Accelerator Decommissioning

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HPS VA Chapter Meeting, Richmond, April 24, 2015
Outline

• Background
• Accelerator characteristics: types, classes, critical components
• Decommissioning process: planning and strategy, organization, implementation
• Stakeholders, cost and rad. waste
• Examples of decommissioning projects
Background

• This talk is based on draft of IAEA Report “Decommissioning of Particle Accelerators”
• Electrostatic type: started with vacuum tubes at end of 19th century
• Concept of “modern” oscillating field accelerators from 1920-ties (Ising/Wideroe); exponential growth since WW-II
Background

- Estimated number of accelerators worldwide exceeds 30,000 – medical therapy linacs form the largest fraction

- Attention to rad. waste since late 1970-ties, examples of costly legacies [Conference on decommis., Sun Valley, ID, USA, 1979]

- NPPs vs accelerators: disparity of regulatory burden
## Accelerator Characteristics

<table>
<thead>
<tr>
<th>Class</th>
<th>Energy [MeV]</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low energy</td>
<td>Electron linacs and electro-static accelerators</td>
<td>Radiotherapy linacs, Van de Graaf, tandem VDG, pelletron &amp; such</td>
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<td></td>
<td>$e^- : 2 – 30$ p, ions: $&lt;10$</td>
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<tr>
<td>2</td>
<td>Medium energy</td>
<td>Proton, H- or multiple particle cyclotrons &amp; linacs</td>
<td>PET/SPECT cyclotrons for radio-nuclide production; therapy machines (linacs, cyclotrons, synchrotrons)</td>
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<tr>
<td></td>
<td>$10 – 100$</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>High energy</td>
<td>Proton cyclotrons and synchro-cyclotrons and linear high energy accelerators</td>
<td>Proton therapy, accelerators for physics research; neutron spallation sources</td>
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<tr>
<td></td>
<td>$100 - 1000$</td>
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<tr>
<td>4</td>
<td>Very high energy</td>
<td>Proton cyclotrons and synchro-cyclotrons, and linear high energy accelerators</td>
<td>Fundamental physics research; wide range of interdisciplinary research with light sources</td>
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<td>GeV - TeV</td>
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Accelerator components

- Schematic view of an electron linac (add water cooling, shielding, vacuum and safety systems ..)
Accelerator components

- Source or gun – charge particle production
- Vacuum system – chamber for beam path, pumps & valves, beam pipe windows
- Magnets – steering, focusing (“optics”); wigglers and undulators (in light sources)
- Cooling system; cryogenic system
- Collimators, jaws, masks, heat shields
- Targets, beam dumps, Faraday cups
- RF system: klystrons, waveguides, accelerator cavities
Decommissioning Process

- Reasons: Safety, funding, technology, ...

- Strategy: Immediate or phased? Depends on resources, technical issues, activity levels, provision of waste capacity, end state, etc.

- Factors: legal/regulatory, financial assurance, facility ties, hist./cult. value, EH&S impacts, knowledge management, human resources ..
Decommissioning Planning

• Planning and preparatory work should begin at startup of the facility and get more details with time – this will minimize rad. exposures, waste

• For new facilities decom. plan should be submitted with license application before operation begins

• Plan should establish a record keeping system during operation and provision of funds when shutdown occurs
Plan Example (CLS)

1.0 Overview
2.0 Purpose
3.0 Scope
4.0 Brief Description
5.0 Principal Hazards and Physical Conditions
   5.1 Conventional Hazards
      5.1.1 Hazardous Materials
      5.1.2 Electrical Hazards
      5.1.3 Magnetic Hazards
      5.1.4 Cryogenic Hazards
      5.1.5 Oxygen Deficiency Hazards
      5.1.6 Mechanical Hazards
      5.1.7 Vacuum and Pressure Haz.
      5.1.8 Asbestos
   5.2 Radiological Hazards
6.0 Hazard Reduction for Decommissioning
   6.1 Conventional Hazards
      6.1.1 Physical Hazards
      6.1.2 Hazardous Material Hazards
   6.1.3 Electrical Hazards
   6.1.4 Magnetic Hazards
   6.1.5 Cryogenic Hazards
   6.1.6 Oxygen Deficiency Haz.
   6.1.7 Mechanical Hazards
   6.1.8 Vacuum and Pressure Haz.
   6.1.9 Asbestos
7.0 Surrounding Natural and Social Env.
8.0 Approach to Decommissioning
9.0 Final End-State Objectives
10.0 Financial Guarantee
11.0 Decommissioning Work Packages
   11.1 Administrative/Regulatory
   11.2 Facility Shutdown
   11.3 Disconnecting and Dismantling Technical Svcs
   11.4 Dismantling Acc/Beamlines
   11.5 Bulk Shielding Demolition and Disposal
11.0 Decommissioning Work Packages – cont.
   11.7 Radioactive Waste Management and Disposal
      11.8 Site and Facility Final Clean-up
12.0 Conceptual Schedule
13.0 Cost Estimates
14.0 Records
15.0 References
16. Appendices
17. Attachments
Few Plan Implementation Items

• Completing and submitting applications and obtaining approvals from regulatory bodies
• Establishing clear lines of communication with stakeholders
• Assigning roles and responsibilities and ensuring they are clearly understood by all persons involved
• Employing a suitably experienced project manager
• Performing and communicating the outcome of the safety assessment and ensuring the availability and correct use of any required PPE
• Securing availability and advance booking of needed specialized equipment
Other Important Aspects

- Organization and management
- Dismantling technology – similar to that applied for other nuclear facilities
- Cost: hard to correlate from one project to another; example: 30 MeV IBA cyclotron & anc. equipment: $6.3 M (including 6000 t of low level waste). Report offers details on cost structure
- Radioactive waste: characterization, storage, disposal; adequate plan, equipment & funding
- Stakeholders/PR management
Design for Decommissioning

- Optimizing design and operation of accelerator for decommissioning will greatly reduce effort and cost:
  - Easy access for maintenance, decon, dismantling and removal (e.g. modular shield)
  - Choose materials to minimize activation and radiation damage degradation
  - Early estimate of rad waste generated over lifetime of facility
  - Include lessons learned from other facilities
Design for Decommissioning
Design for Decommissioning
Examples

• Report includes multiple decommissioning examples from around the world:
  – LEP at CERN – the largest & most complex project, due to size and Swiss + French regs
  – Bevatron at LBNL: $47.6M, 230,000 hours, 1900 cubic yards of soil cleanup
  – Intense Pulsed Neutron Source, Argonne
  – Upgrade (with some decommissioning) at JLab
  – Number other projects (USA, Germany, Japan)
Visualization of the areas where radioactive waste was expected in the LEP machine on the basis of the preliminary characterisation
Example of LEP accelerator structure (experimental hall)
Bevalac (Bevatron + Hilac)

Aerial view from 1972 of the Bevalac, with the white dashed line indicating the path of ions injected from the Super-HILAC into the Bevatron.
Advanced stage of the Bevatron enclosure disassembly, with the removal of the accelerator completed (October 21, 2010).
Jlab – SOS from Hall C

Short Orbit Spectrometer (SOS)
Decommissioned from Hall C

Radioactive waste material: 150 metric tons of metals and 230 metric tons of concrete