IAEA
International Atomic Energy Agency

# 7. Case Study 4: ALARA and the dismantling of the Belgian Reactor 3

# BR3 reactor

| 1962 | 1987 | 1989 |
|---|---|---|

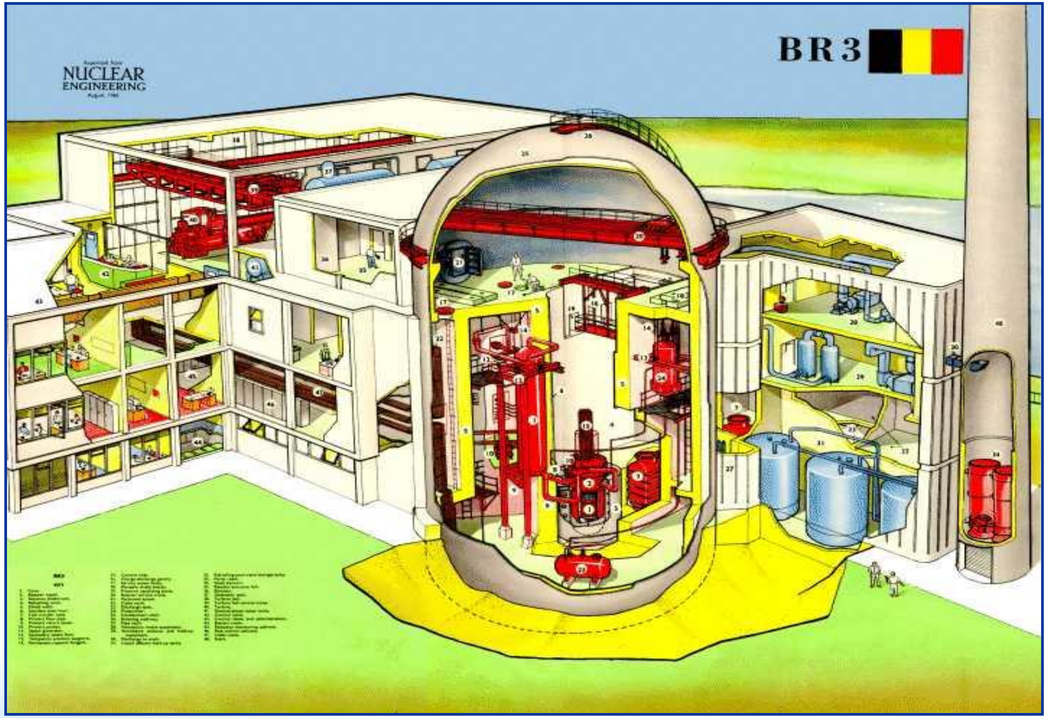
BR3 reactor was the first pressurized water reactor in western Europe

It became critical 19th august 1962

Definitely stoped on June 30th 1987

Selected in 1989 by the European Commission, as dismantling pilot project

# The BR3 Installation



# BR3 and MOL Research Centre

BR3 is one nuclear installation among several different research installations located on the same research centre in Belgium : the CEN•SCK MOL centre

Therefore the work organisation responsibilities are split between the installation management and the centre management

# BR3 dismantling
# Plan of the Case study

Optimization implementation and BR3 dismantling.

Need of 3D adapted Optimization tools: from the simple Micro Shield to the sophisticated VISIPLAN for BR3.

A global optimization of protection and safety approach example: asbestos and radiation risk management at BR3.

# Your experience

IAEA

Have you some experience in dismantling of devices or installations?

If yes which ones? And then what lessons did you learn?

If no; what, in your opinion, are the specificities of a dismantling with regards to normal operations

# PART 1
# Optimization procedure and BR3 dismantling

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BR3 was the first reactor to be decommissioned in Belgium

BR3 was selected as pilot project by the European Commission for testing several dismantling techniques (decontamination, cutting…)

From the beginning of the dismantling to its end , 20 years later, optimization was implemented.

Formalising optimization has led very quickly to setting up an optimization programme relying on:

- A formalized procedure
- A very efficient and sophisticated predictive and analytical tool : VISIPLAN now used by tenth of nuclear facilities (see part 2).

# BR3 dismantling an historical overview of successive operations (1)

- **1991** – Primary loop decontamination
- **1992–1996** – internals dismantling
- **1997–2002** – Primary circuit and annexes dismantling
- **1999–2000** – Reactor vessel extraction and cutting
- **2000** – Turbine dismantling
- **2001** – Steam generator decontamination
- **2002** – Irradiated fuel evacuation
- **2003** – Vessel head and bottom cuttings,

# BR3 dismantling an historical overview of successive operations (2)

**2003–2004**
Purification circuits dismantling

**2004**
Fuel storage racks dismantling; Decontamination of the Fuel transfer tank

**2005**
Steam generator and pressurizer cuttings.

**2006**
Dismantling of the first liquid effluents collecting tank. Concrete decontamination in nuclear auxiliary building

**2007**
Start of the teleoperated dismantling of the Neutron Shield Tank

**2007–2008**
Equipment dismantling in the ventilation building.

**2008**
Conventional dismantling of the ventilation chimney

# ALARA from the design stage of the operation

First global approach of the radiological stakes

↓

Integration of radiation protection into selecting technical scenarios

↓

Second detailed approach of the stakes for the selected scenario

↓

Implementing the optimization procedure

↓

Deciding the ALARA plan

↓

Implementing the ALARA plan; following its implementation

↓

Feedback analysis

# First global approach of the radiation protection stakes for the BR3 dismantling

Radiation protection for a dismantling has many specificities and stakes are not trivial (first rough assessment exceeds 5 to 10 man.Sv) due to :

01 Dismantling requires human presence in areas with potentially high radiation field

02 The loss of knowledge (no documentation) induces unforeseen situations in terms of radiation protection

03 Opening of loops and piping induces high internal contamination risks

04 BR3 has never been designed to be decommissioned

05 The environment is continuously changing (hence much more difficult to predict).

06 It is a one-shot operation (no feedback experience contrarily to maintenance jobs)

# Radiation protection and technical scenarios

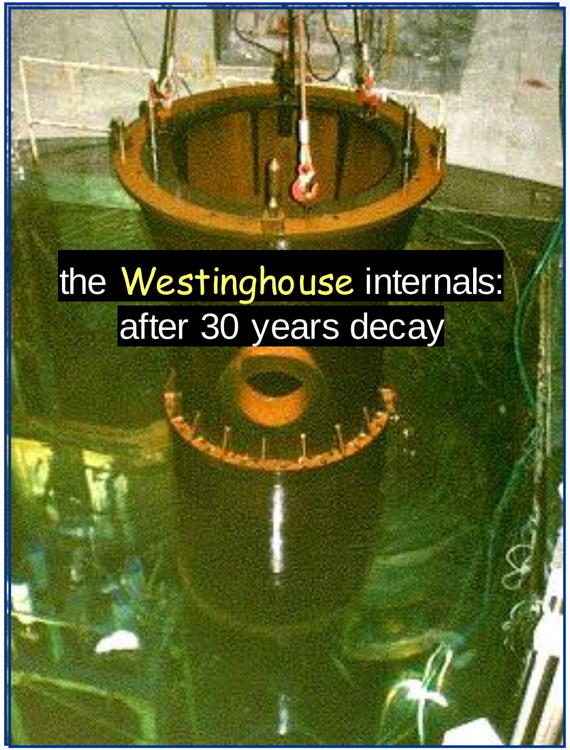
Due to the important radiation protection stakes not only the expected doses were assessed but some technical operations were designed for radiological protection purpose mainly

The question of the use of the decay law was addressed

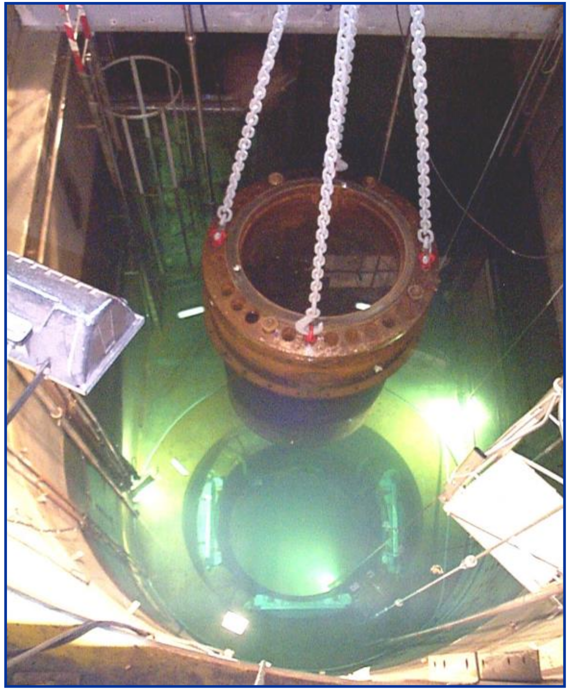
As well dismantling of main components led to taking them off before cutting them into pieces.

# Use of the decay law?

Two sets of Internals were dismantled;
this allowed to compare dismantling strategies

# Reducing sources



The reactor vessel was taken off from its environment before to be cut into pieces

# ALARA from the design stage of the operation

First global approach of the radiological stakes

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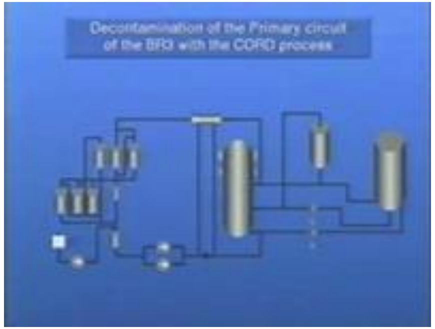
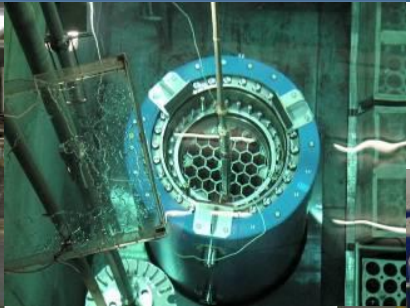
Feedback analysis

# Each task has been followed up through operational dosimetry (1)



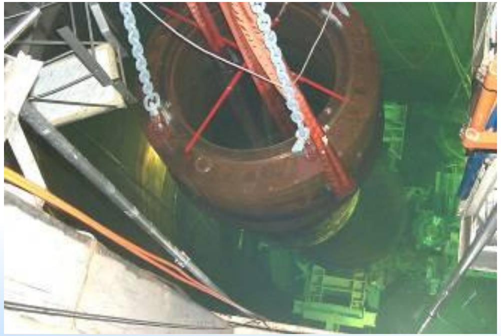

- Primary circuit decontamination CORD® Process: 158 man.mSv
- Thermal shield cutting : 39,55 man.mSv
- Asbestos withdrawal from all circuits s: 22,4 man.mSv
- Dismantling under the Operating Deck (reactor building): 22,21 man.mSv

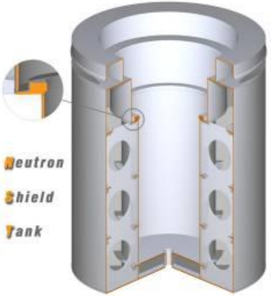


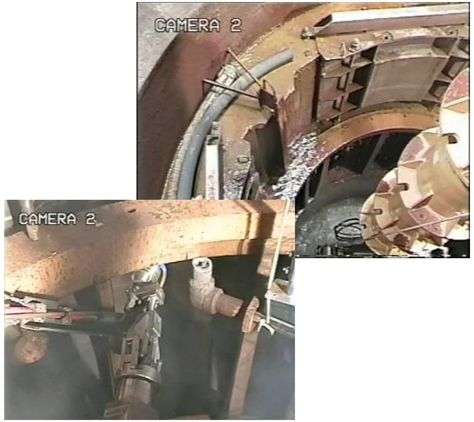



# Each task has been followed up through operational dosimetry (2)

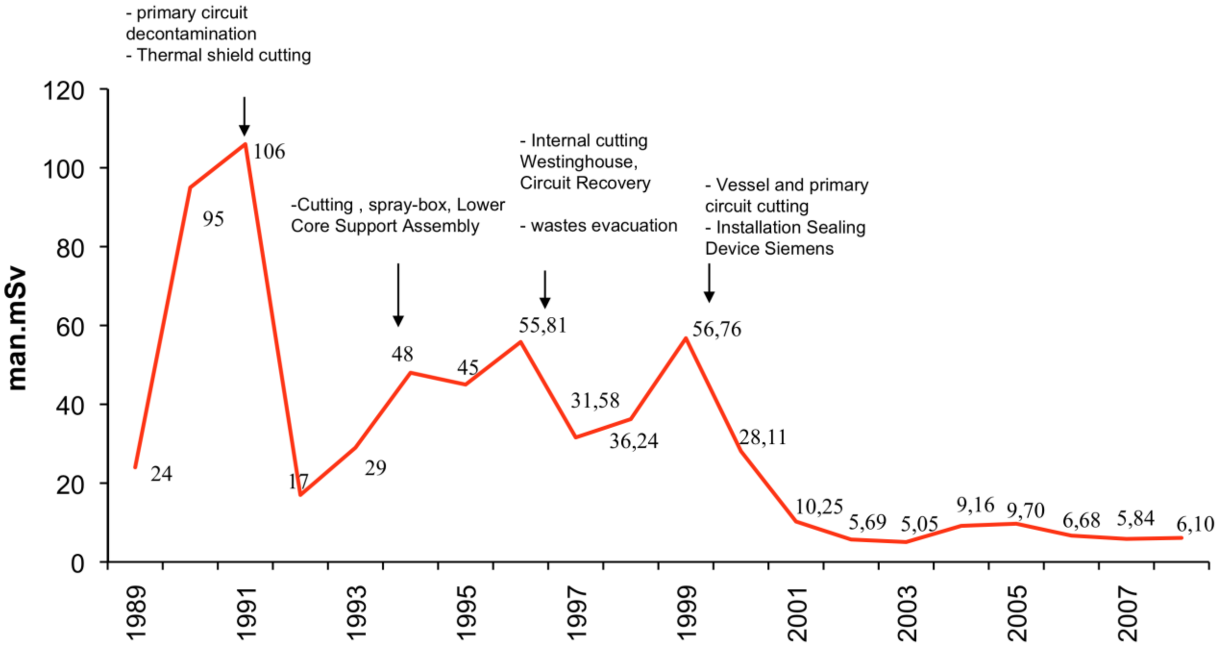
- Reactor vessel removal: 2,42 man.mSv
- Reactor pool sealing off system installation : 14,42 man.mSv
- Vessel cutting: 28,09 man.mSv
- Neutron Shield Tank dismantling (phases 1 and 2) via HPWJC: 7,34 an.mSv





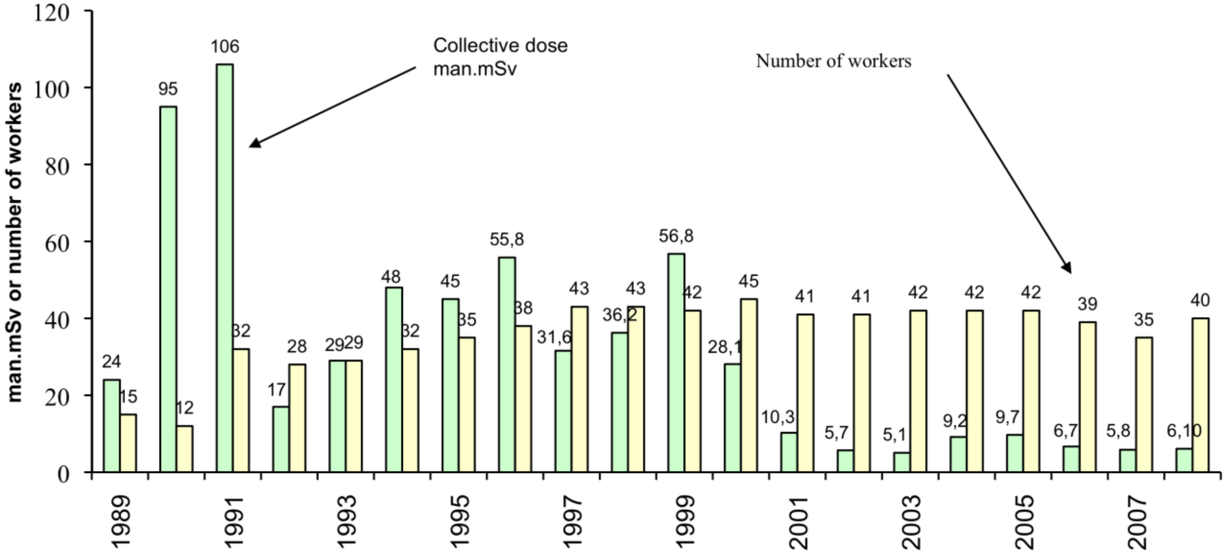



# The total collective dose




The total collective dose, between 1989 and 2008, relying on the passive dosimetry (TLD), corresponds to 630,97 man.mSv

# The individual doses between 1989-2008




The highest individual doses were undertaken between 1989 and 1999.
The average dose per worker between 1989 and 2008 is 0,88 mSv/year

# ALARA from the design stage of the operation

First global approach of the radiological stakes

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Implementing the ALARA plan; following its implementation

↓

Feedback analysis

# Lessons learned from BR3 dismantling

To decontaminate the primary circuit

- Is one of the first tasks to be performed .
- Allow an important reduction of later occupational doses (DF 10; dose reduction estimation between 4 to 8 Man.Sv).

It is important to test all new techniques on non radioactive mock up. It allows to:

- Determine optimal cutting parameters, without workers exposure.
- Test withdrawal and safety procedures.
- Train the workers before the actual work, this reduces heavily the exposed worktime (EWT).

To cut the highly activated pieces under water

- Allows a significant reduction of the occupational doses.

# The optimization set of procedures at CEN MOL

They have been introduced through the BR3 experiment

And generalised to the whole centre in 1994

They comprise structures and procedures as well as a computerised ALARA data base

# Several stakeholders are concerned depending on the optimization stakes (1)

The installation engineers (in charge of an affair/task/operation) are responsible for implementing the optimization procedures (for that affair/task/operation)

Local optimization Coordinator : contact person within an installation for optimization implementation. He has access to the ALARA data base through which he requests the “optimization” green light for performing the task

RPO (health physicist or Radiation Protection Officer)

# Several stakeholders are concerned depending on the optimization stakes (2)

## SCK•CEN ALARA Coordinator :

- Health Physics Department responsible.
- Checks all requests. Gives green light when OK
- Is the ALARA data base manager.

## ALARA Committee :

- Comprises representatives from HP department, medical, wastes, installations,…
- Follows all operations with high doses
- Provide green light when the dose prediction is high (see hereafter).
- Reports to the Management of the Centre and distribute reports to all local ALARA Committees members.

# The procedures are different according to the stakes ; i.e. the dose levels

When collective dose:

**S < 0,5 man.mSv**

- When first time – the green light from the SCK CEN ALARA coordinator is needed.
- When not first time – automatic green light – just complete form C of the procedure

**0,5 man.mSv < S < 5 man.mSv**

- green light from the SCK CEN ALARA coordinator is always needed.

**S > 5 man.mSv ou MID* > 1 mSv**

- green light from the SCK CEN ALARA Committee is always needed.



* Maximum Individual Dose

# Part 1 conclusions

The cost of the whole dismantling was 630,97 man.mSv on the basis of passive dosimetry (TLD) from 1989 and 2008.

The average dose per worker during the same period is 0,88 man.mSv.

The most costly task in terms of dose was the primary circuit decontamination (158 man.mSv).

BR3 dismantling has favoured the existence of an ALARA set of procedures at the facility level.

# Part 1 conclusions and questions

There was a need to develop a specific adapted tool:

- Due to the complexity of the situation
- Due to the continuously evolving situation
- Due to the uncertainty of the hypothesis

Have you heard of such types of aiding tools for implementing optimization?

If yes, what are they ?

# Part 2
# Need of 3D adapted Optimization tools:

Need of 3D adapted optimization tools, from the simple Micro shield to the sophisticated VISIPLAN developed for BR3 dismantling

In 1998 during the first European ALARA Network workshop which was devoted to optimization and dismantling, one major recommendation was:

To develop 3D modelling to prepare the work in an optimization perspective and select optimal options making use of easy to use interfaces

This should be particularly useful for dismantling operations as they are performed in a context :

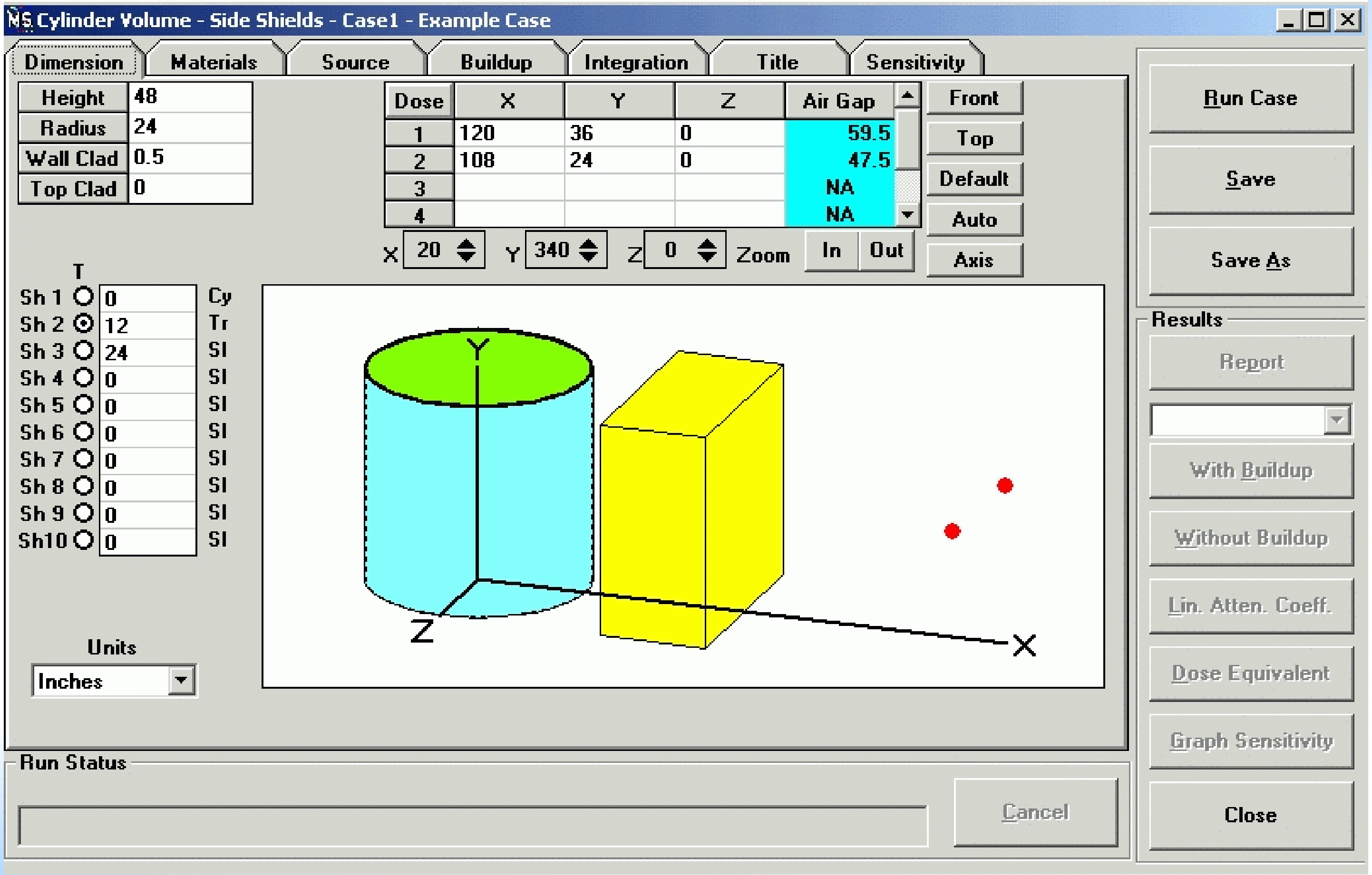
- Continuously evolving
- With complex geometry and kinetics
- With potential quite high risks

# What was existing at the end of the 90's

Up to the end of the 90's even if some quite sophisticated codes already were developed internally within big companies, the only predictive tool available on the market was Micro Shield that we will present now.

It could not be called an optimization tool, but it provided already interesting input for any simple optimization study as it allowed to assess the efficiency of shields to reduce dose rate when installed between a source and a workplace/worker ?

# One input screen from Micro-shield



# Micro-Shield was and remains very useful for optimization studies

- But only for simple situations where there is a single source, with photons and gamma radiations.
- It does not calculate doses but only dose rates,
- It does not compare options and scenarios
- It is not so much useful for designing a new installation or assessing globally a new complex maintenance or dismantling operation.
- Therefore new tools were needed

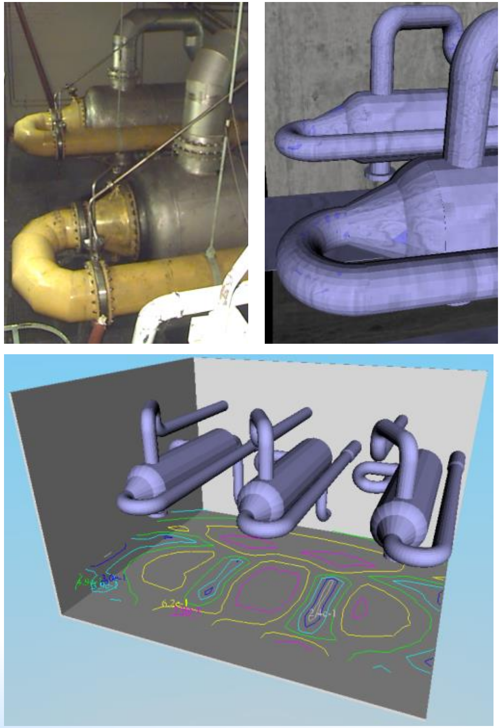
# New tools developed since the beginning of the 21st century

Most of the major nuclear operators have since then developed such kind of 3D codes dealing with complex situations.

- CHAVIR at CEA in France
- ERGODOSE at NNC in the UK
- VRDOSE at IFE HALDEN in Norway
- VR-domain at Rolls Royce in the UK
- Virtual radiation field, University of Florida, USA
- …
- And VISIPLAN at SCK CEN in Belgium

The training for such type of code is quite short (2 days for VISIPLAN)

# The main characteristics of the 3D VISIPLAN tool



**Based on:**

- 3D model, including material, geometry and sources
- Point-kernel dose calculation, with build-up correction

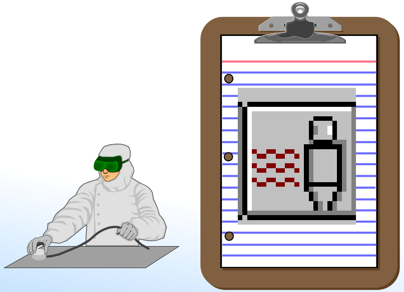
**Allows:**

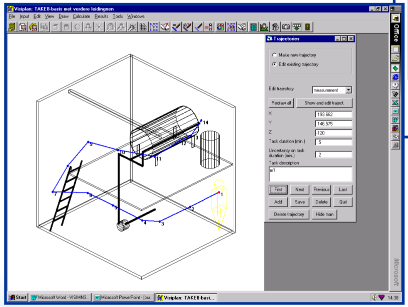
- Dose assessment for tasks, trajectories and scenarios
- Individual and collective dose assessment
- Source strength calculation assessed on measured dose rate sets.
- Source Sensitivity Analysis

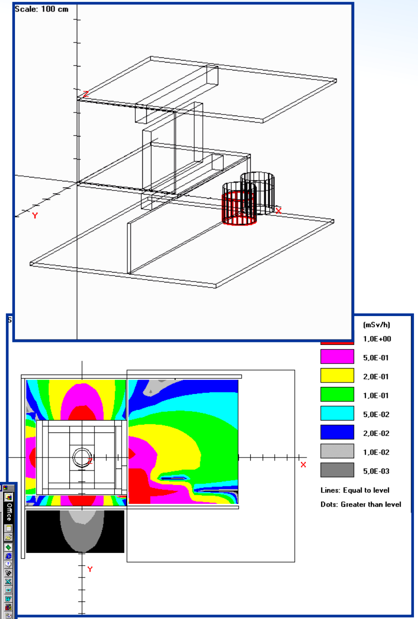
VISIPLAN-3D

# VISIPLAN general method: the fours steps

- model building stage
- general analysis stage
- detailed planning stage
- the follow up stage







# VISIPLAN Model building stage

- Geometrical input
  - From technical drawings
  - Survey techniques
  - Photogrammetry
  - Laser scanning

  Primitive volumes

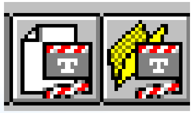
- Materials input
  - Technical data
  - Experts on site

  Materials dataset

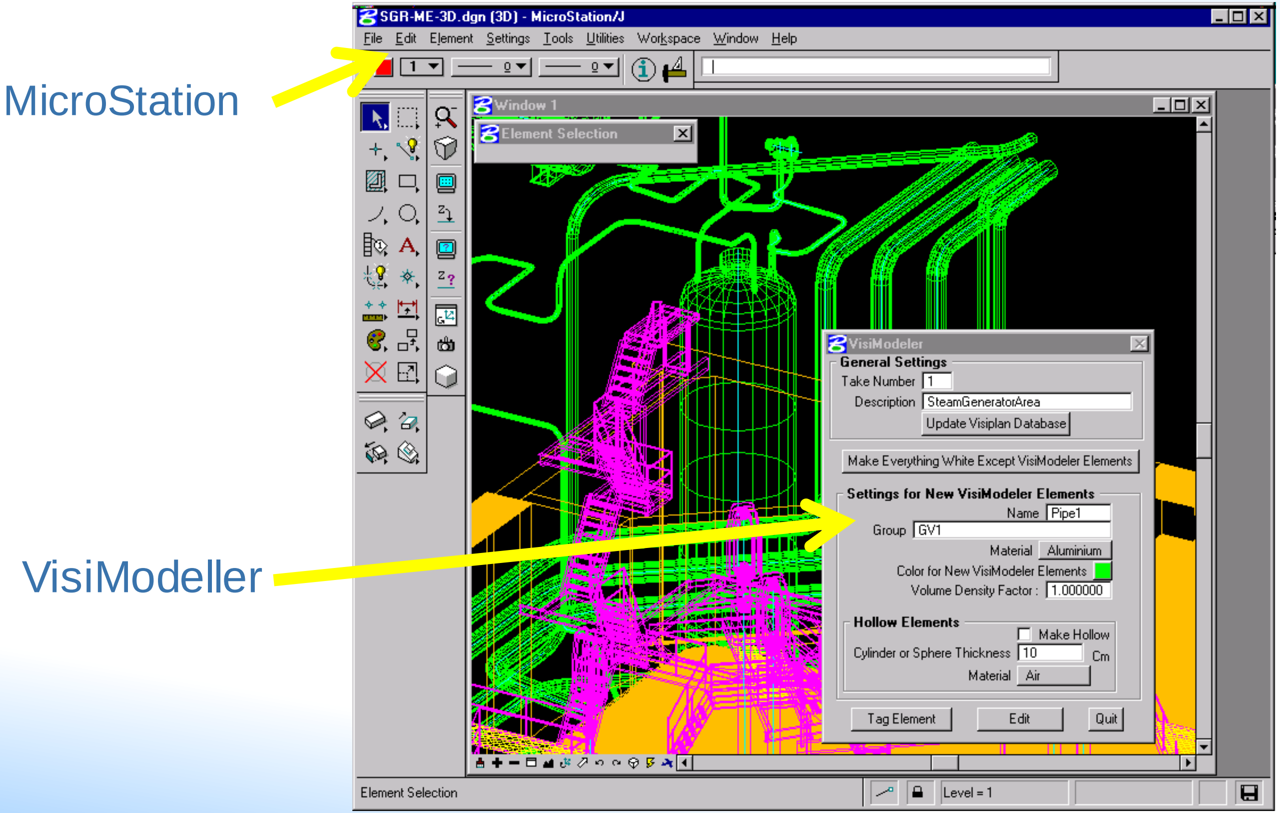
- Radiological input

  Technical data
  Survey
  Site history

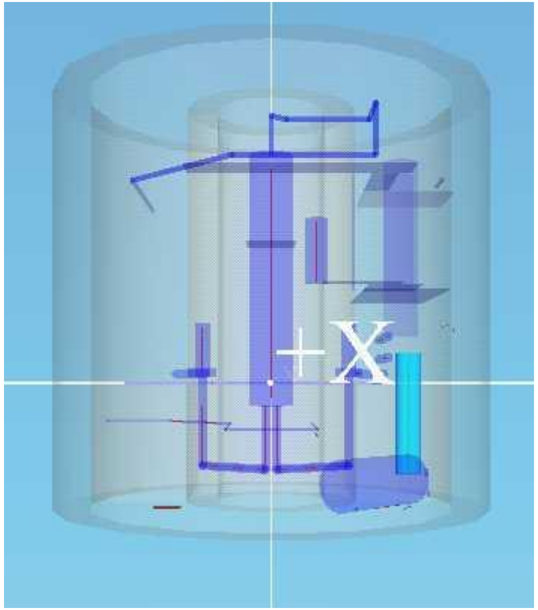
  Source dataset

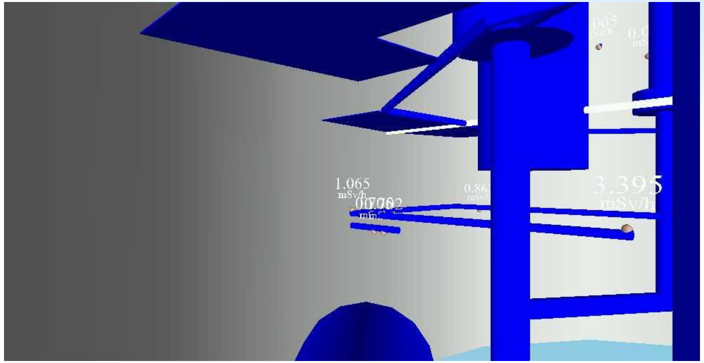
Take 

# An input tool : Microstation - VisiModeller



# The model building stage at BR3






Contact measurements

Geometric and material data are taken from existing paper documentation and plans

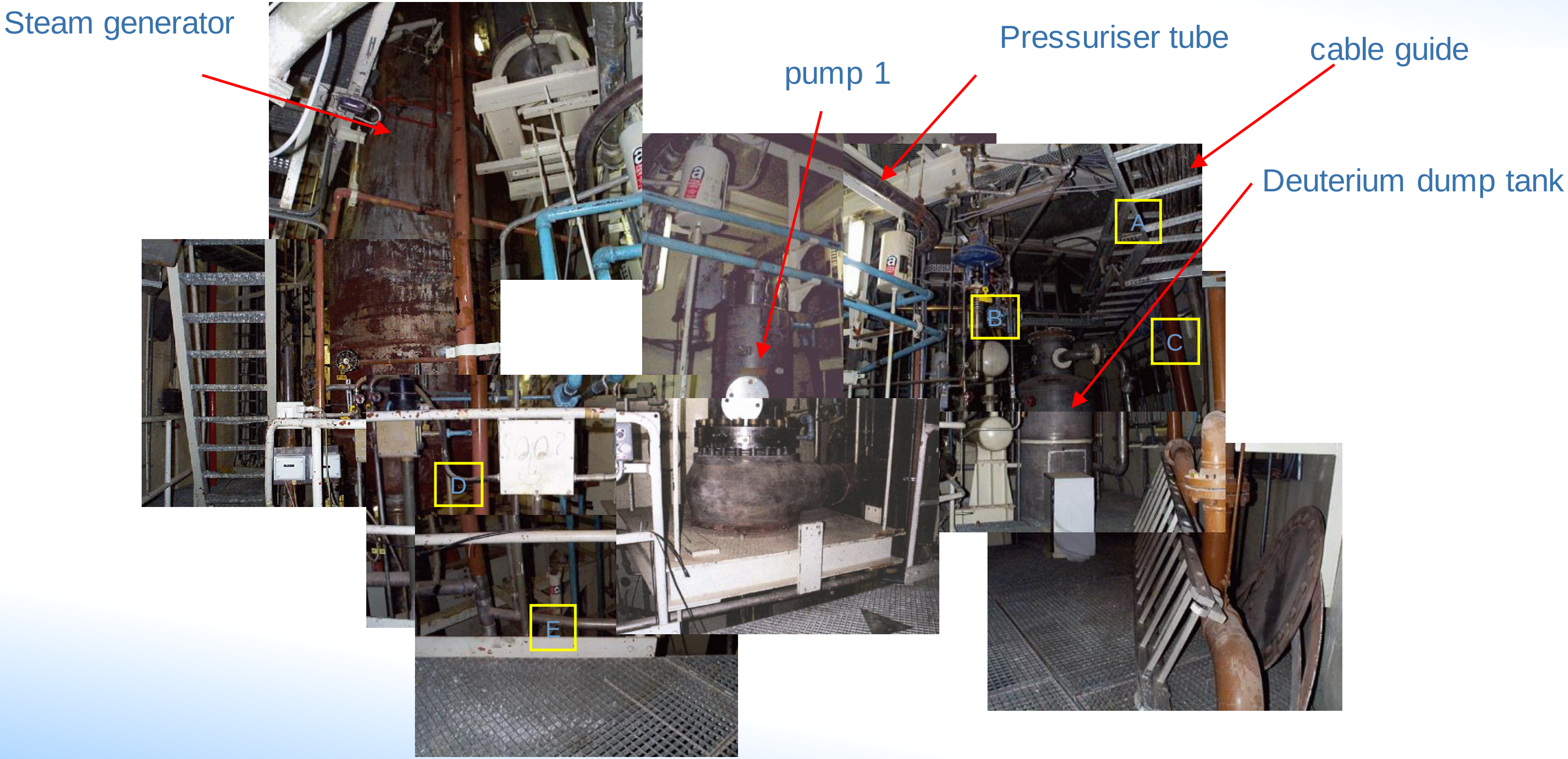
Data on sources come from measurements campaigns and from the installation life history knowledge

# Data: Radiation Characterisation

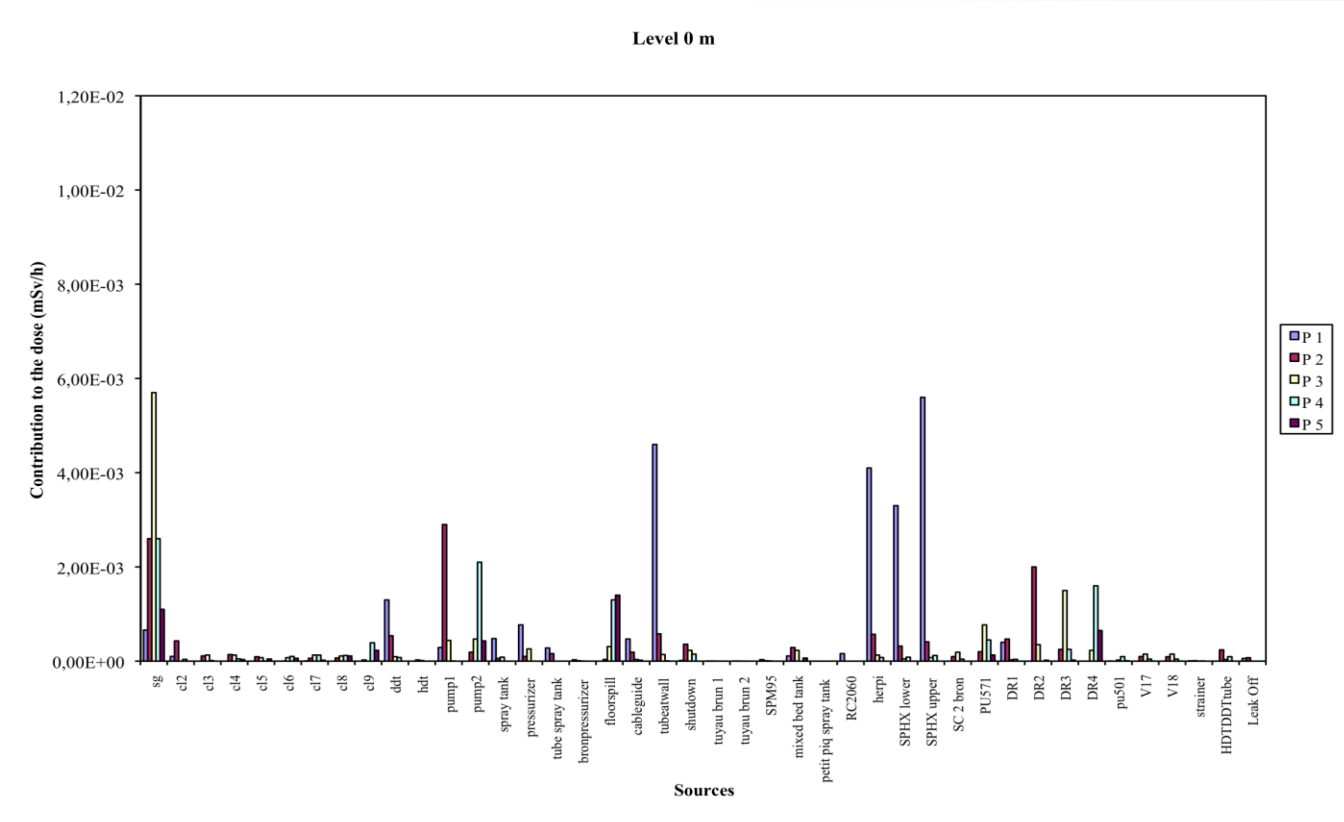
- $4\pi$ dose measurements
- Use of Radscan for determining sources positions
- Use of existing historic information on site

# Getting data: Gamma Scanning at the BR3 decommissioning site

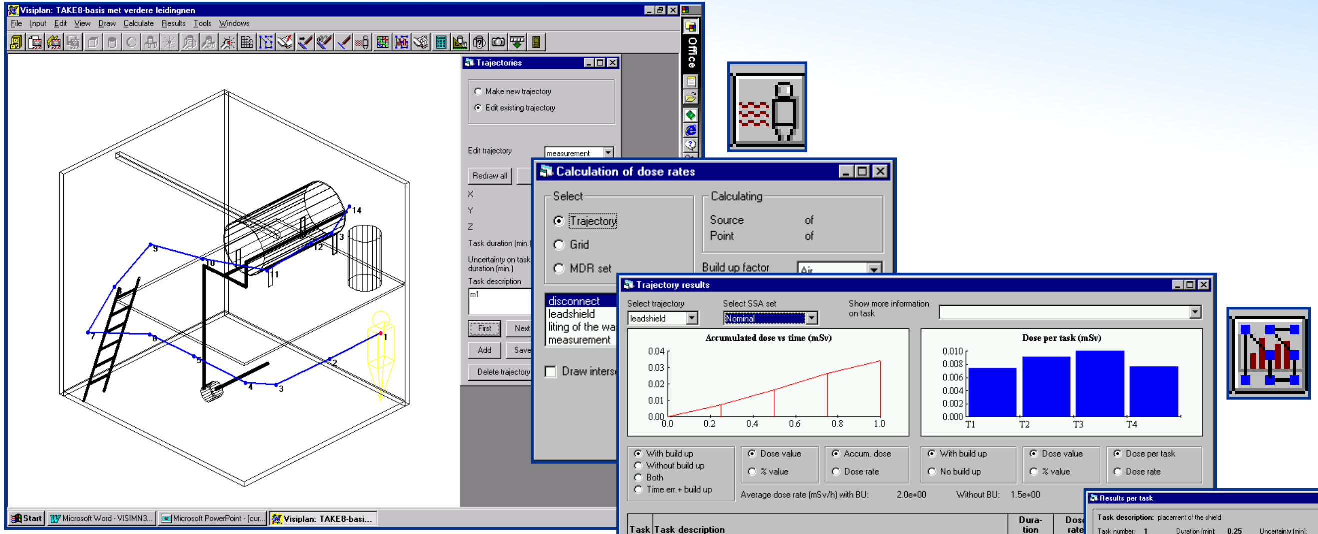
## Areas of the detected hotspots with gamma scan

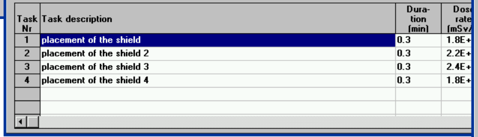


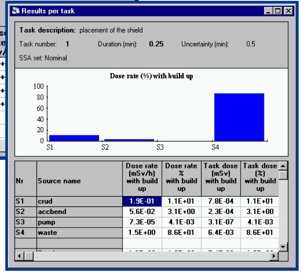
# Calculation : each source contribution to dose rates in each point



# VISIPLAN: Calculation of individuals trajectories



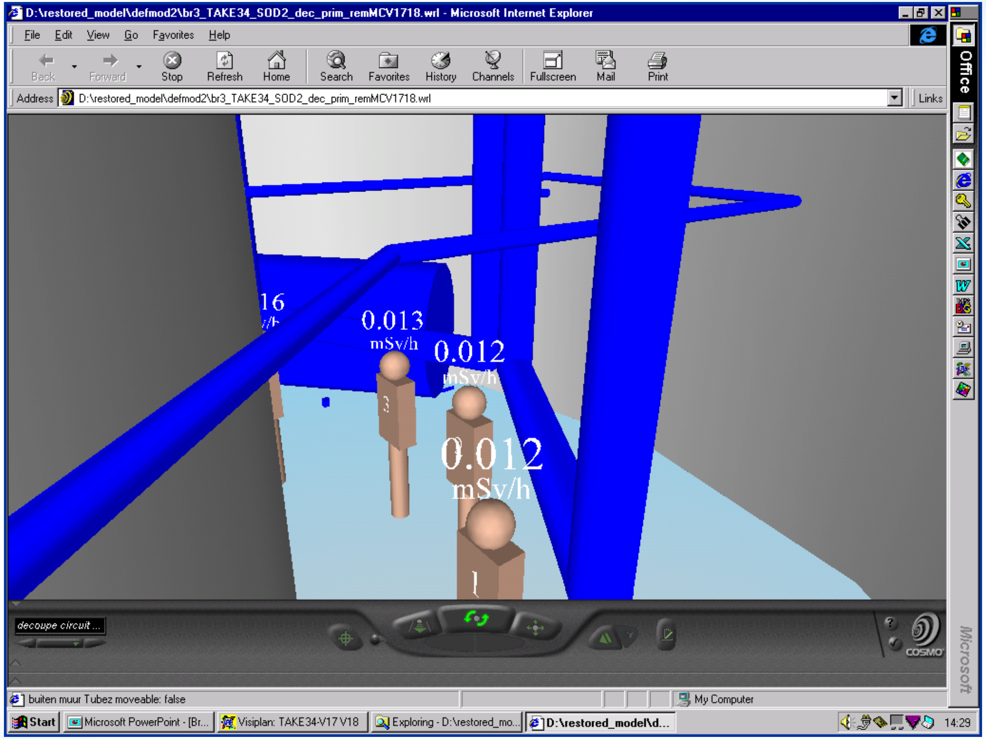



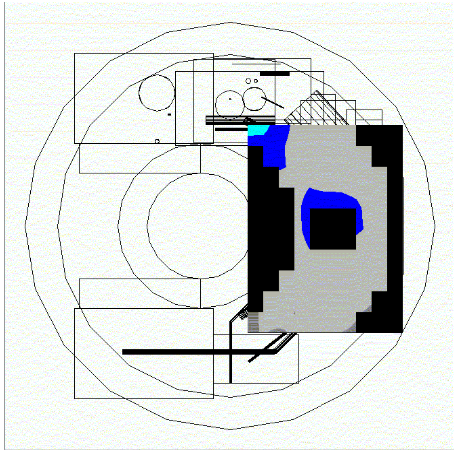

It is then possible to determine for each individual the dose rates he is exposed to and the cumulated dose according to his exposed work times (EWT)

The *contribution of each source* to the dose per task

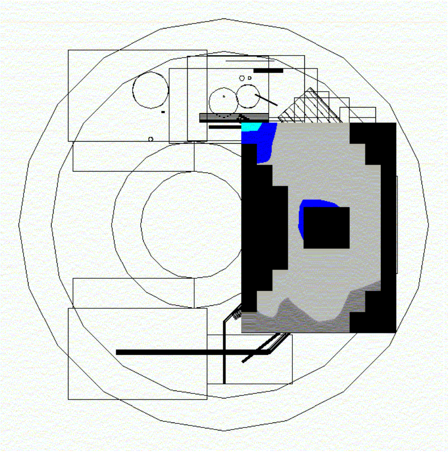
# Trajectory : trajectory for primary circuit cutting at BR3



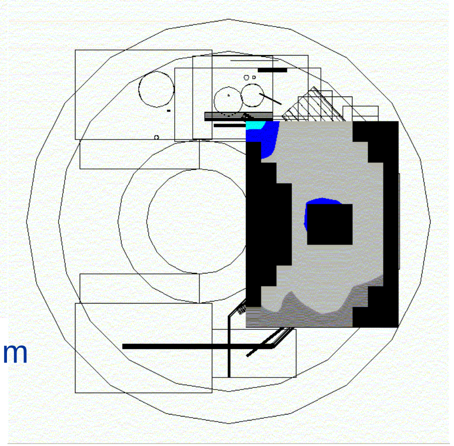
# Global analysis:
# Evolution on level 0 m



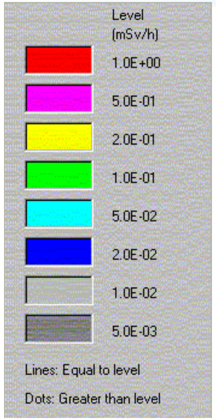
A. Situation before the operations.



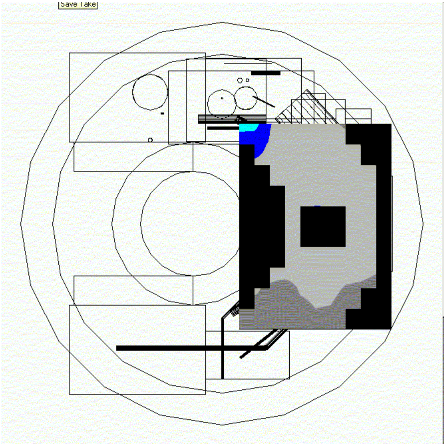
B. Hot spot removal on level 0 m



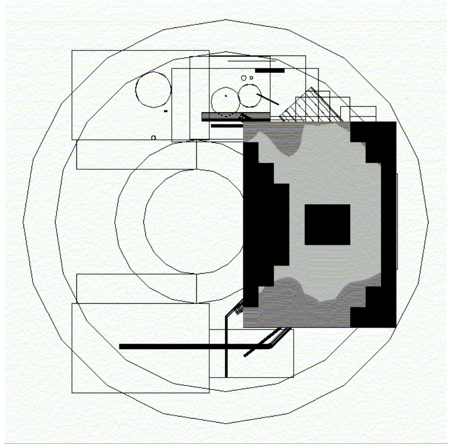
C. Hot spot removal around DDT lower part



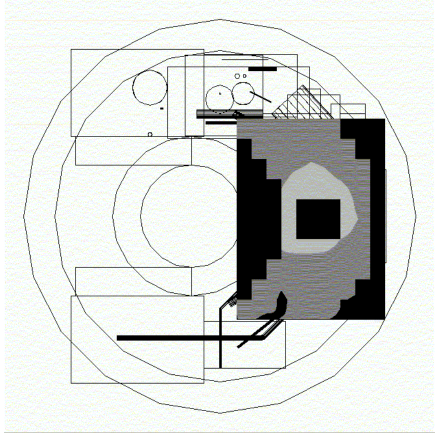
# Global analysis: Evolution 0 m (2)



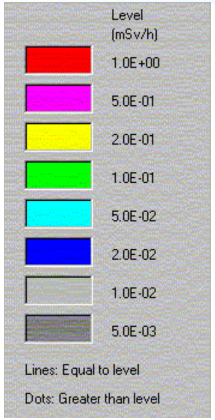

D. Removal of the rotors.



E. Removal of the SPHX



F. Removal of the shutdown circuit

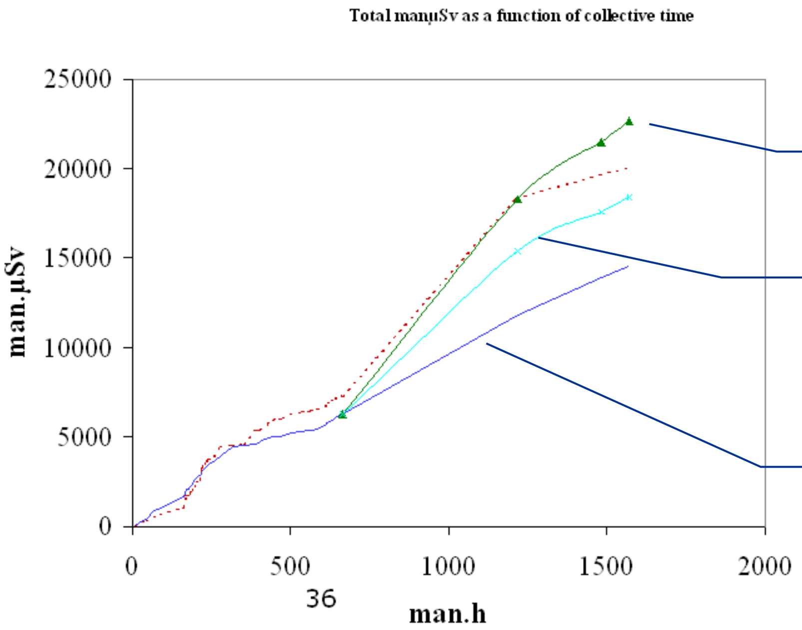


# Phase detailed planning at BR3

| Opération envisagée - SOD "1" | Nombre d'opérateurs (man) | Durée (hours) | Durée cumulée (work-load) | Ambiance "moyenne" (µSv/h) | Dose (man*µSv) |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| **"WORK PREPARATION** | man | h | | | |
| · obturation des fenêtres de la piscine RC (7) | 2 | 5 | 10 | 3 | 30 |
| · Ventilation mobile BR2 | 3 | 8 | 24 | 8 | 192 |
| · Stand de découpe (installation / check) | 3 | 4 | 12 | 8 | 96 |
| · Marquage tuyauteries | 2 | 12 | 24 | 8 | 192 |
| | | | 0 | | 0 |
| **CIRCUITS MODIFICATIONS** | | | 0 | | 0 |
| · Eau de service | 2 | 10 | 20 | 8 | 160 |
| · Air comprimé | | | 0 | | 0 |
| · SOD | 3 | 24 | 72 | 5 | 360 |
| · OD (niet) | 2 | 10 | 20 | 7 | 140 |
| | | | 0 | | 0 |
| **ACTION ON SAFETY** | 2 | 5 | 10 | 66 | 660 |
| vase d'expansion | 2 | 2 | 4 | 10 | 40 |
| | | | 0 | | 0 |
| **HOT SPOTS DISMANTLING** | | | 0 | | 0 |
| · Pompe MC n°2 | 2 | 2 | 4 | 10 | 40 |
| · Herpi's | 2 | 2 | 4 | 40 | 160 |
| · Ligne collecte d'effluents | 2 | 3 | 6 | 7 | 42 |
| · Déshabillage DDT supérieur | 2 | 4 | 8 | 30 | 240 |
| · Déshabillage SPHx | 2 | 4 | 8 | 30 | 240 |
| · Spray System | 2 | 5 | 10 | 12 | 120 |
| · Déshabillage DDT inférieur (dont L.O. + HDT) | 2 | 3 | 6 | **120** | 720 |
| · Piquages tuyauteries primaires | 2 | 3 | 6 | 30 | 180 |
| · Déshabillage MBT + évacuation | 2 | 4 | 8 | 20 | 160 |
| · Piquages GV | 2 | 3 | 6 | 12 | 72 |
| · Démantèlement ligne N² | 2 | 2 | 4 | 5 | 20 |
| | | | 0 | | 0 |
| **CABLE ROADS EVACUATION** | 2 | 5 | 10 | 15 | 150 |
| | | | 0 | | 0 |
| **SCAFFOLDING INSTALLATION** | | | 0 | | 0 |
| · niv - 4,805 m | 4 | 6 | 24 | 24 | 576 |
| · sur balançoires MC | 4 | 9 | 36 | 2 | 72 |
| | | | 0 | | 0 |
| **MODIFYING SPRING BOXES** | | | 0 | | 0 |
| · MK7 (GV) | 3 | 12 | 36 | 2 | 72 |
| · Autres MK3 - MK6 (balançoires MC, TP) | 3 | 12 | 36 | 20 | 720 |
| | | | 0 | | 0 |
| **PRIMARY PUMPS ROTORS EVACUATION** | 2 | 4 | 8 | 5 | 40 |
| | | | 0 | | 0 |
| **SPHx EVACUATION** | 2 | 5 | 10 | 5 | 50 |
| | | | | | |
| | | | **426** | | **5544** |

At that stage, a sensitivity analysis may be implemented in providing as input not only the mean exposed work time EWT but also a maximum and minimum ones for each worker and each task

# Scenario comparison at BR3




Direct operation without dose reducing actions

Operation with hot spots removed

Operation with hot spots and small heat exchangers removed

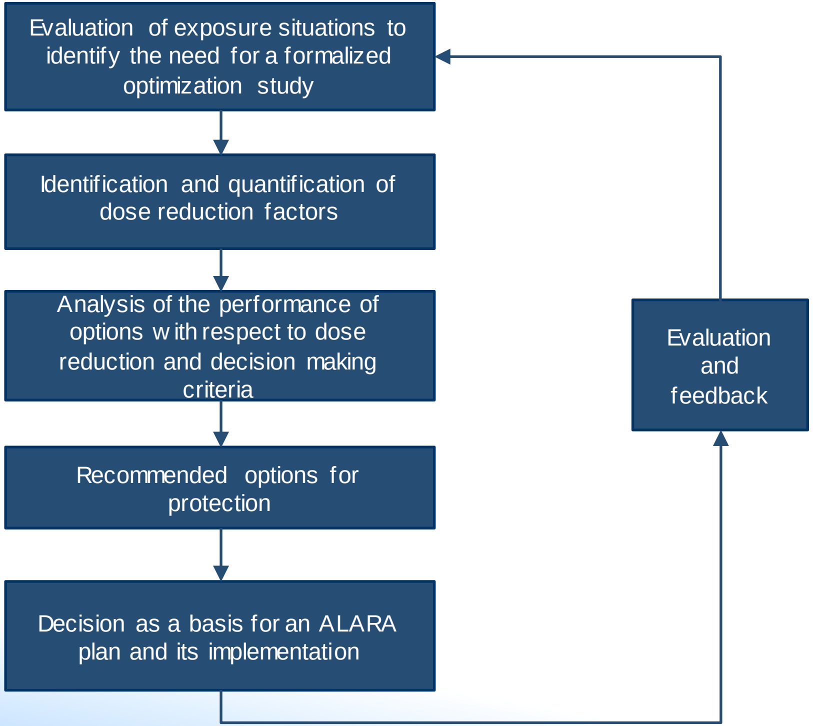
# Such tool may be used also for workers' information

Before any intervention potentially dose costing, the outputs from VISIPLAN, such as mapping, hot spots locations, dose rates, trajectories, exposed workload, doses,… are presented to all the workers.

They may then, "revisit" hypothesis, and brainstorm on how to better implement their work.

VISIPLAN may also provide a map with dose rates and hot spots to be displayed near by the controlled work area entrance.

# Lessons learned from the use of VISIPLAN at BR3




## Its analytical and 3D approach:

- Has allowed quantifying individual and collective doses per task and therefore pointing out the stakes (Optimization procedure step 1)
- Has allowed comparing scenarios as far as doses were concerned, and facilitating radiological protection options selection (Optimization procedure steps 2 and 3; but also Optimization 1st global approach )
- Has allowed simulating tools breakdowns and hence optimising fixing interventions!!!!!
- Has allowed better preparation of tasks through adequate information on the risks, visualisation of hot spots and training of operators.

# What tools to be used for aiding to optimization implementation?

Other analytical and 3D software's have quite similar objectives while their functions may differ slightly

Therefore the use of such tools is very promising for a cost of a few thousands of € or $ including training (both her MS and V)

However when not available or too costly very simple tools such as excel charts developed by the RPO' themselves may be very useful.

What are the minimum required information to be put in an excel chart from your point of view as an aiding tool?

# Part 3
# Towards a global approach for managing occupational risks

During maintenance, of course occupational radiological risk is not the only risk to be managed; but during a dismantling, such a diversity is even more important : presence of asbestos, use of acids, building classical risks,…

This may even leads to conflicts, if not well managed

Have you experience with such conflicts ? Please describe that experience.

This will be illustrated through the need that appeared at BR3 to implement a global and coherent approach

# Other risks encountered when dismantling BR3

Risks due to :

- Cutting tools and flames
- Chemical products and acids used for decontamination
- Dangerous gazes (hidden in loops of pipes, products of decontamination, …)
- Toxic substances to be removed such as asbestos, …
- Work in height
- Manipulations of heavy materials

# May there exist conflicts between risks management approaches?

What has been observed is that radiological risk management particularly for avoiding contamination might induce other risks taking:

- For example very often wearing special suits against contamination (particularly when not ventilated) can lead to claustrophobia and excessive heat and also to a loss of skilfulness that induces an increase of classical risks, particularly when manipulating dangerous products.

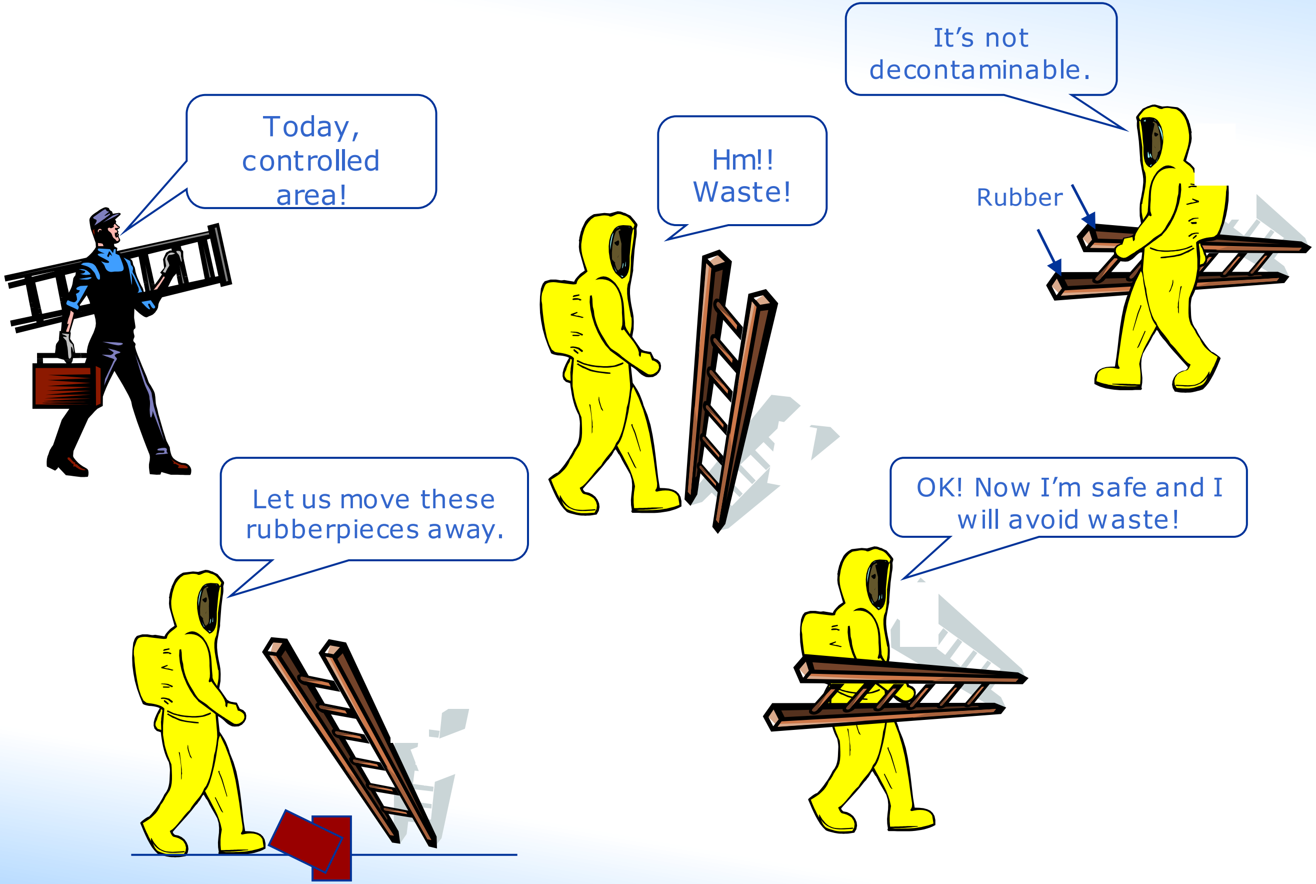
This has been illustrated as follows

# Some workplaces!

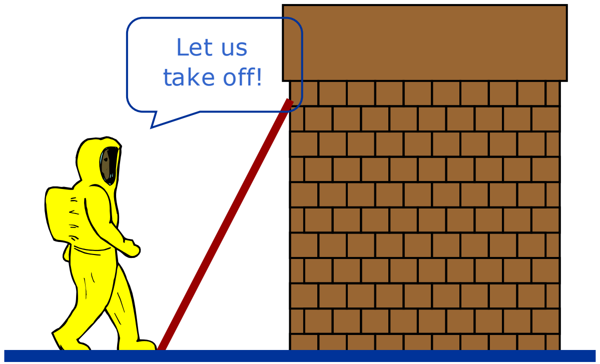
Radiological risks

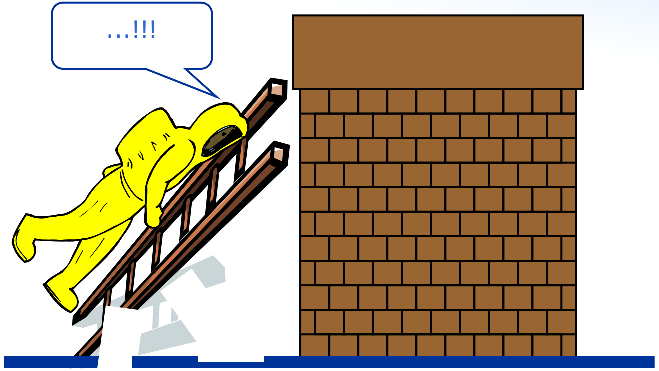
Non Radiological risks

# Transfer of risk

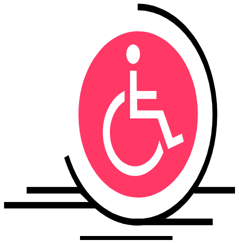


# Transfer of risk







3 months at home with a broken leg!

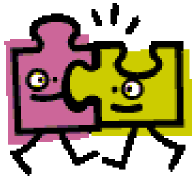
# Conversely, one example where complementarities occur when a coherent approach is implemented (1)

One of the most important risk corresponds to the removal of asbestos when dismantling one quite old nuclear facility …

There may be then conflicts as radiological protection and taking care of asbestos correspond to so different contexts

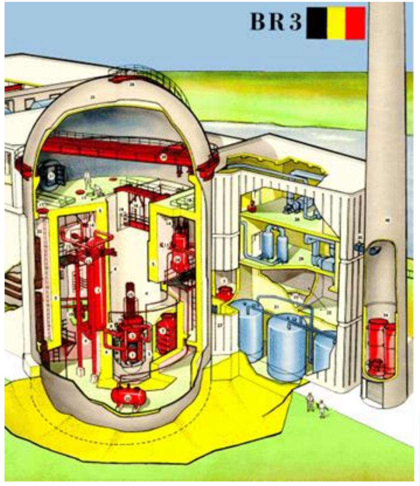
It can be avoided when using a coherent approach as done at BR3

# Interaction between risks with very different contexts



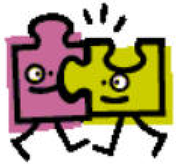
**Asbestos**

- Annual inventory
- Concentration too high
- Removal imposed
- Specific technical procedures
- their own habits




- Decommissioning project
- Reactor build in the early sixties
- Skilled workers
- ALARA procedure

How?



# Conversely, one example where complementarities occur when a coherent approach is implemented (2)

Such an approach was of course anticipative and has requested

- Discussing with the contractor in charge of the removal to check priorities and possible conflicts
- Analysing the impacts of both regulations
- Implementing the ALARA approach for both risks

This has led the contractor to modify its current work procedures

Then on the spot it has led to

- Train all operators
- A regular follow up with videos cameras, anthropogammametry, operational dosimetry

# Conversely, one example where complementarities occur when a coherent approach is implemented (3)

It has been demonstrated that wearing traditional masks against asbestos inhalation is not enough for avoiding totally ionising particles contamination

Taking into account the existing potential contamination by Cobalt, it was decided to use the more accurate and adapted filters and masks devoted to radiological protection. They also allowed to avoid asbestos contamination.

To explain it a specific training to radiological protection has been organised for the contractor's operators

That coherent and global approach has led to reducing jointly both risks

# Conversely, one example where complementarities occur when a coherent approach is implemented (4)

After that during the BR3 dismantling the radiological risk progressively regressed and the classical risks took the lead.

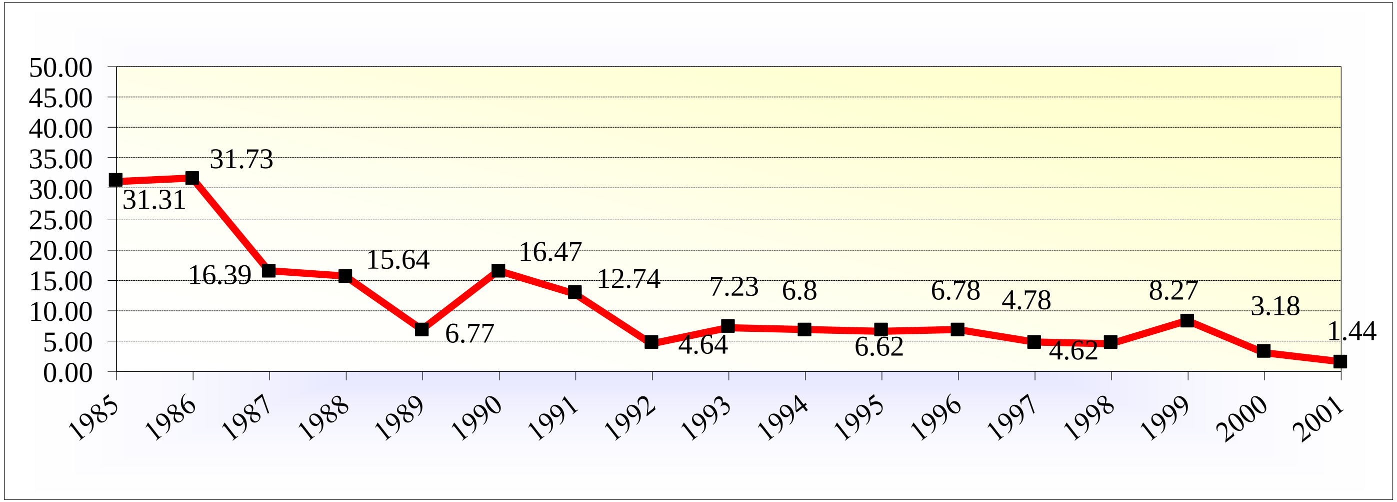
This is not specific to BR3 this is what is observed everywhere for dismantling of nuclear installations.

Since then a data base dealing with lessons learned an feedback analysis for all risks has been set up at the level of the research centre as a whole.

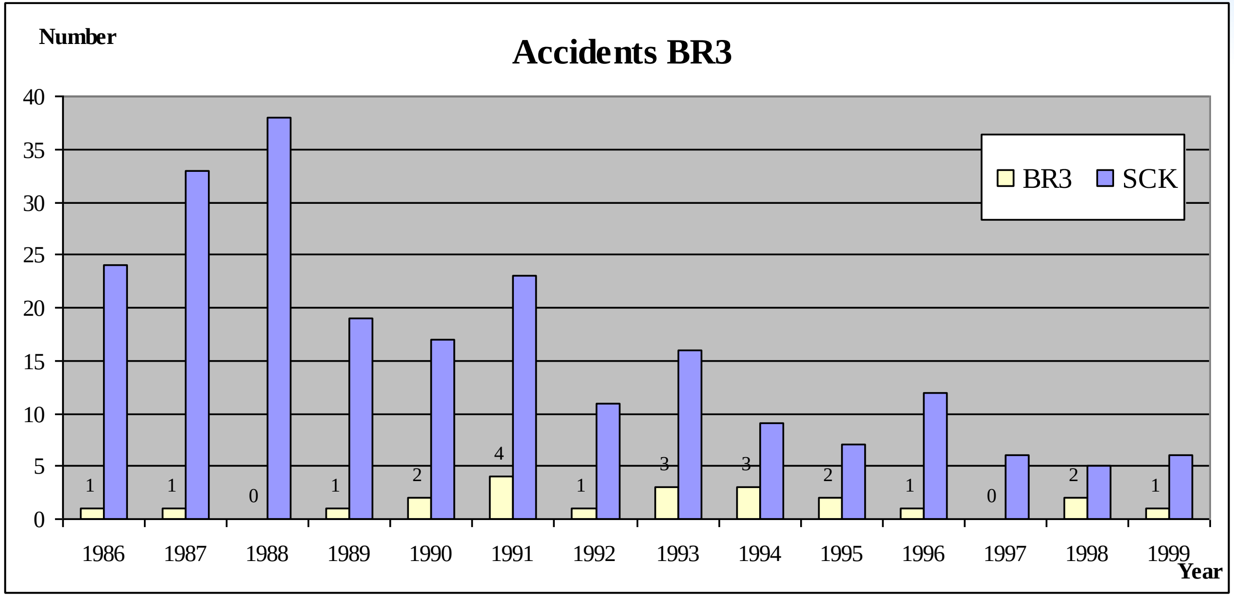
It allows analysing also precursors and good practices.

As well as sensitization policy to safety and security is implemented among all stakeholders.

# Maximum individual dose at BR3 (mSv)



# Accidents number at BR3
# 1986 - 1999



# The 4th workshop of the EAN
# The main recommendations


(Based on the case studies and the implementation of a Global Risk Management in many sectors)

- Need for further studies on risk-transfer
- Need for developing a risk culture
- Need to involve all the stakeholders

# Making use of optimization is a facilitator for improving globally the situation

It facilitates a formalised approach

It has demonstrated its interest and efficiency for radiological risk management

Being a quality type approach it can be a good catalyst for spreading a safety and security culture

It has also been demonstrated that it is worthwhile implementing it for both radiological and non radiological occupational risks