International Atomic Energy Agency

Evolution of R&D for nuclear decommissioning

Michele Laraia,

Independent Consultant, ex-IAEA Unit Leader for Nuclear Decommissioning

Scope of presentation

- Technological maturity and R&D
- R&D in nuclear decommissioning
  1. The beginning
  2. Technological evolution to this day
- Technical areas under development. The future
- IAEA Coordinated Research Projects
- Conclusions

Beginning with definitions….(from University College London)

- R&D comprises investigative work undertaken in order to increase knowledge, including the knowledge to devise new applications. It consists of three activities: basic research, applied research and experimental development.
- Basic research (R) is work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts without any direct application or use in view. NOT VERY RELEVANT TO DECOMMISSIONING
- **Applied research (R)** is directed primarily towards a specific practical aim or objective.
- **Experimental development (D)** is systematic work, drawing on existing knowledge gained from research and/or practical experience that is directed to producing new processes, systems and services, or to improving substantially those already produced or installed.
- **Over the years R&D in nuclear decommissioning moved gradually from (R) to (D)**

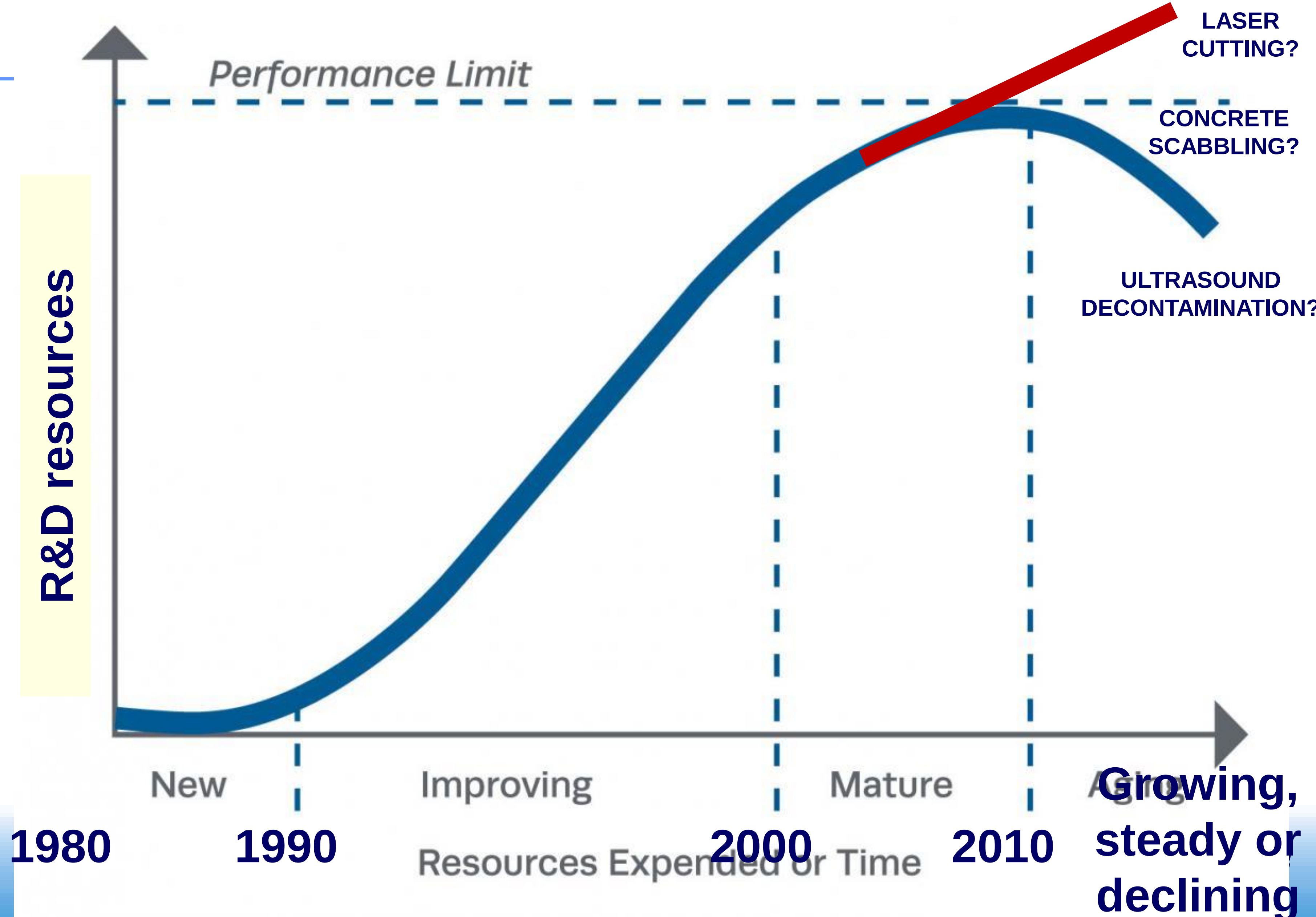
Is decommissioning a mature technology?

- Technological maturity determines the need of and resources for R&D. But maturity is more an objective, always coveted, never reached, than a fact, so R&D never ends. While the car industry has been mature for decades, improvements are still underway.
- Decommissioning technology is capable to effectively (efficiently?) deal with most activities (Fukushima?) but:
- Optimization (R&D) is still required e.g. to:
  - reduce costs (far too high and rising…) and industrial risks
  - control waste generation
  - reduce occupational exposures
  - improve industrial safety
  - respond to unexpected events/unknowns
  - deal with “difficult” materials (e.g. graphite)

Is technology mature? (cont’d)

- „Technology Readiness (TR)“ (scale from 1 to 9) is a more quantifiable concept than „Technological Maturity (TM)“
- But most decommissioning techniques were launched at a time TR Levels were not in general use, so the popular, but imprecise term TM is used in this lecture
- This lack of precision implies that to state the success of decommissioning R&D techniques is highly subjective

Maturity of decommissioning techniques (not in scale)



Is technology mature? (cont'd)

- Wide-ranging R&D programmes (1980s,1990s) came to an end by the turn of the millennium, with "R" gradually shifting to "D"
- Selective R&D efforts underway since
- No major technological "breakthroughs" in sight (*the very definition of TM*)
- Adaptations of already available equipment/tools is the rule

Is technology mature? (cont'd)

- Difficult transfer of technology/know-how to countries with limited resources and small experience in decommissioning: these may need specific R&D efforts to develop domestic techniques
- Co-ordinated Research Projects launched by the IAEA to disseminate information and share R&D achievements

Beware ! Decommissioning is not „rocket science“. R&D or high-tech are not always essential

Hand-held bandsaw, a low-cost technique available at hardware shops

Cillit Bang, a 2 € detergent that helped remove plutonium stains at Dounreay

The Decommissioning Industry

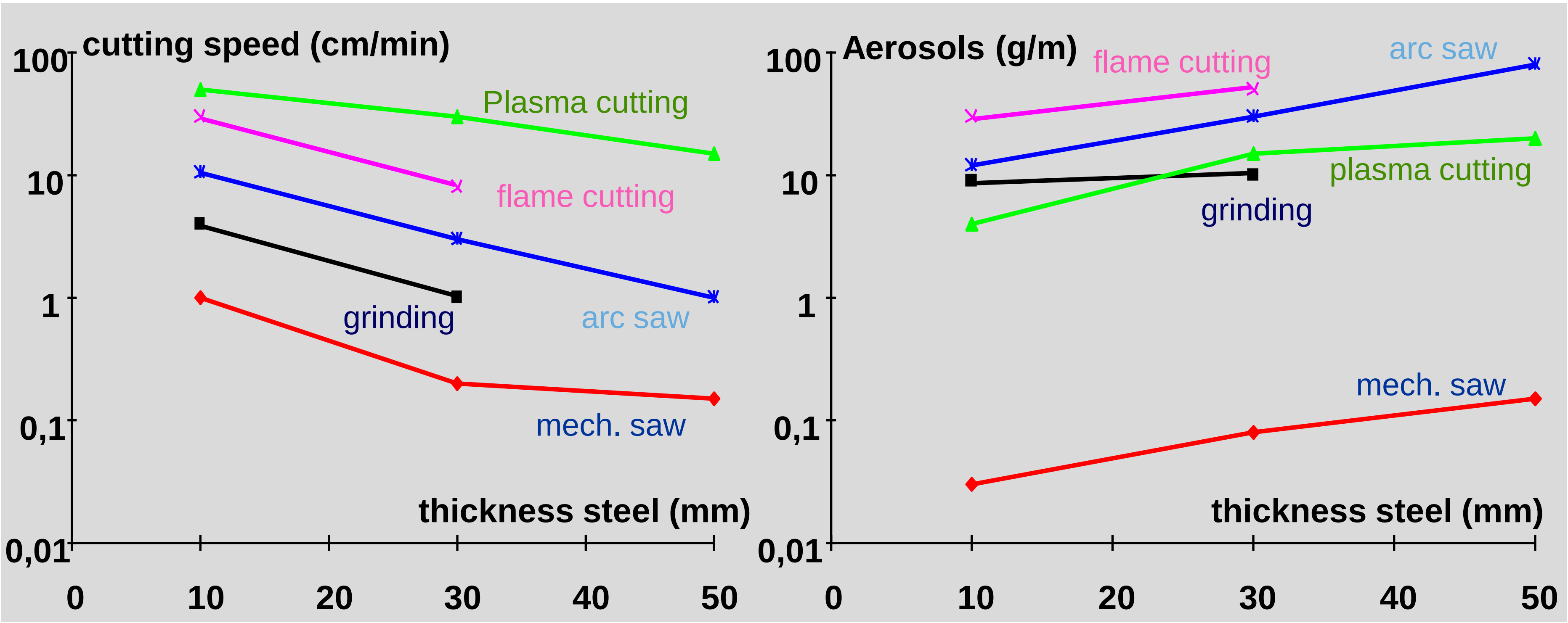
- Total dismantling of prototype facilities was completed in 1990s to unrestricted release, e.g.: KKN, Shippingport NPP, JPDR
- Large commercial facilities were decommissioned in 2000s to unrestricted release (Maine Yankee, Trojan and other US NPPs)
- From 1990 until 2000 the general technology has dramatically improved
- The decommissioning "market" (contractors, consultants, selected services) has grown rapidly, at least in industrialized countries

Chernobyl „boosted“ R&D in robotics (Picture below from museum of robotic equipment used during the Chernobyl accident, Chernobyl site

R&D in Nuclear Decommissioning

- European Commission Framework Programmes
  - Pre-1990 Laboratory scale R&D
  - 1989-1993 Pilot projects (BR-3 PWR, Belgium;AT-1 Reprocessing Plant, France; KRB-A BWR, Germany; WAGR, UK); continued R&D; info exchange
  - 1995-1999 Continuation of pilot project (+ Greifswald WWER, Germany); Databases on tools and costs; Limited R&D efforts

BR-3, Mol, Belgium – Comparison of dismantling techniques (under EC R&D Programme)

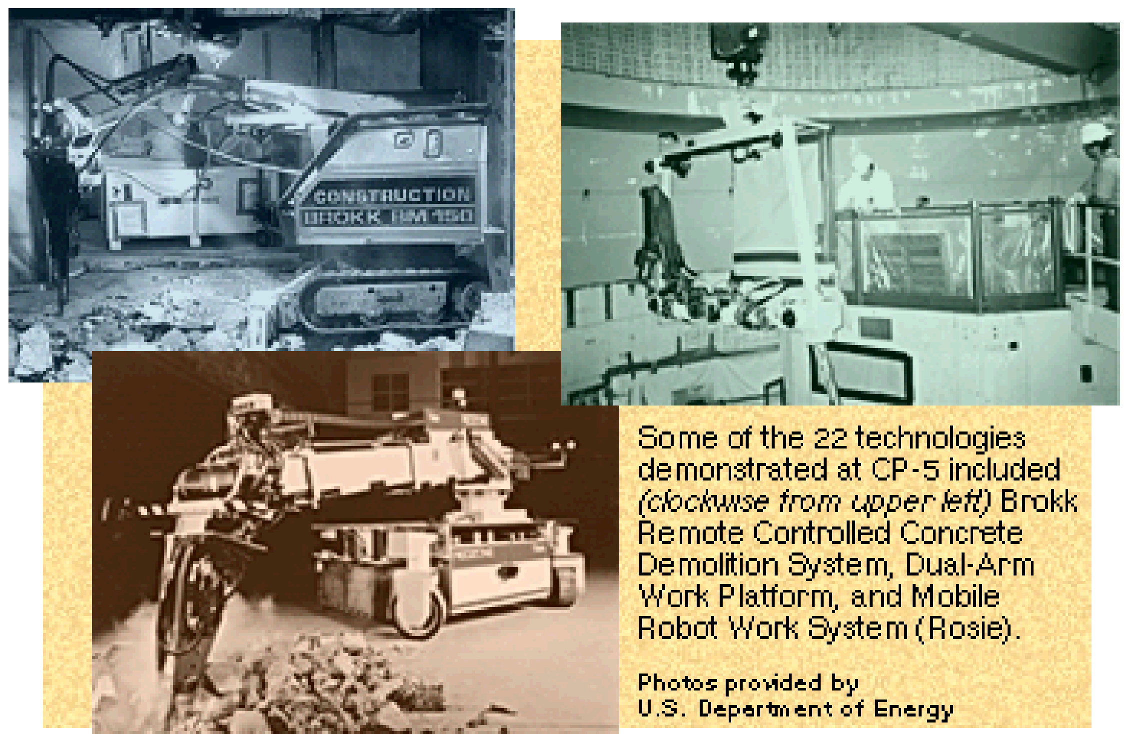


R&D in Nuclear Decommissioning (cont'd)

- In the USA, the US-DOE started massive R&D efforts for its Environmental Management (EM) programme of site clean up.
  - EMSP: Science Program
  - DDFA: D&D Focus Area
  - LSDDP: Large Scale Demonstration & Deployment Projects. See Innovative Technology Summary Reports (ITSRs)

At Knoxville conference in 2000 (IDS 2000), DOE stated that it was the last all-encompassing conference on R&D programmes for DOE sites.

ISOCS demonstrated under DOE's LSDDP



R&D in Nuclear Decommissioning (cont'd)

- **In Japan, the JPDR decommissioning was used to test and optimize a number of new decommissioning techniques. JPDR was totally dismantled until 1996.**

Results of this R&D programme

was disseminated for several

years to the international community.

JPDR R&D Programmes

- R&D Covering Eight Areas
- Computer system for project management, Decontamination, Remote handling, Dismantling tools, Radioactive inventory estimation, etc.

- Demonstration by JPDR Dismantling Project
- Reactor internals: Underwater plasma arc cutting
- Reactor Pressure Vessel: Underwater arc saw cutting

- Piping to RPV: Shaped explosive, Disk cutter
- Bio-shield: Mechanical cutting,
- Controlled blasting, Water jet cutting

- R&D Techniques for Regulation
- Computer tools for safety evaluation

Needle gun at JPDR project

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The following slides includes arbitrarily selected techniques as examples of recently completed or innovative R&D. There are a lot more techniques which would deserve a mention.

Please note that the distinction between fully developed and commercial ("mature"), techniques and those under development reflects only personal views.

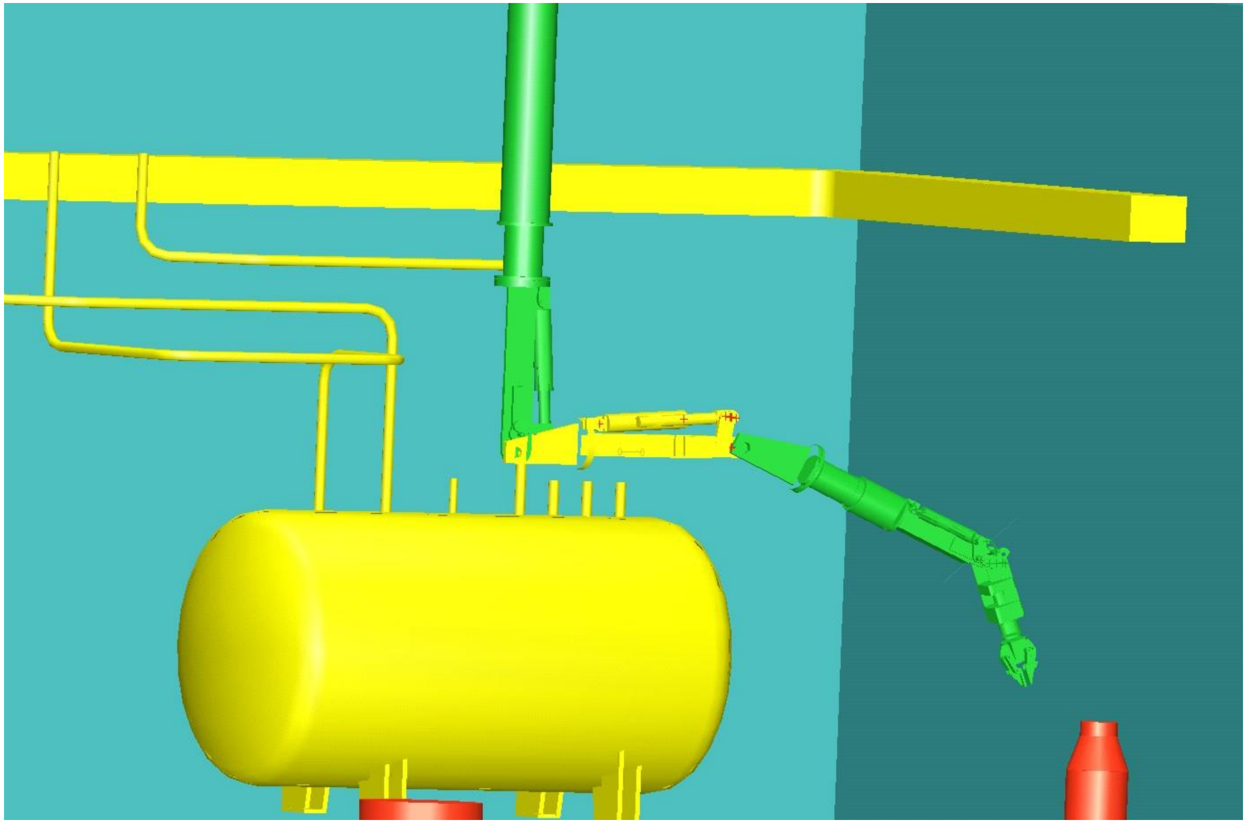
Techniques subjected to intense R&D in 1990s - 2000s and now commercially available (examples)

- Gamma cameras
- Simulation of decommissioning activities for optimization purposes (3D CAD, VR, VISIPLAN, etc.)
- Piping inspection (Pipe explorer –various countries)
- In-situ spectrometers
- Foam, fog and gel decontamination

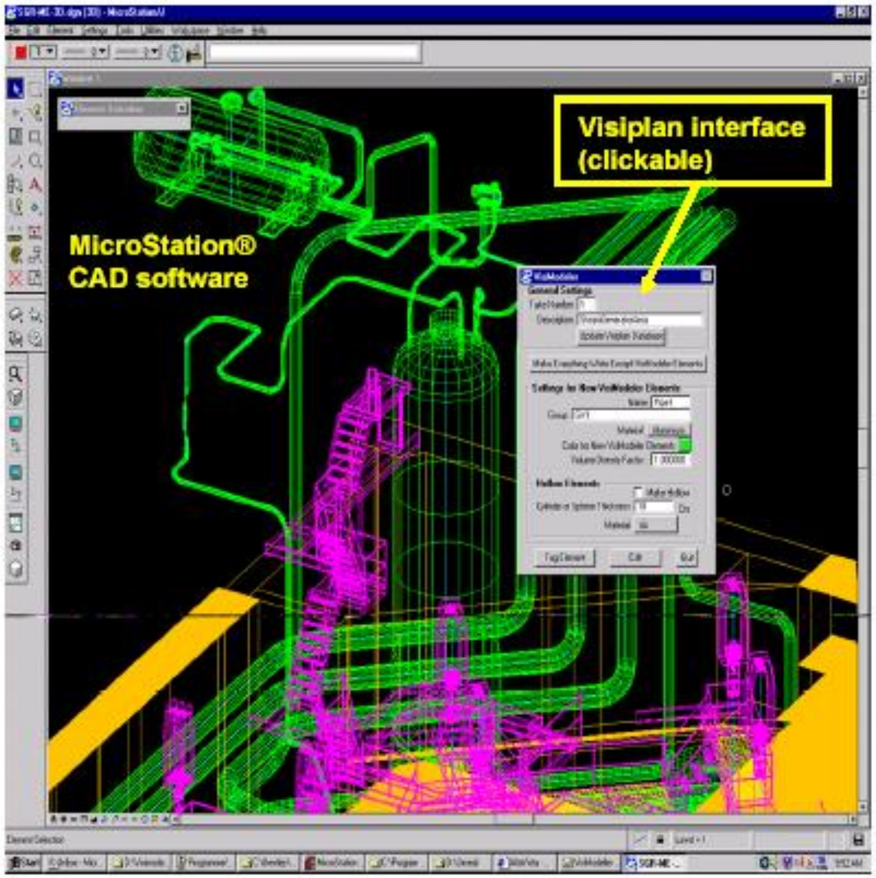
Automated collection of surface contamination readings coupled with GPS (Groundhog)

Aladin (test case in Slovakia, early 1990s)

A-1 project, Slovakia, 3D modeling and simulation (early 1990s)



Visimodeller, SCK-CEN, Belgium



Visimodeller typical screen shot. The selection of geometrical elements from complex environments is made by simple click of the mouse.

Piping inspection model (Czech Republic)

DeconGel

Techniques under development (examples)

- Laser ablation
  - In development (relatively low efficiency)
- Laser cutting (new models being commercialized)
- Concrete shaver
  - Tested (and used)
- High pressure water jetting
  - Tested (and used): in some cases caused the contamination penetrate deeper in the material

- Alpha cameras (not there yet)

Laser Snake Testing

Automatic wall shaver (Belgium)

Close up view of the machine

Use on a reprocessing cell wall

Courtesy from Belgoprocess

High Pressure Water Jets

Uses high to very high pressure (2,500 bar) to remove contaminated surface layers. Chemicals can be added.

Drawbacks:

- **Industrial safety**
- **Liquid and airborne contamination spread**

Techniques that have been R&D‘d for many years, have been patented, but never reached commercial use (examples)

- Microwave heating for concrete decontamination
- Electrical heating of the rebars
- Cavitation decontamination

Decommissioning technology in IAEA (developing) Member States

- Diverse social, economical, political, cultural environments of IAEA membership
- Difficult “absorption” of alien technologies
- Technologies expensive to buy in the open market
- Proprietary, political concerns
- Lack of a well developed market
- Maintain researchers’ jobs
- Development of domestic, low cost technologies
- Re-invent the wheel?

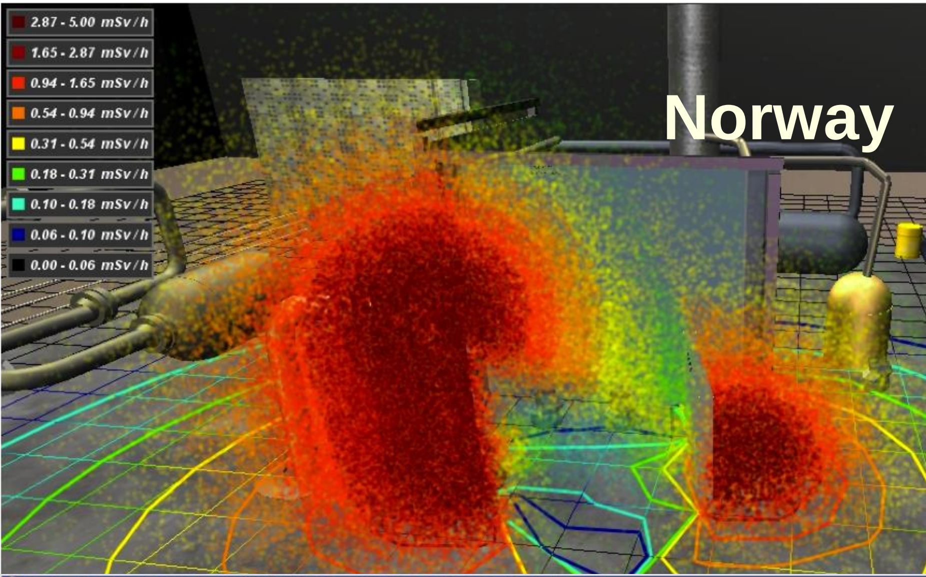
Coordinated Research Projects (1)

- CRPs are typical IAEA mechanisms to share information and methods between industrialized and developing Member States. Typical participation is around 13-15 organizations. CRPs include periodic progress report meetings (RCMs) and a final TECDOC
- Decontamination and Decommissioning of Nuclear Facilities (1984-87), TECDOC-511 (1989)
- Decontamination and Decommissioning of Nuclear Facilities (1989-93), TECDOC-716 (1993)
- New Methods and Techniques for Decontamination in Maintenance or Decommissioning Operations (1994-98), TECDOC-1022 (1998)

Coordinated Research Projects (2)

- **Decommissioning Techniques for Research Reactors (1997-2001), TECDOC-1273 (2002)**
- **Disposal Aspects of Low and Intermediate Level Decommissioning Waste (2002-2006), TECDOC-1572 (2007)**
- **Innovative and Adaptive Technologies in Decommissioning of Nuclear Facilities (2004-2008), TECDOC-1602 (2008)**
- **Planning, Management and Organizational Aspects of the Decommissioning of Nuclear Facilities (2008-2011), TECDOC-1702 (2013)**

TECDOC 1702



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Conclusions

- Q. Is decommissioning a mature technology?
- A. In general yes, in that no major technological changes (such as those that came to light in 1990s) are expected in the near future. However:
    - R&D (adaptation to specific applications, cost reductions etc.) is still required;
    - Most techniques are still far from routine, off-the-shelf implementation;
    - Dissemination of techniques worldwide is not yet satisfactory.

Learning from Fukushima for future D&D. A fleet of robots doing decommissioning work instead of humans? Is this the new frontier of decommissioning?

Thanks for your attention

and

Don't ask too much;)