Nuclear Research in South Africa and on the African Continent

Z. Z. Vilakazi, iThemba LABS
Note:
The presentation has a bias on South Africa: Apologies for any omissions – largely a function of lack of detailed knowledge of the continental landscape.
1-The Inshas Cyclotron Facility (ICF) (Egypt)

Other Names: Cyclotron Project, MGC-20 Cyclotron
Location: Nuclear Research Center (NRC), Inshas (NE Cairo suburb) Subordinate to: Atomic Energy Authority (AEA)

Size: 20 MeV

Status: Operational

Description: The ICF is a multipurpose R&D facility based on the Russian MGC-20 AVF cyclotron. A Russian supplier (The NIIEFA Institute, St. Petersburg) signed a contract to supply the facility to Egypt in 1991.
Inshas Tandem Accelerator
Other Names: Tandem Electrostatic Accelerator
Location: Nuclear Research Center (NRC), Inshas (NE Cairo suburb) Subordinate to: Atomic Energy Authority (AEA)
Size: 3 MeV
Status: Under commission, possibly operational
1-Centre national pour la Recherche Nucléaire Appliquée/Division VDG Other Names: CRNA 3.75MV VDG Location: COMENA Algiers Subordinate to: Commissariat à l’Énergie Atomique Size: 3.75MV Status: Operational
Nigeria

1-Centre for Energy Research & Development Pelletron Tandem Accelerator Other Names: CERD 1.7 Pelletron Location: CERD-Ife Ife (Osun State) Subordinate to: Nigerian National Nuclear Commission Size: 1.7MV Status: Operational
Beginning of Nuclear Research in SA

• 1948 – 1950: At CSIR, newly appointed head of the Nuclear Physics Division sent to the Nobel Institute in Stockholm to do Nuclear Physics research with a classical cyclotron.

• 1950: Decision to design and build a 16 MeV deuteron classical cyclotron at the Nuclear Physics Division, CSIR

• JPF Sellschop (1956) proposes the establishment of a research accelerator at University of Witwatersrand

• Pioneering Neutrino experiments (led by F Riennes) in the mines of Johannesburg (circa: 1966)

CSIR: Council for Scientific and Industrial Research
Organisational changes in nuclear sciences in SA: 1953 - 1960

Time line

- '46
- '50
- '55
- ISOL
- '60

- ‘Biophysics’ & ‘Radioactivity’ Divisions of the NPRL
- ‘National Centre for Fundamental Nuclear Research and Training’ at the CSIR
  Nuclear Physics Division of the NPRL

Developments in Nuclear Science

- Honeymoon: PhD-students & Money
  Atomic Energy Program in CSIR

- Staff
  Independent AEB
  Divorce
Evolution of Nuclear Technology and Business at AEB

Research and Development Era – 1960 to mid 1970s

- SAFARI reactor operating at 20 MW and many other high level research and development programs
- Weapons Program [“Strategic” Era]

Strategic Era – mid 1970s to early 1990s

- PWR and SAFARI fuel Manufacture
- PIE program and facilities
- Isotope Production

Commercial Era – early 1990s
The dream of a multi-disciplinary medium energy national accelerator ~1964

Limited useful life of the cyclotron (and of all other nuclear accelerators in SA).

* Started discussing the use of medium energy particle beams in nuclear physics;

* Investigated the use of high intensity medium energy beams in isotope production.

Monitored the development of the open sector cyclotron concept, as a viable multi-disciplinary medium energy accelerator - started a low key theoretical study of it.
1. Meeting - 1966: Nuclear physicists & chemists (OSC versus Tandem v d Graaff for NAC)

Referendum on accelerators: 76% supported OSC
Outcome circulated 1971

Nuclear medicine

Southern Teaching Hospitals:
Tygerberg Hospital (major isotope user)
Groote Schuur Hospital (Interest in compact cyclotron for isotopes & neutron therapy - funds promised by Cape Prov. Admin)

Feasibility study for a NAC 1973 Approved by Cabinet CPA funding of R200000

3. - 1972 UCT & US SUNI

Cape Provincial Administration

Universities with interests in nuclear physics

AEB

CSIR NPRL Nuclear Physics

Scientific Advisor - PM

Government
Aerial View of iThemba LABS
iThemba LABS
Core Activities

- Nuclear physics research
- Materials research
- Radionuclide production
- Proton and Neutron Radiation Therapy, Clinical Research
- Accelerator research and applications
- Post graduate research and training
- Technical in-service training
The iThemba LABS Cyclotron
Separated-Sector Cyclotron Facility

- Polarized ion source
- ECR ion source
- Radioisotope production
- Proton therapy
- Neutron therapy

K=600 Spectrometer
The Separated Cyclotron Facility

AFRODITE Array
The Separated Cyclotron Facility
Proton Therapy
Neutron Therapy
Currently, iThemba LABS produces weekly the medical radionuclides $^{67}$Ga, $^{123}$I and $^{81}$Rb.

$^{67}$Ga and $^{123}$I are used to prepare radiopharmaceuticals for the local users.

$^{81}$Rb is used to manufacture the $^{81}$Rb/$^{81m}$Kr generator.

$^{82}$Sr is produced for use in medical generators to obtain the PET radionuclide $^{82}$Rb.

$^{22}$Na is produced to manufacture positron sources.
Single ended 6 MV Van de Graaff accelerator Research areas

Air pollution studies using PIXE and the dedicated beam line

Neutron beams – non-intrusive characterization of materials, imaging based on contrast of cross sections for neutrons, containerized waste management, explosives and drug detection

Solid-state beam line – collimated ion beam for RBS, ERDA Studies related to coatings, thin layers on a substrate, dynamics of the layer growth (reaction of layers in chamber with simultaneous RBS analysis), elemental diffusion channeling mode

Nuclear microprobe
Microanalysis using focused ion beams (protons, alpha particles)
NTP located at the Necsa Pelindaba Site
NTP Radioisotopes (Pty) Ltd

a subsidiary of Necsa Ltd.

Pelindaba, South Africa

www.ntp.co.za

Reliable suppliers of world-class radiochemicals, radiopharmaceuticals and radioisotope products to Health Care, Life Science and Industrial markets throughout the world.
Status at the End of the Strategic Era

- An underutilised reactor
- MTR fuel manufacturing plant
- Inventory of HEU
- A large hot cell facility
- Inventory of depleted uranium
- Waste disposal facilities
- Core competency in theoretical and experimental reactor physics
- Chemists experienced in isotope separation technology
- High technology manufacturing workshops
- Extensive expertise in hot cell design, construction and operation
Nature of the Global Mo-99 Market

Demand per Region – Normal Conditions

- US: 51.6%
- Europe: 22.8%
- Japan: 11.2%
- South America: 6.0%
- Australia: 2.6%
- Asia / Middle East: 3.6%
- ROW: 2.2%

Supply - Normal Conditions

- MDS Nordion: 40.5%
- IRE: 12.0%
- Covidien: 29.0%
- NTP: 17.7%
- Others: 0.6%

Demand – Normal Conditions

- Covidien (US): 21%
- LMI: 30%
- GEH: 8%
- IBA: 6%
- Covidien (Eu): 6%
- NMP: 6%
- Fuji: 6%
- Others: 16%

Supply - Crisis Conditions

- ARI: 5%
- NTP: 40%
- IRE: 30%
- Covidien: 25%

Total: 12 000 Ci/week

Total: 8 000 Ci/week
Part II

Energy Imperative
South Africa ...

- Has very large reserves of uranium and a very active mining industry on which many other countries will rely for their supplies of uranium.
- Can add value to the uranium that it produces by enriching it, in order to maximize its earnings in export markets.
- Has already developed and used substantial facilities for the conversion and enrichment of uranium. These were dismantled but the expertise was developed and still exists in SA.
- Built a nuclear fuel fabrication factory and a plant for making zircaloy tubing. These were used to make the fuel for Koeberg. They were taken out of service when SA discovered that it could obtain the fuel more cheaply by purchasing it from other suppliers. The expertise was however fully developed and still exists in SA.
Possible Nuclear Energy Scenario for South Africa

- 10 GW (1000 MW) nuclear power in SA by 2020
  - SA’s current grid load is 36 GW
    - 4 new LWRs acquired by Eskom
    - 24 PBMRs acquired by Eskom

**Trajectory for Nuclear R&D:**

- Upper limit of 2500 tons U per annum required, so enrichment not economical
  - PBMR Fuel manufacture
    - PBMR reactor
  - Waste management
  - Applications of radiation

*Rob Adam, NECSA*
Science advancement

Interventions aimed at promoting an awareness and appreciation of science amongst learners (primary and secondary schools), teachers and the general public through interactive workshops, science shows, public lectures, and publications.
Participation of SA in CERN

- **Cape Town in ALICE:** currently 6 senior staff + several students
  - UCT joined **2001**, became **UCT-CERN** research center in **2003**
  - iThemba Labs joined in **2008**

- **Projects**
  - **Dimuon Arm:** algorithms for online High Level Trigger (dHLT, commissioned in 2008)
  - **Grid Computing:** Computing Cluster integrated into ALICE GRID
  - **Physics:** Dimuon studies (acceptance, efficiency); W production in pp; ..

**HLT data challenge:**
- Online test on ‘Grid’
- Test latency tolerance
- Run stable for > 15 hours
- Rate limited by bandwidth


UCT group 2004
Overall Conclusions

• SA will significantly increase its nuclear power capacity over the next 20 years.

• SA has a long history of leadership in the field of Nuclear sciences and technology
  – Steps for building capacity in Nuclear Research need to be accelerated
FUTURE VISION of the SA Nuclear Research Landscape

iThemba LABS: Key node in African network of Sub-Atomic Science & Technology

Centre for Nanoscience; AMS facility

iTLPTC (iThemba Particle Therapy Centre)
  Growth: Training, Patients, Research

Radioactive Ion Beams; NEW flagship of iThemba LABS
  Nuclear Physics & Materials Science

Developing new products and market for Radionuclides.
THANK YOU
Medical Physics : Dr. Dan Jones (iTL: ret)
Nuclear Medicine : Prof. Ellman (Stellenbosch U.)
PET-CT : Prof. M. Sathekge (U. Pretoria)
Members of iTL Accelerator Department
Prof W Rautenbach (CSIR: ret.)

- Dr Rob Adam & R von Gogh (Necsa)
- Prof. J Sharpey-Schafer (ex director: iTL)