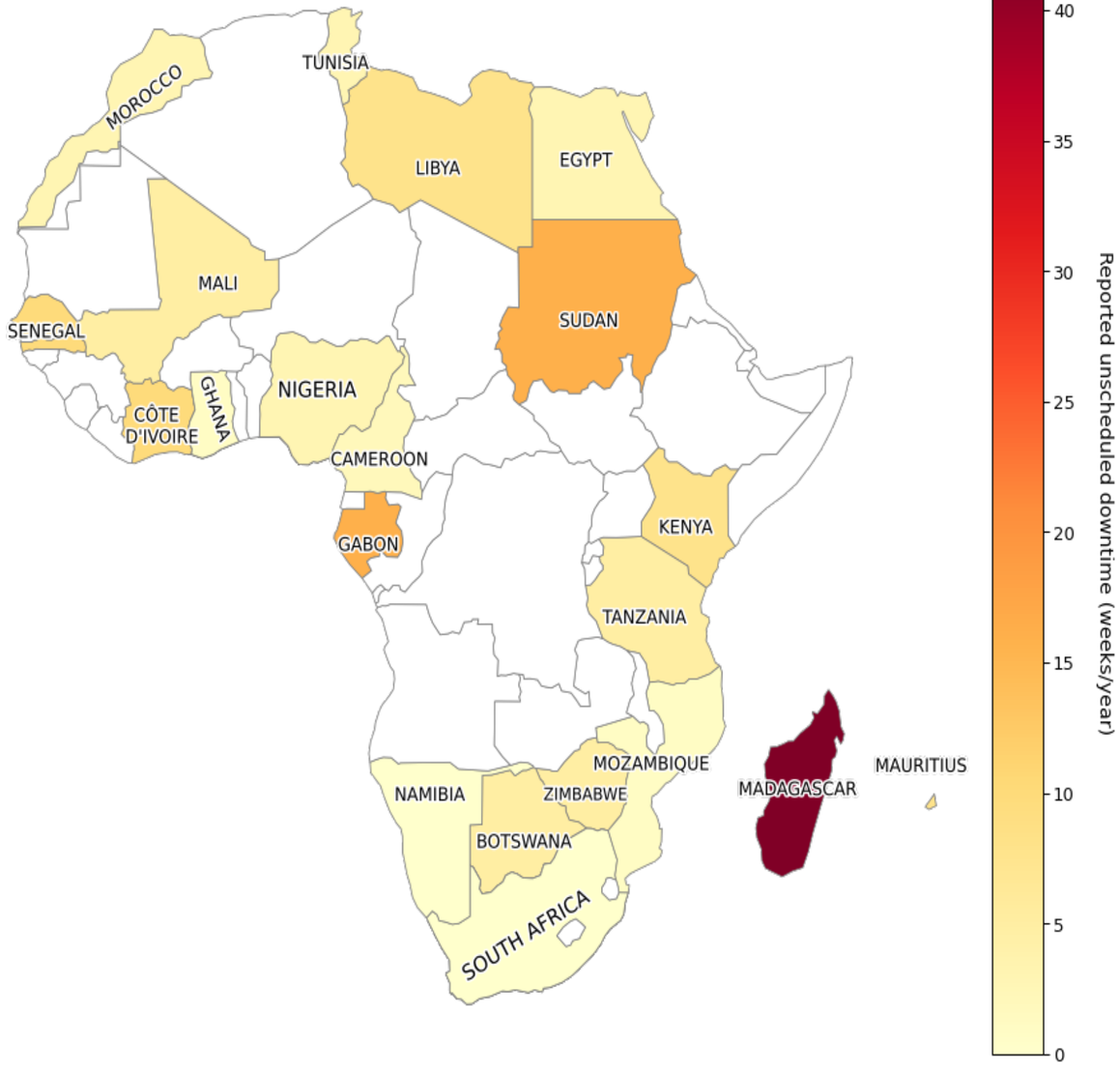
HICs: 52

Africa: 59

Map showing experienced downtime

What is actually responsible for this downtime?

- We are investigating the impact of different responses on machine downtime.
- Univariate and multivariate analysis: observe how distributions of downtime vary for facilities grouped by question response.
- Also surveyed facilities in the UK, Canada, Switzerland and the USA, for comparison.



Biggest issues in LMIC hospitals

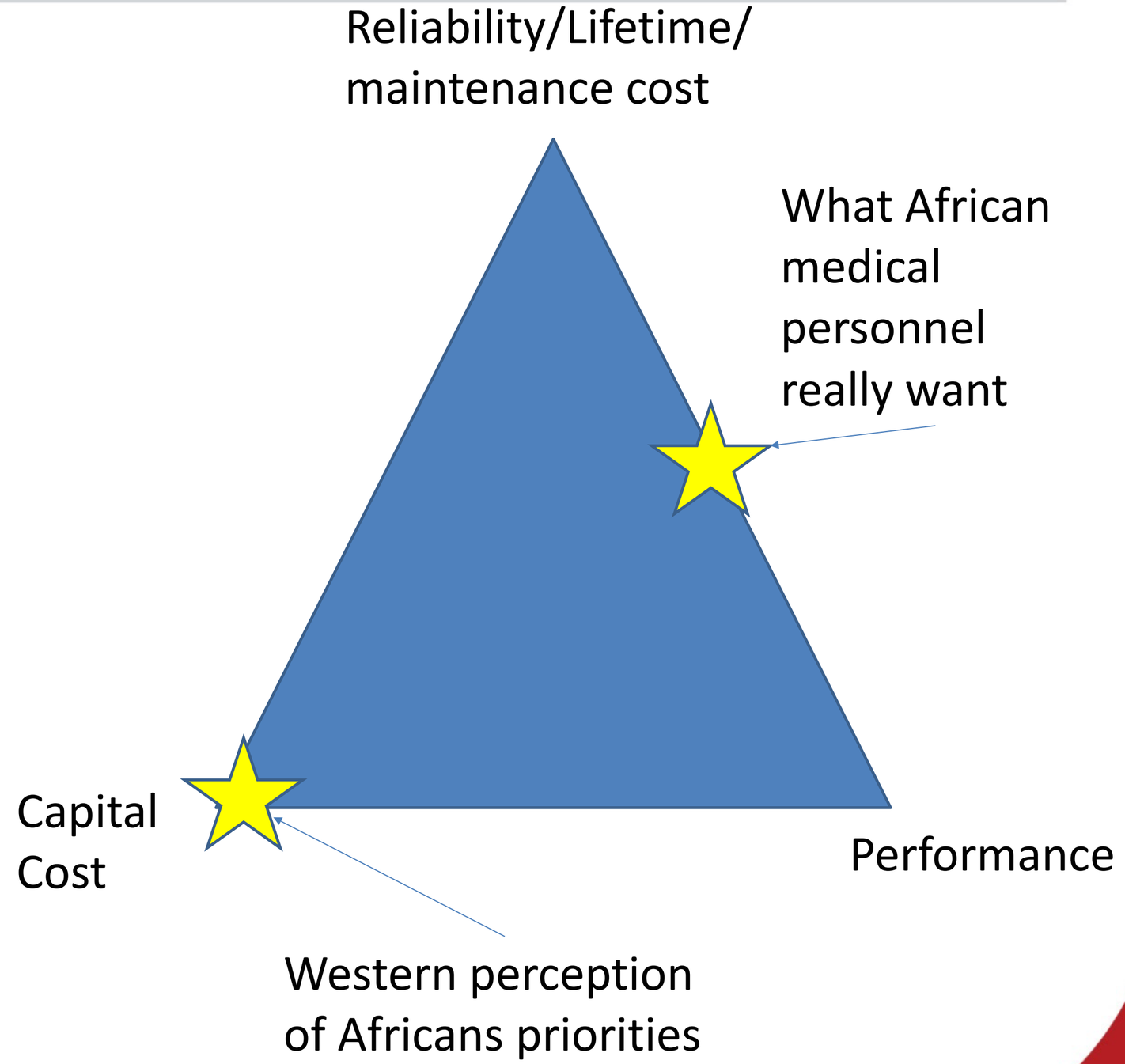
Lancaster University

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



Project Goals for RT-LINAC

- **Key issues** from reviewing **the various surveys, data gathering exercises, failure mode data and discussions at workshops**
- Categorisation Priorities:

Machine	• Severities and cost of repairing technical failures • Frequency of failures (i.e. component lifetime) • Easy upgradability • Size of the machine
Environment	• Making the electrical system robust to fluctuations and minimising the power requirements • Robustness to temperature fluctuations and dust • Initial capital cost and the cost of spare parts • Delivering higher dose
Staffing	• Staff training and skill requirements to run a RT machine • Ongoing education, mentoring and sharing experience

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**

Ultimate Goal

- 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

This work would not be possible without the great collaborators:
ICEC, ITAR, STELLA, LMIC Colleagues https://www.iceccancer.org/

Recommended Reading

- Atun R, Jaffray D, Barton M et al. Expanding global access to radiotherapy. *Lancet Oncol* 2015;16(10):1153-1186.
- Pistenmaa, D., Coleman, C.N., and Dosanjh, M.K.; Developing medical linacs for challenging regions (2017): http://cerncourier.com/cws/article/cern/67710
- Dosanjh, M.K et al Developing Innovative, Robust and Affordable Medical Linear Accelerators for Challenging Environments (2019): Clinical Oncology, doi.org/10.1016/j.clon.2019.02.002 https://www.clinicaloncologyonline.net/article/S0936-6555(19)30055-X/fulltext
- Ige TA et al., *Surveying the Challenges to Improve Linear Accelerator-based Radiation Therapy in Africa: a Unique Collaborative Platform of All 28 African Countries Offering Such Treatment,* **Clinical Oncology,** https://doi.org/10.1016/j.clon.2021.05.008
- Pistenmaa, D., Dosanjh, M.K., et al. **Perspective**: Changing the Global Radiation Therapy Paradigm: Design Characteristics of a Novel Linear Accelerator for Challenging Environments (In press with Radiotherapy and Oncology, June 2018, Radiotherapy and Oncology, DOI: 10.1016/j.radonc.2018.05.025
- Coleman CN et al. *Capturing acquired wisdom, enabling healthful aging and building multinational partnerships through senior global health mentorship* Global Health: Science and Practice, October 2020, https://doi.org/10.9745/*GHSP*-D-20-00108.