SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

SCK•CEN ACADEMY
FOR NUCLEAR SCIENCE AND TECHNOLOGY

The VISIPLAN 3D ALARA planning tool and its applications

Fernand Vermeersch & Robby Nijs

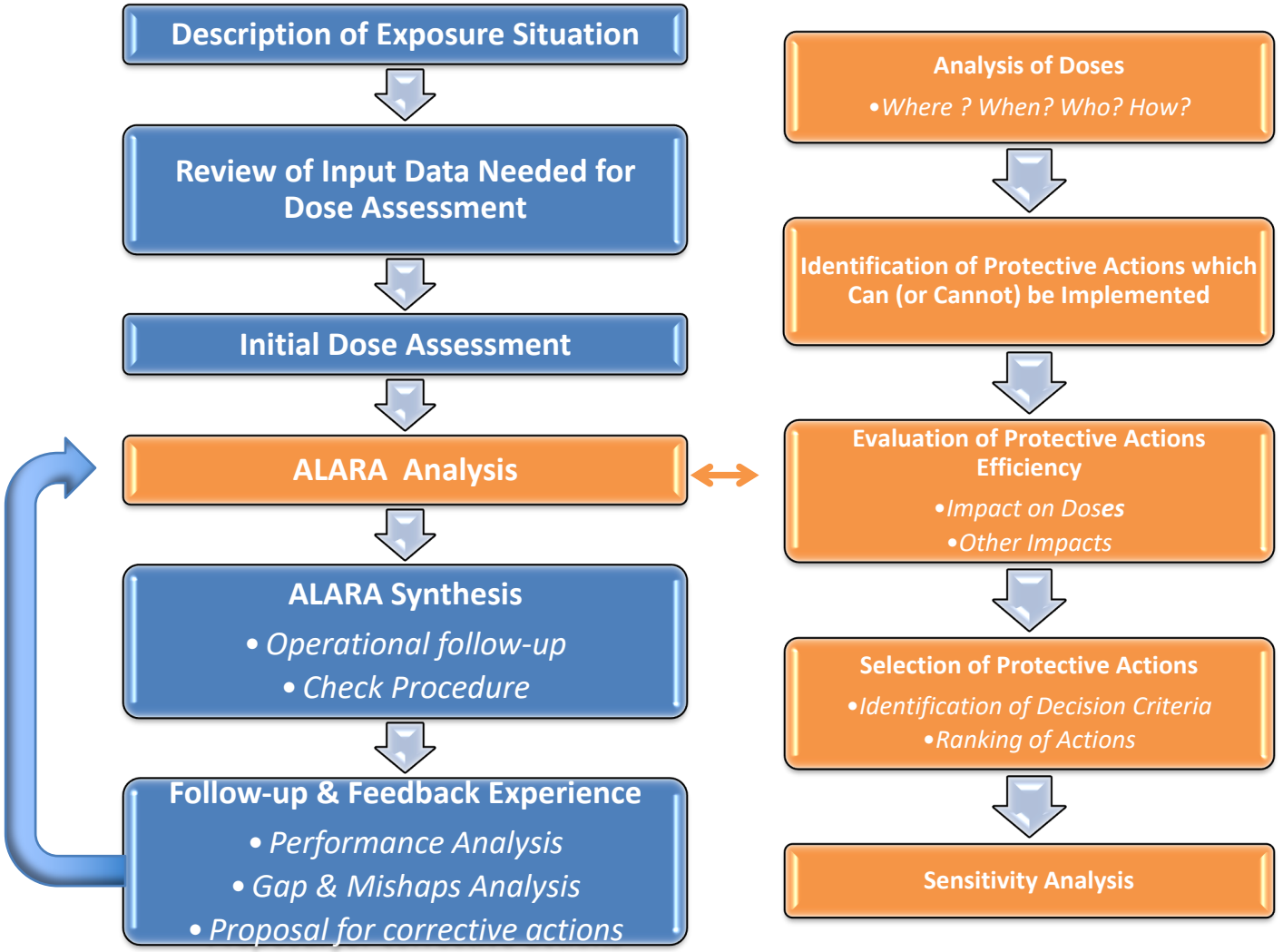
fernand.vermeersch@sckcen.be & robby.nijs@sckcen.be

Content

- Why VISIPLAN?
- VISIPLAN development, capabilities and methodology
- Applications of VISIPLAN & International projects
- Sneak preview of VISIPLAN 5.0 (under development)

Why VISIPLAN?

Because we want to apply the ALARA procedure

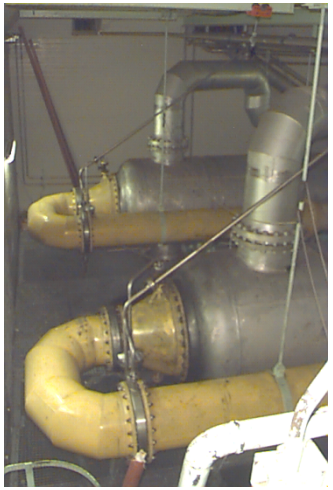


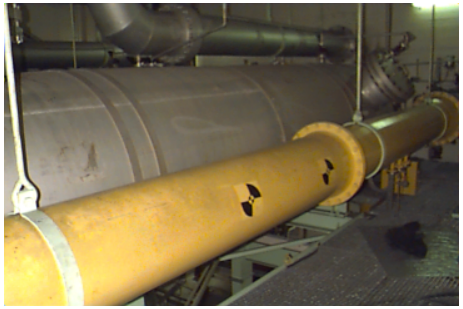
Dose optimization in general

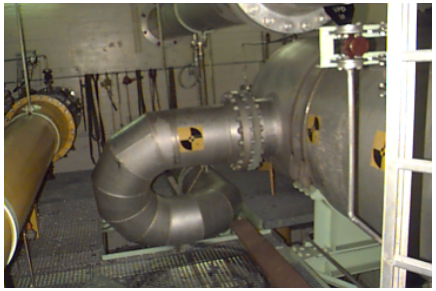
- Application of ALARA in nuclear installations is complex.
- We need to evaluate the dose for the different activities and environments.

Dose is influenced by:

- Geometry of the installation
- Source distribution and strength
- Shielding configuration, fixed or mobile
- Work organization



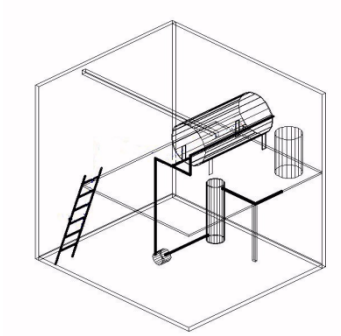


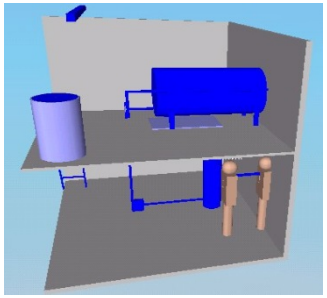


Optimization in rapidly changing environments

- ALARA in changing installations is even more complex
  - Changing geometries
  - Changing source distributions and strengths
  - Changing shield distributions
  - Changing work groups

VISIPLAN 3D
ALARA planning tool





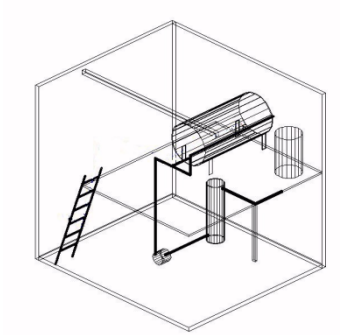
- VISIPLAN is a dose assessment program developed to assist the ALARA analyst in ALARA pre-job studies.
- The VISIPLAN tools assist both in the calculation and the communication in ALARA evaluations.

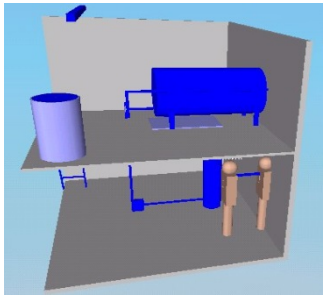
Current user group

Framatome (France)
ANSALDO (Italy)
HSK (Switserland)
CEA (France)
Tractebel(Belgium)
VUJE(Slovakia)
APAT(Italy)
IRE(Belgium)
RWE Nukem LTD(UK)
Belgonucleaire (Belgium)
Steag encotec (Germany)
RPC (Lithuania)
NRG (The Netherlands)
SOGIN (Italy)
EDF(France)
IPSN(France)
Belgoprocess(Belgium)
Ignalina(Lithuania)
COVRA(The Netherlands)
SCK•CEN (Belgium)
Rotem Ind. LTD (Israel)
Techint Cimi Montubi(Italy)
CIAE (China)
DECOM (Slovakia)
.....
Radboud Univ. Nijmegen (The Netherlands)

About 108 licenses in use

VISIPLAN 3D
ALARA planning tool



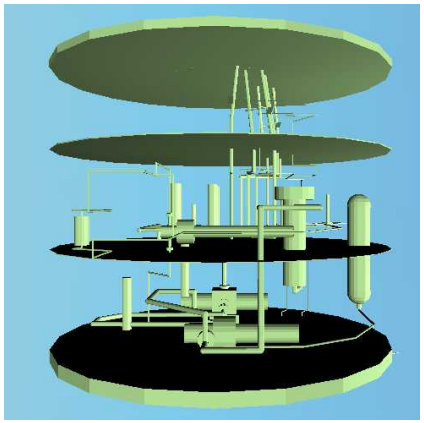


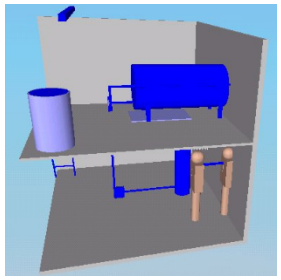
Current academic users group

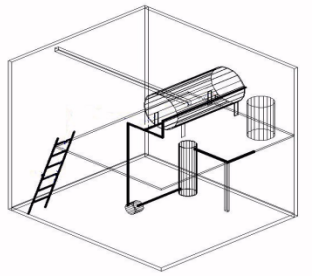
ISIB (Belgium)
University of Ontario Institute of Technology (Canada)
Bologna Univ. Nuclear Engineeering (Italy)
CEA ISTN (France)
University Gothenburg (Sweden)

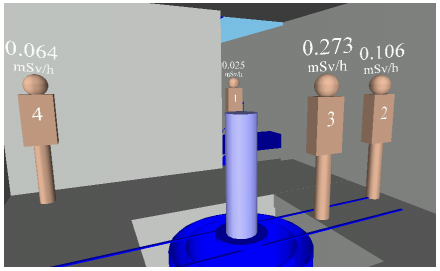
<u>About 30 licenses in use</u>

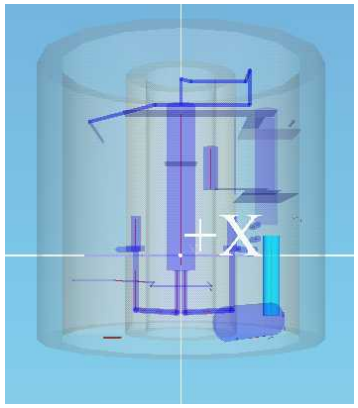
VISIPLAN 3D
ALARA planning tool



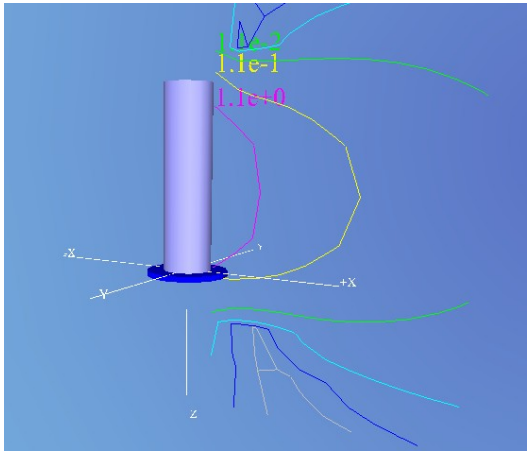








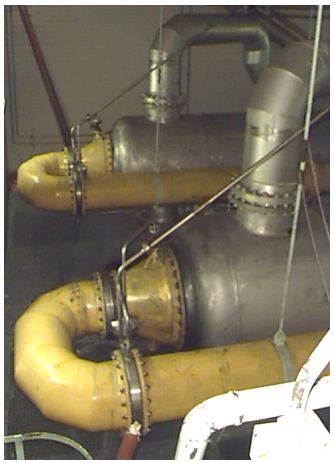
ALARA
VISIPLAN-3D

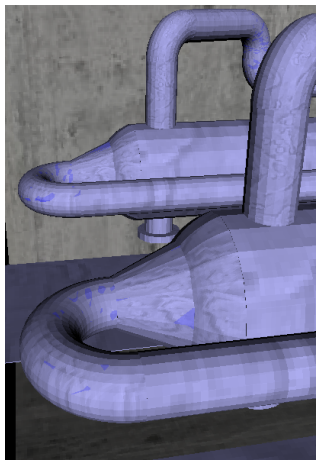


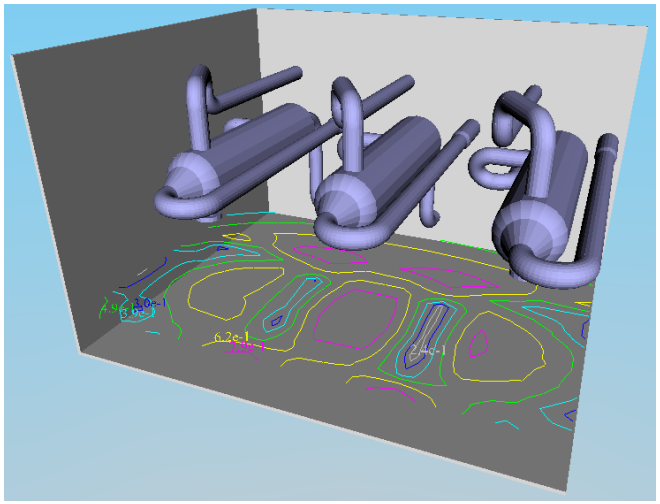
Dose assessment of work scenarios in a 3D environment

VISIPLAN development, capabilities and methodology

3D dose modeling and planning tool







Based on:

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

VISIPLAN-3D

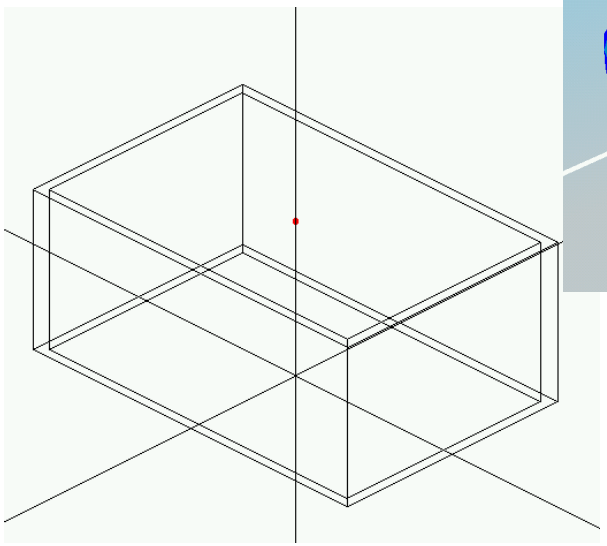
Allows:

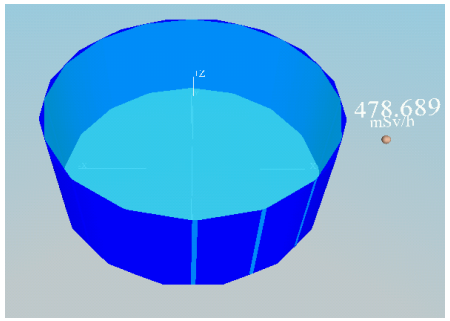
- Dose assessment for tasks, routes or trajectories and scenarios
- Individual (MID) and collective dose (S) assessment
- Source strength calculation from measured dose rate sets.
- Source Sensitivity Analysis

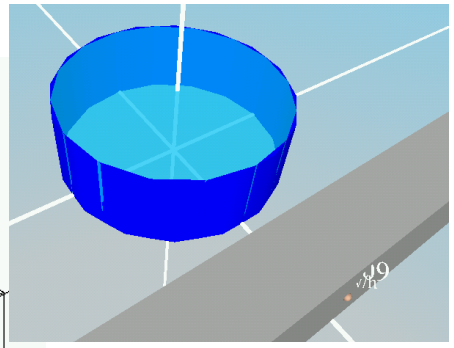
Validation and Verification

Comparison of the VISIPLAN results with the results from reference calculations

- ANSI/ANS 6.6.1 1979 “The calculation and measurement of direct and scattered radiation from LWR Nuclear Power Plants.”.
- ESIS problem 1 from ESIS (1981) “Specification for gamma ray shielding benchmark applicable to a nuclear radwaste facility.” Newsletter #37, European Shielding Information Service.
- Comparison with other shielding calculation tools MicroShield, QAD and MCNP



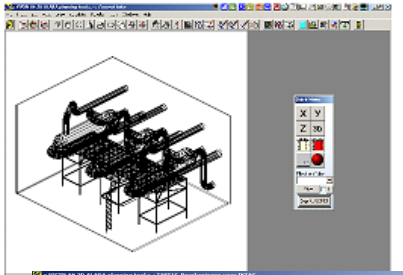


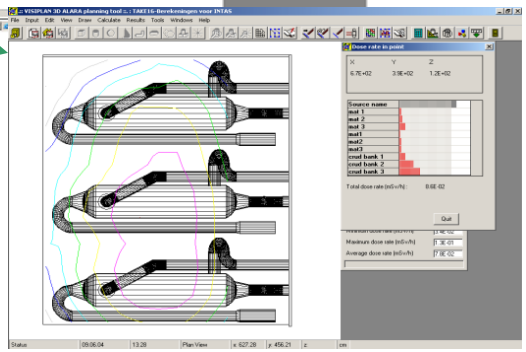


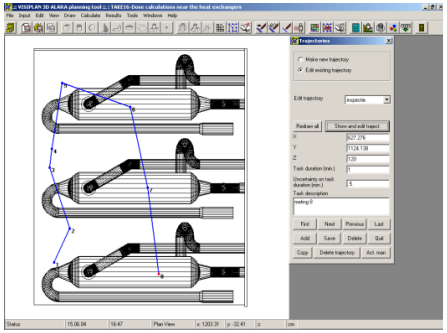
VISIPLAN 3D ALARA planning tool. *Calculation Method &Validation Tests.* NS/FVe/IDPBW/00-849

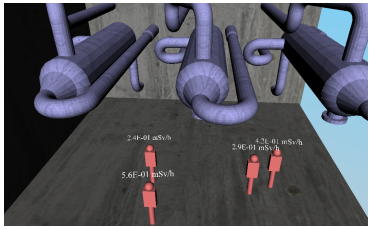
VISIPLAN
General methodology

- Model building stage
- General analysis stage
- Detailed planning stage
- The follow up stage









Measurement

Prediction

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

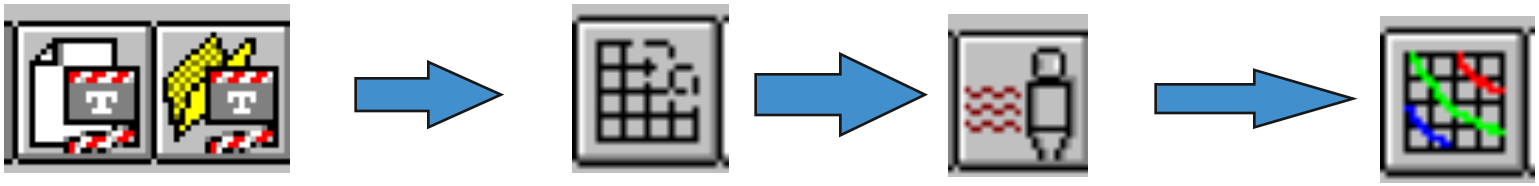
- Technical data
- Survey
- Site history

Source dataset

Take

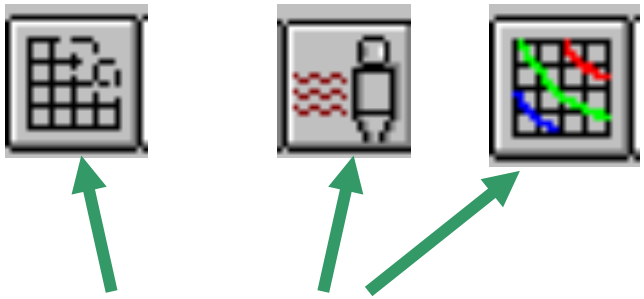
General planning stage

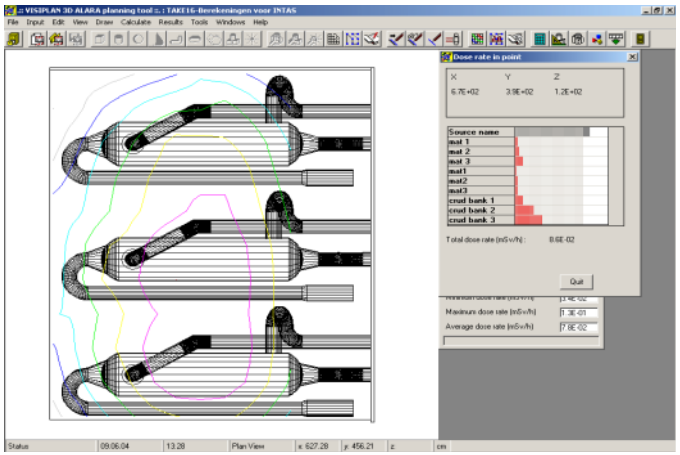
- First Evaluation based on calculated dose maps
- Evaluation of possible shielding solutions



- Take 1 Basic situation
- Take 2 Shielding solution 1
- ...
- Take n Shielding solution n

General Analysis





- x-, y-, z-grid on screen definition
- Isodose, Pattern or grid dot display
- Dose rate determination at pointer position on the grid
- Display of the source contribution at the pointer position on the grid

VISIPLAN
Detailed planning stage

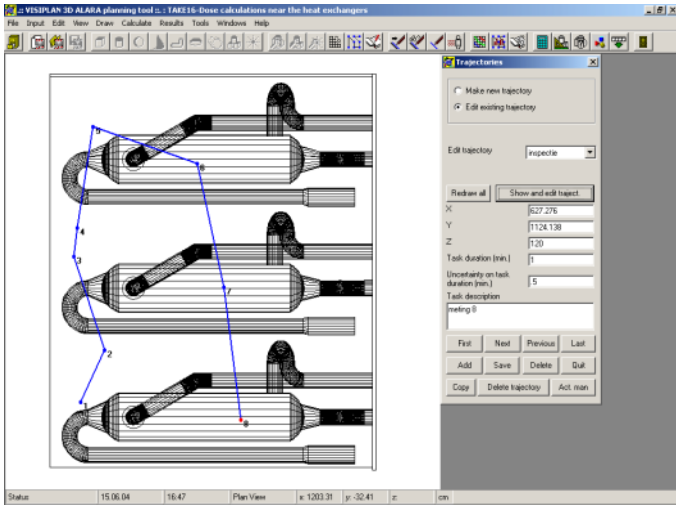
Trajectory definition

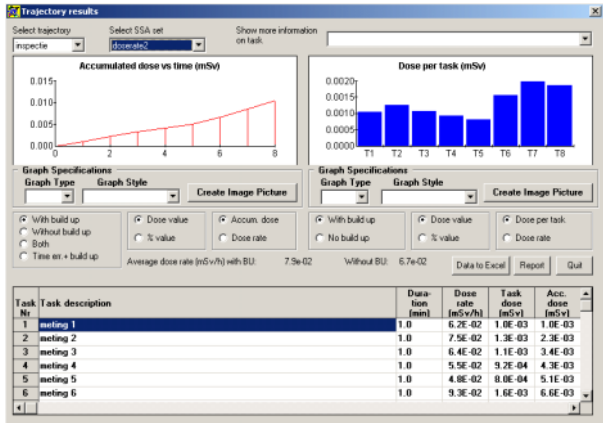
- Position
- Task description
- Task duration
- Uncertainty on task duration

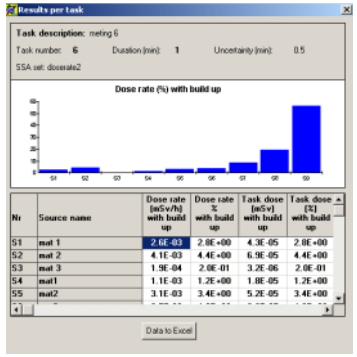
Trajectory Results

- Accumulated dose vs time
- Dose rate at task location
- Dose and dose rate per task
- Contribution of the different sources to the task dose
- Minimum, maximum dose estimate based on the time uncertainty
- Bias with source sensitivity analysis set

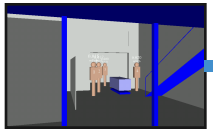
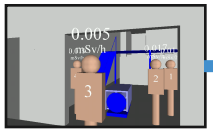
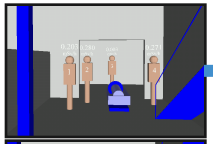
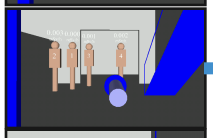
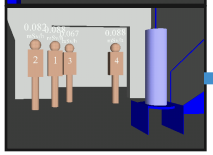
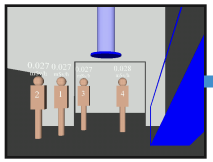
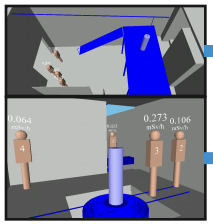
Detailed planning







Creating Scenario's

Worker selection

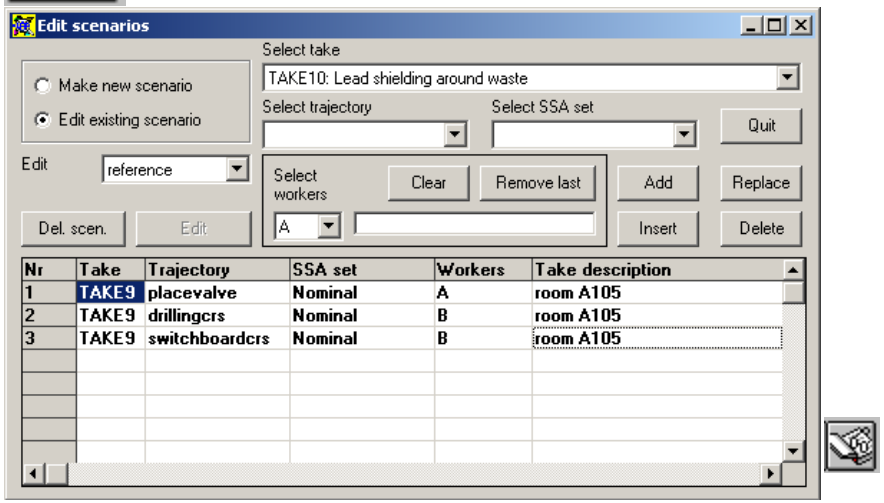
Trajectory selection

Scenario: fuel loading in a reactor

Scenario Results

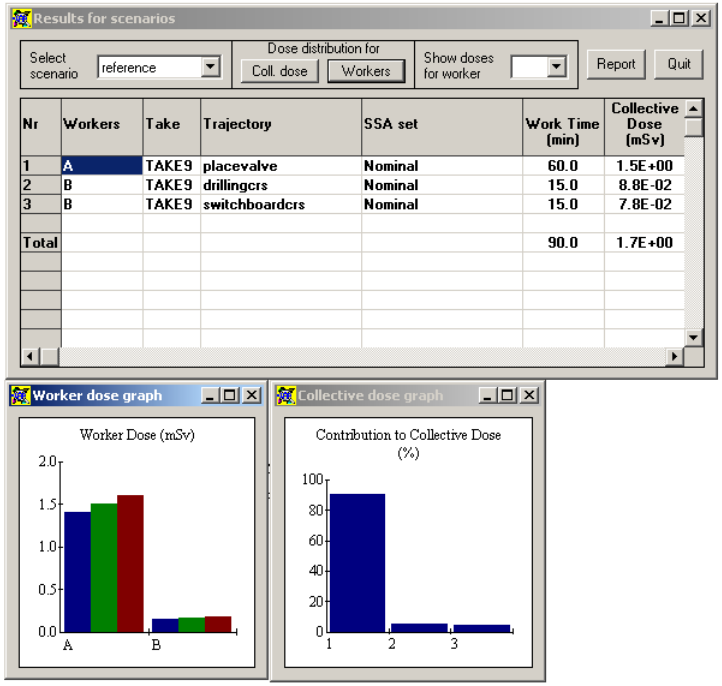
Scenario's

Scenario definition



- Selection of trajectories in different takes
- Selection of Source sensitivity Analysis file
- Dedicate a worker or a group of worker to a trajectory

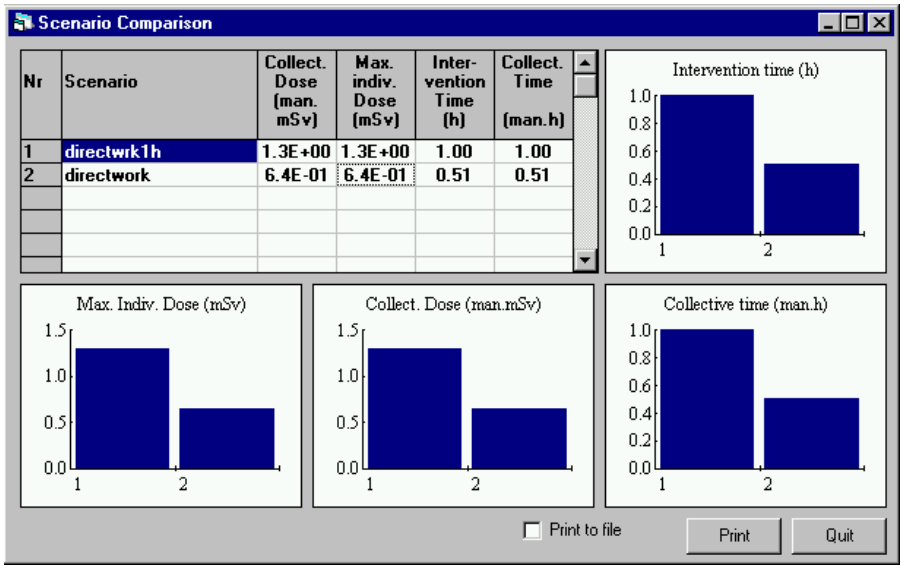
Scenario Results



- Collective dose
- Collective dose per trajectory
- Accumulated dose per worker per task

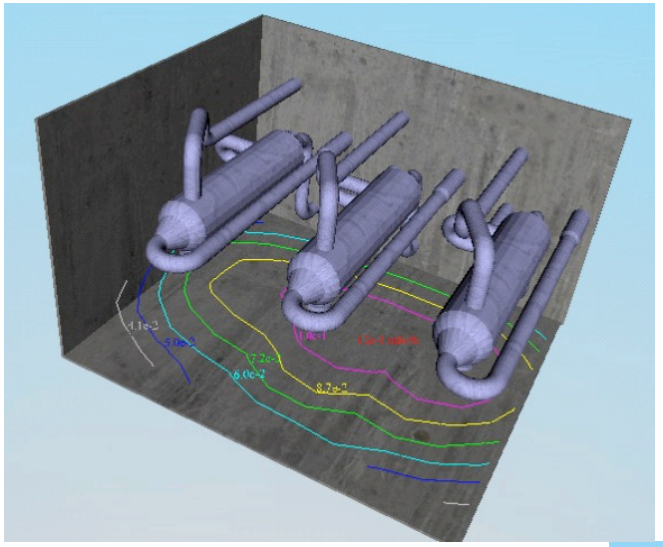
Scenario Comparison Results

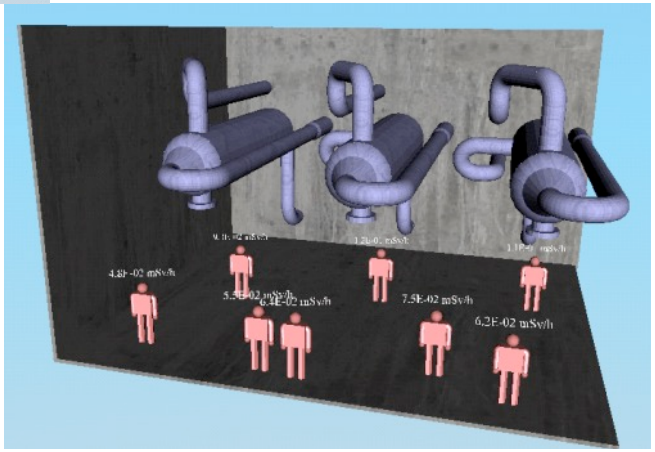
- Collective dose (man.Sv)
- Max individual dose (mSv)
- Intervention time (h)
- Collective time (man.h)

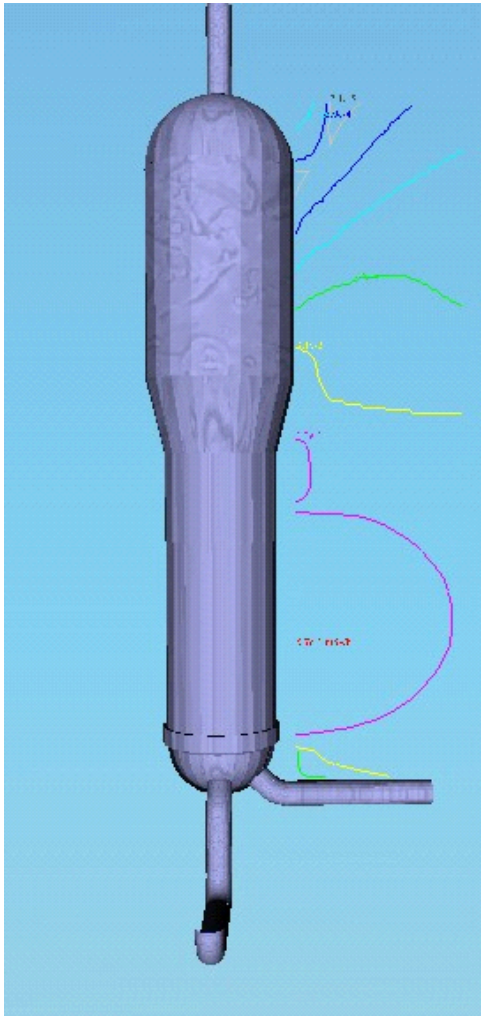


Tool for the ALARA analyst

VRML output



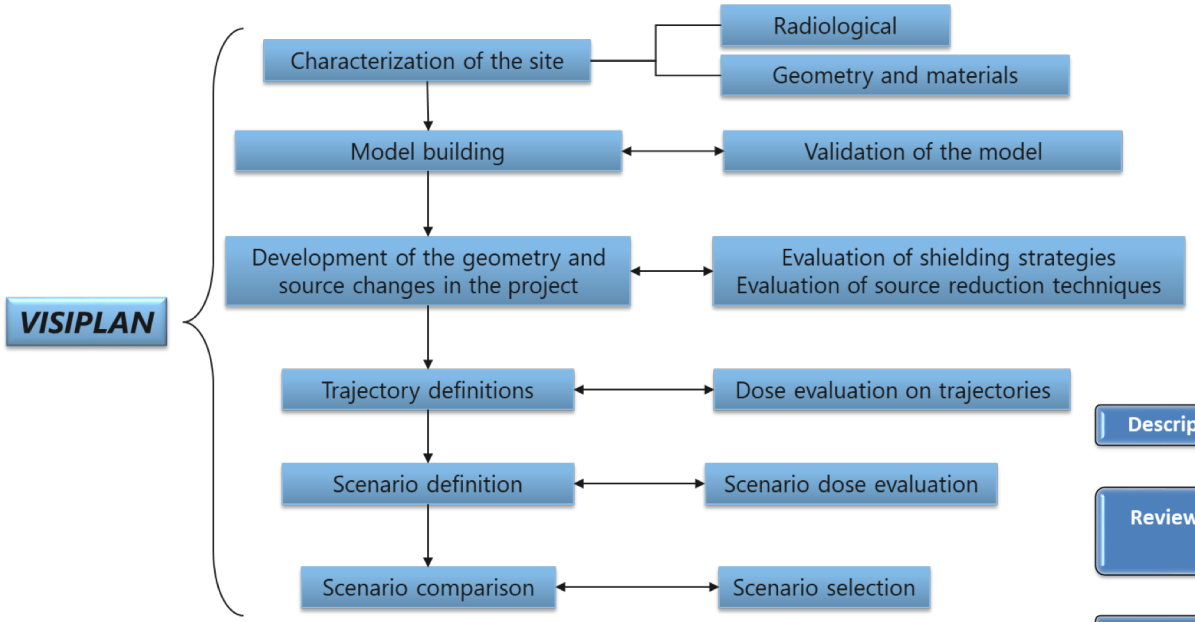




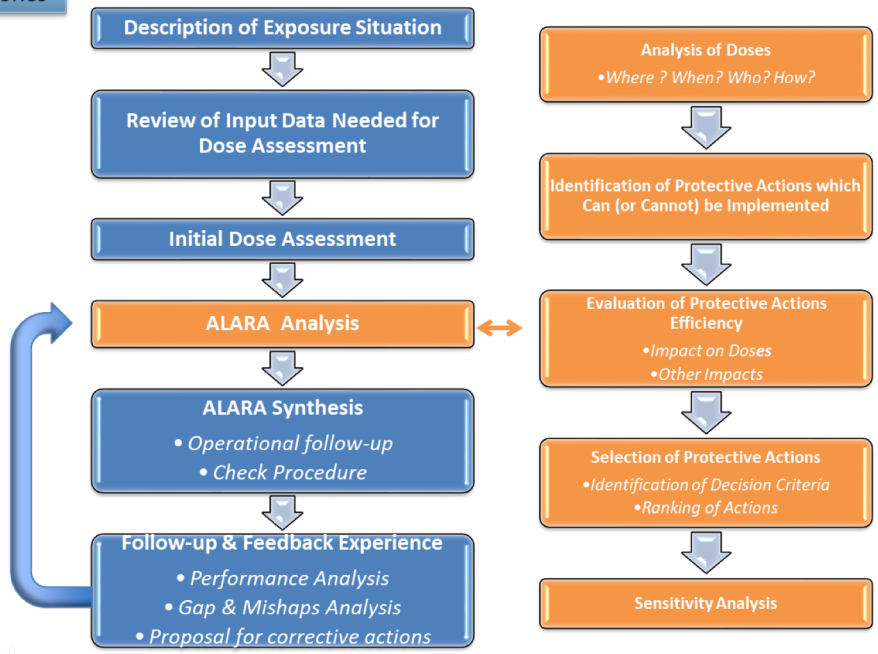
VRML :
***V**irtual*
***R**eality*
***M**odelling*
***L**anguage*

(open format that can viewed by any web browser)

ALARA assessment with VISIPLAN



VISIPLAN enables and supports the ALARA procedure

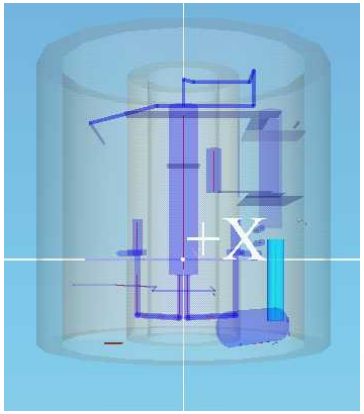
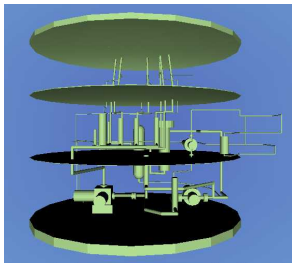
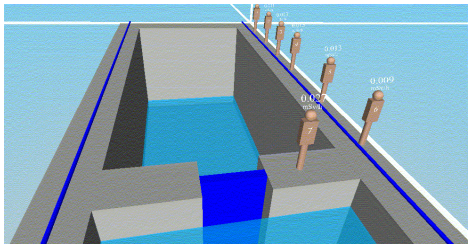
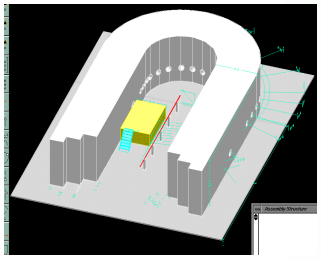
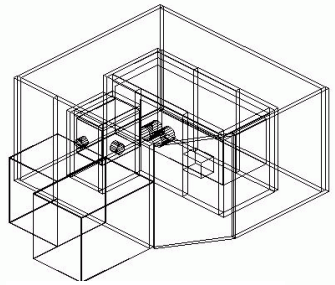
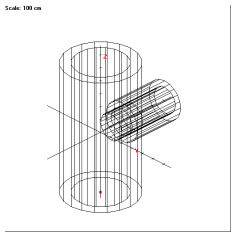
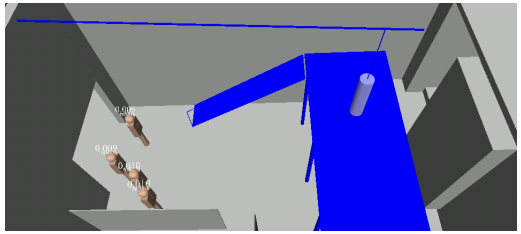
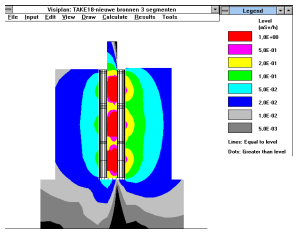
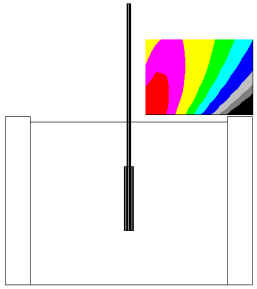
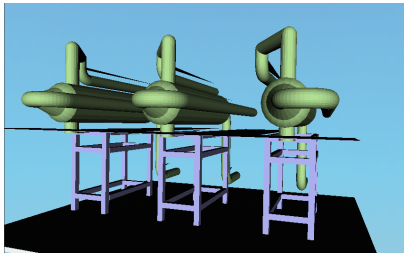


Applications of VISIPLAN & International projects

VISIPLAN applied to different ALARA problems

1. BR3 decommissioning site
2. IRMM Geel, Gelina accelerator
3. HADES underground laboratory
4. BR2 reactor
5. BR2 Heat exchangers
6. CELL 10 dismantling
7. CORALUS dose calculations
8. BP hot cell dismantling
9. BR3 decontamination area
10. REBUS loading study
11. Filter replacement study
12. Fuel pond decommissioning study
13. BR2 sub pile room
14. Decom. Cel 41

….

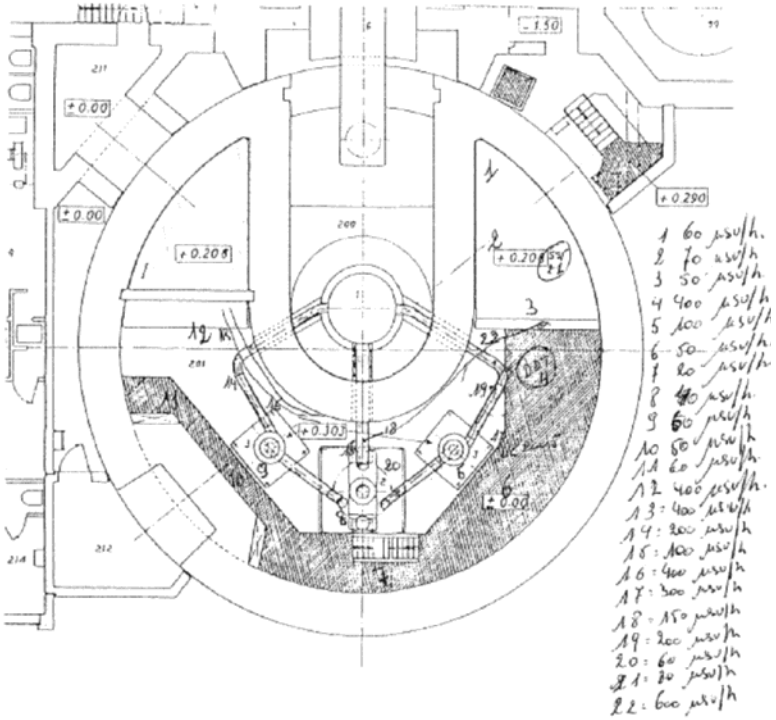











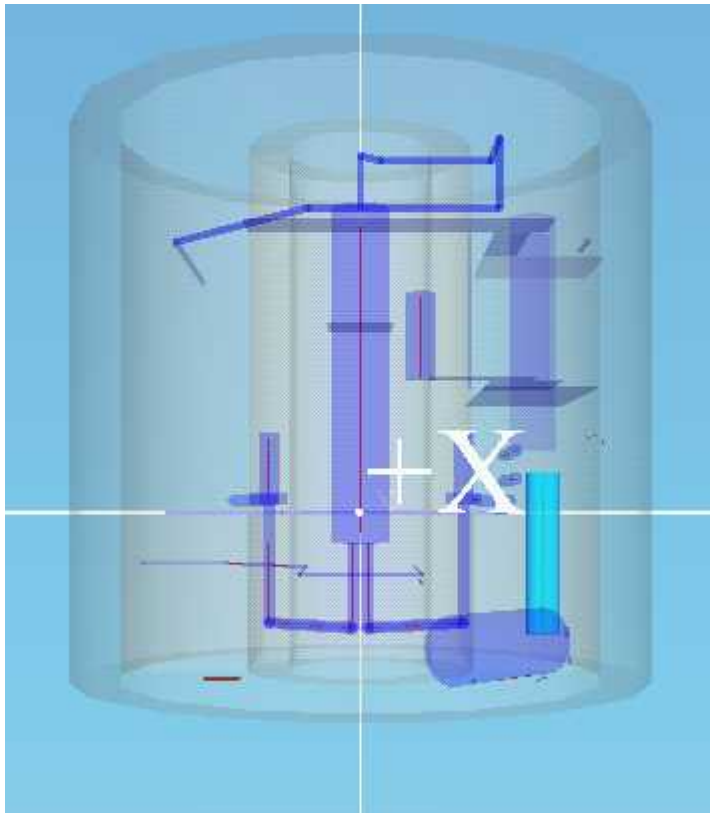
Decommissioning of BR3
Operations under the operation deck

Radiological Characterization

- 4π dose measurements
- Source location measurements with RadScan
- Historical information on the site.

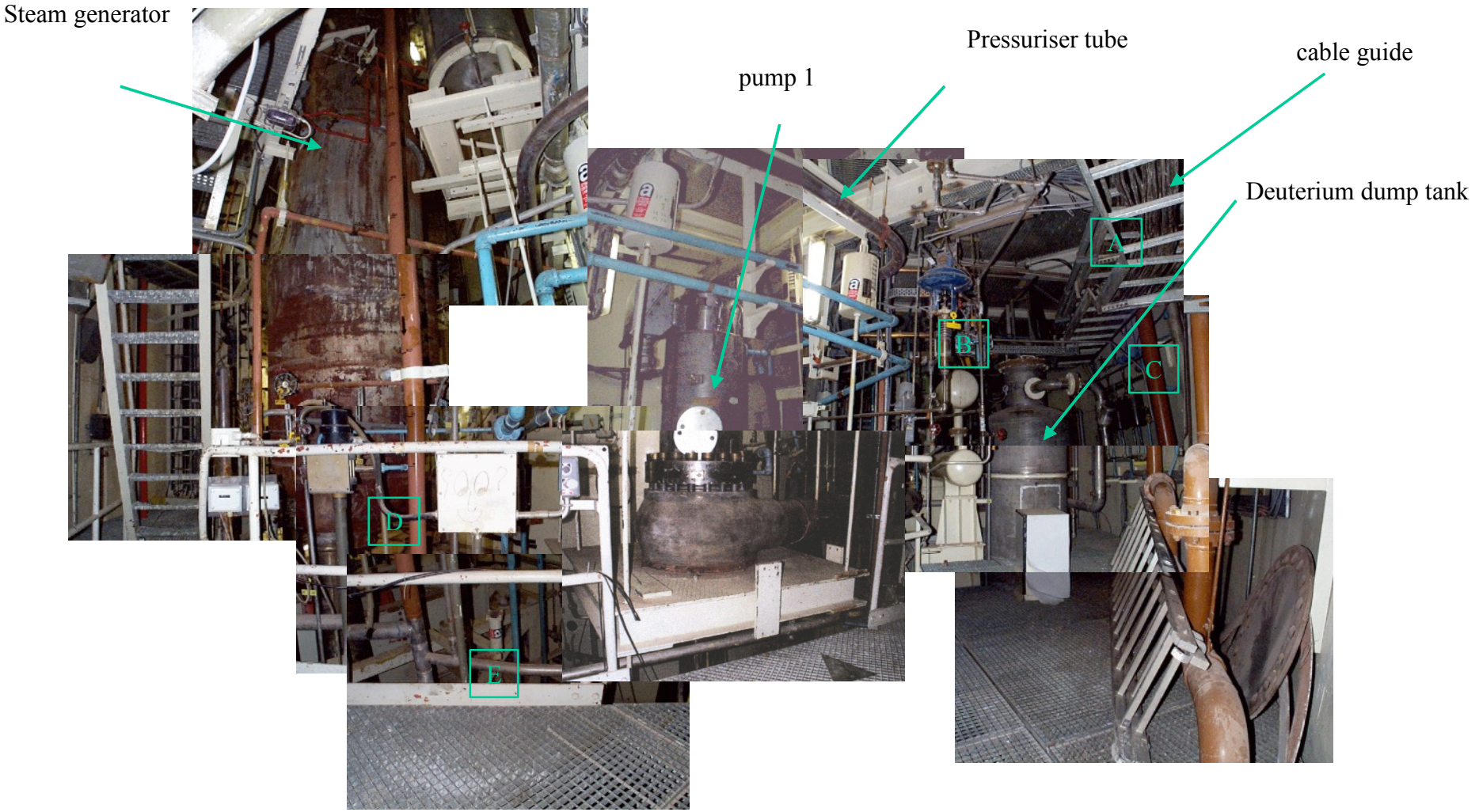
Characterization
dose rate measurements



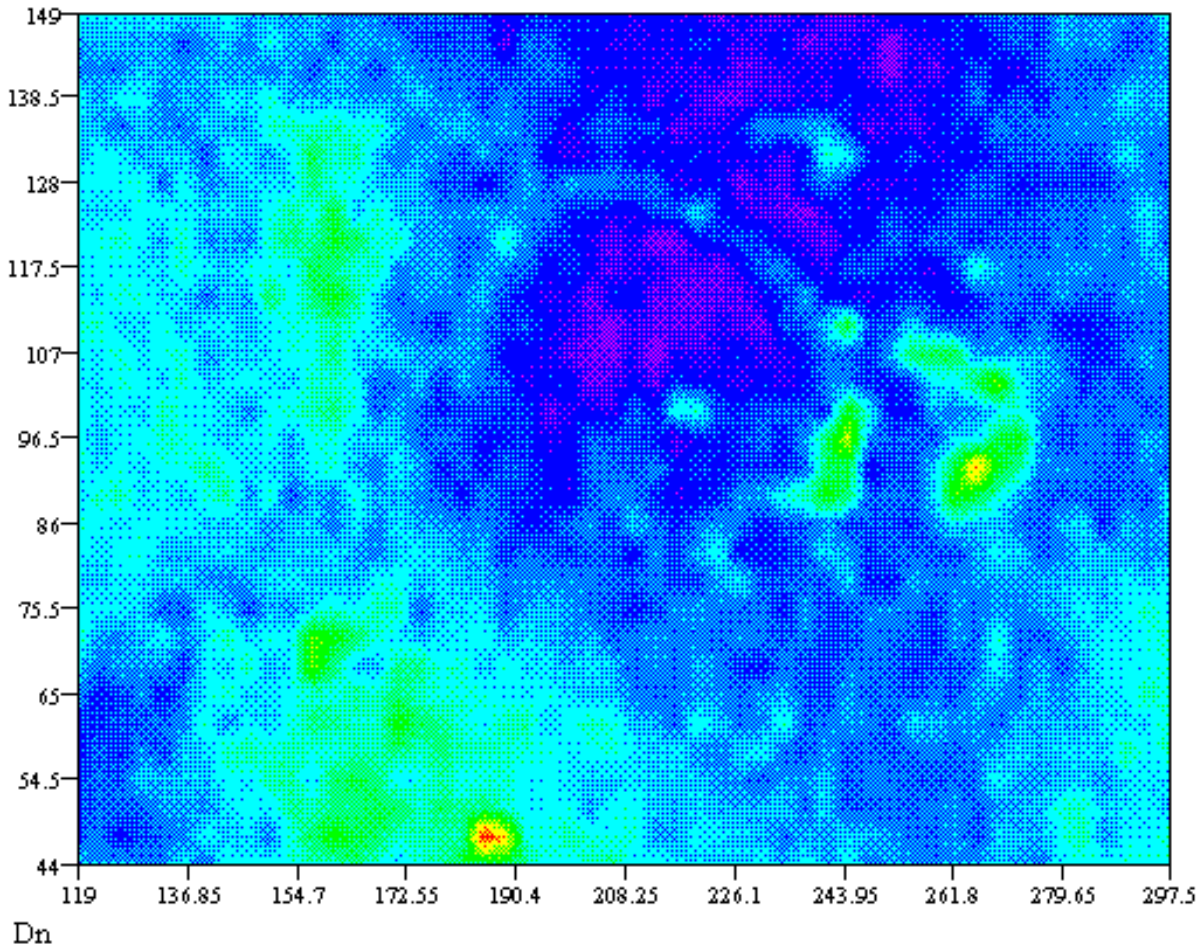


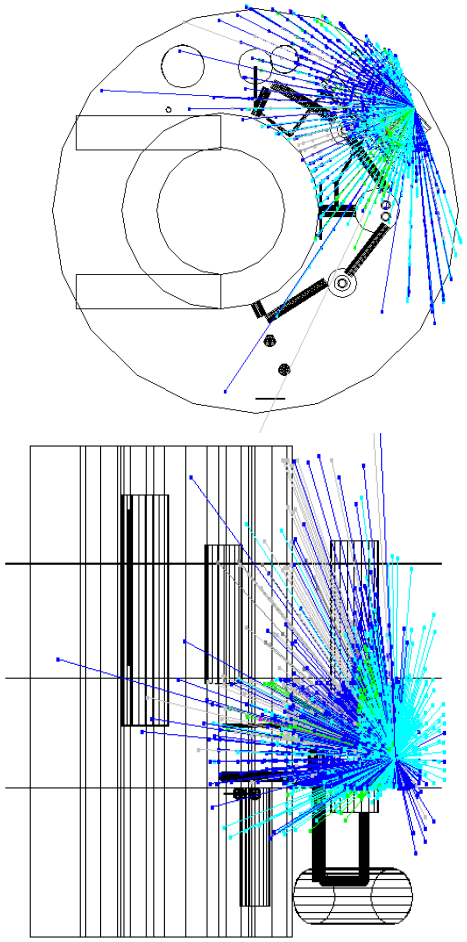
Gamma Scanning at the BR3 decommissioning site

Areas of the detected hotspots in scan 5 (Composite picture).



Intensity map scan 5

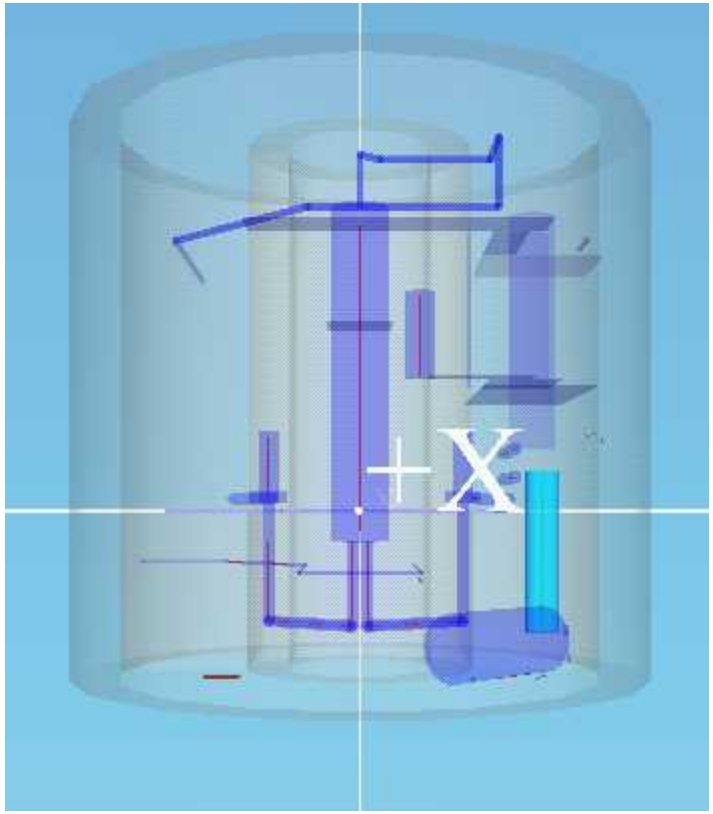




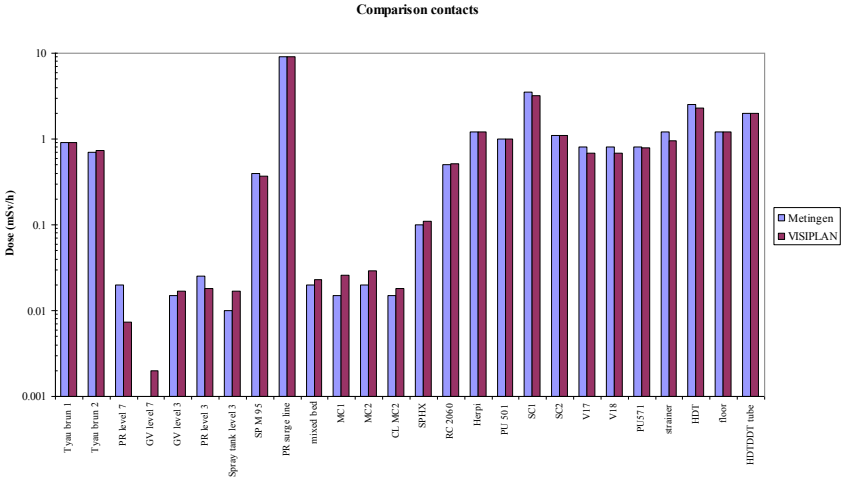
range 10 to 35 cps, from purple over blue to red

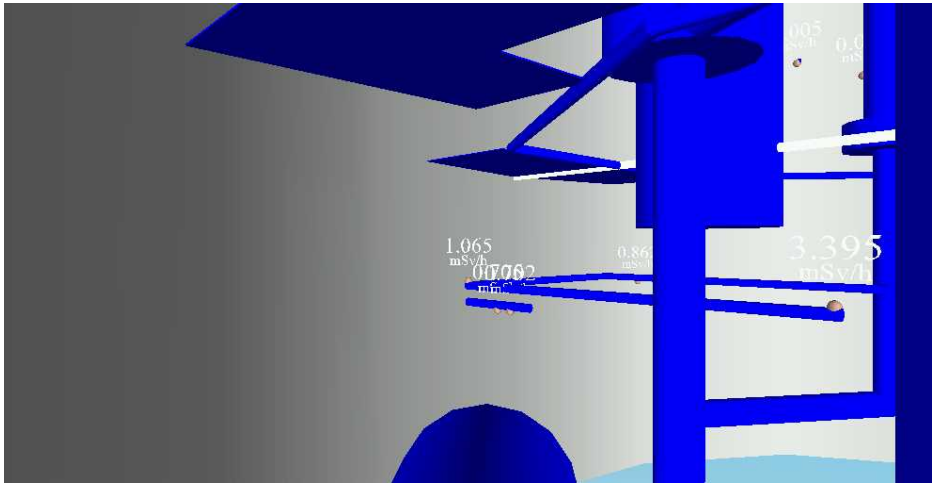
Example decommissioning activities at BR3 (1)

Model Building and validation



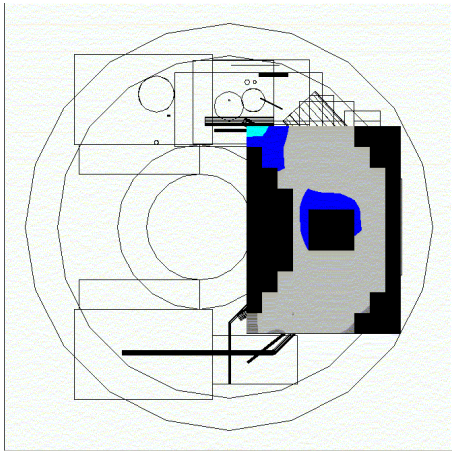
Geometric and material data taken from paper plans



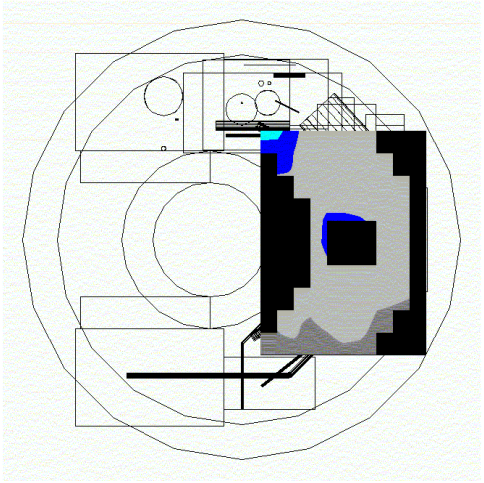


Example decommissioning activities at BR3 (2)

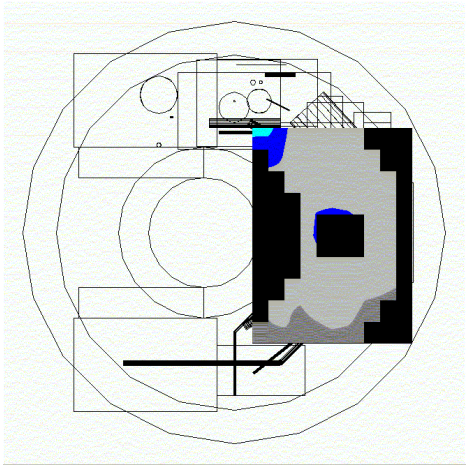
General planning



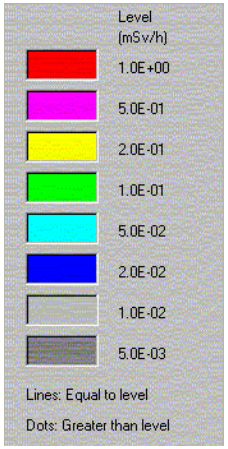
A. Situation before the operations.

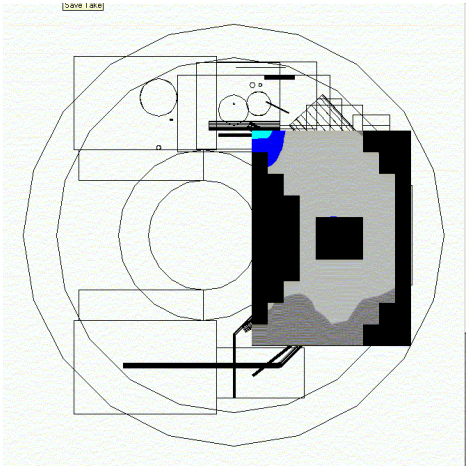


B. Hot spot removal on level 0 m

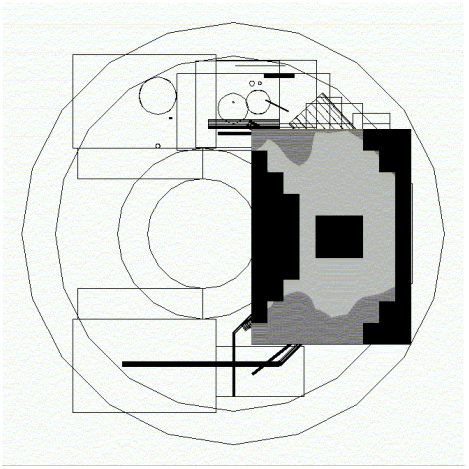


C. Hot spot removal around DDT lower part

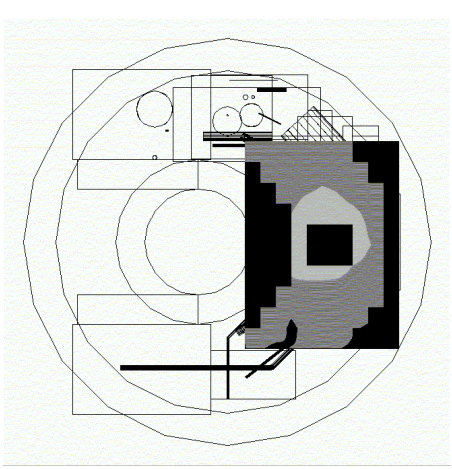




D. Removal of the rotors.



E. Removal of the SPHX



F. Removal of the shutdown circuit

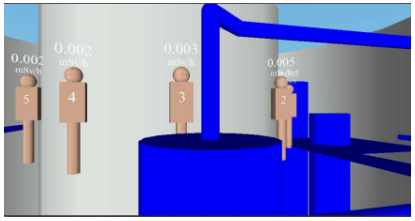
SPHX : heat exchanger

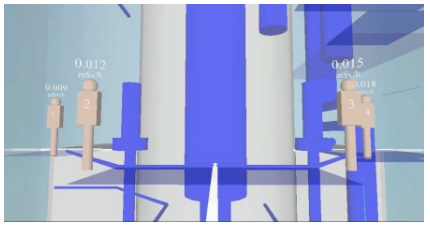
Example decommissioning activities at BR3 (3)

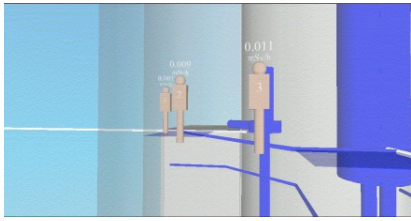
Detailed planning

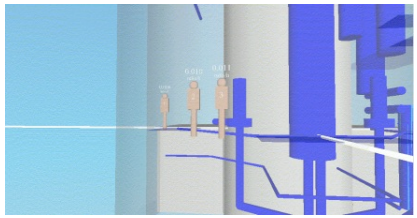
"Préparation" du chantier	man	h
obturation des fenêtres de la piscine RC (7)	2	5
Ventilation mobile BR2	3	8
Stand de découpe (installation / check)	3	4
Marquage tuyauteries	2	12
Modifications des circuits		
Eau de service	2	10
Air comprimé		
SOD	3	24
OD (niet)	2	10
Mise en sécurité NST	2	5
vase d'expansion	2	2
Démantèlement points chauds + autres opérations		
Pompe MC n°2	2	2
Herpi's	2	2
Ligne collecte d'effluents	2	3
Déshabillage DDT supérieur	2	4
Déshabillage SPHx	2	4
Spray System	2	5
Déshabillage DDT inférieur (dont L.O. + HDT)	2	3
Piquages tuyauteries primaires	2	3
Déshabillage MBT + évacuation	2	4
Piquages GV	2	3
Démantèlement ligne N²	2	2

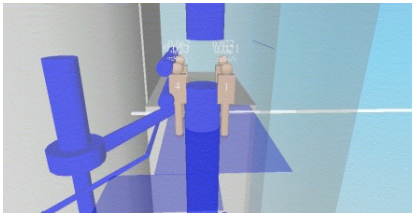
	man	h
Évacuation chemins de câbles	2	5
Montage échafaudages (firme extérieure)		
niv - 4,805 m	4	6
sur balançoires MC	4	9
Modification état des boîtes à ressort		
MK7 (GV)	3	12
Autres MK3 - MK6 (balançoires MC, TP)	3	12
Évacuation des rotors des pompes primaires	2	4
Évacuation des SPHx (optionnel)	2	5

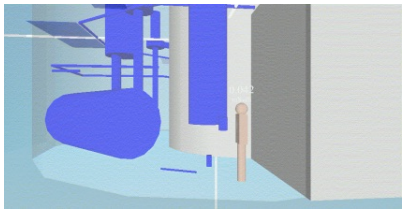


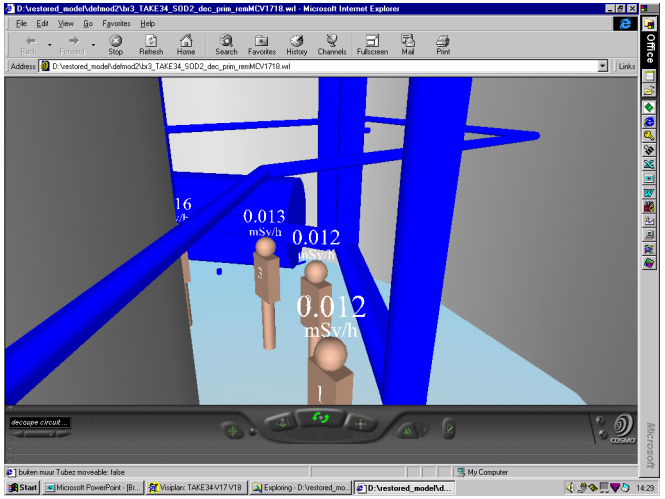






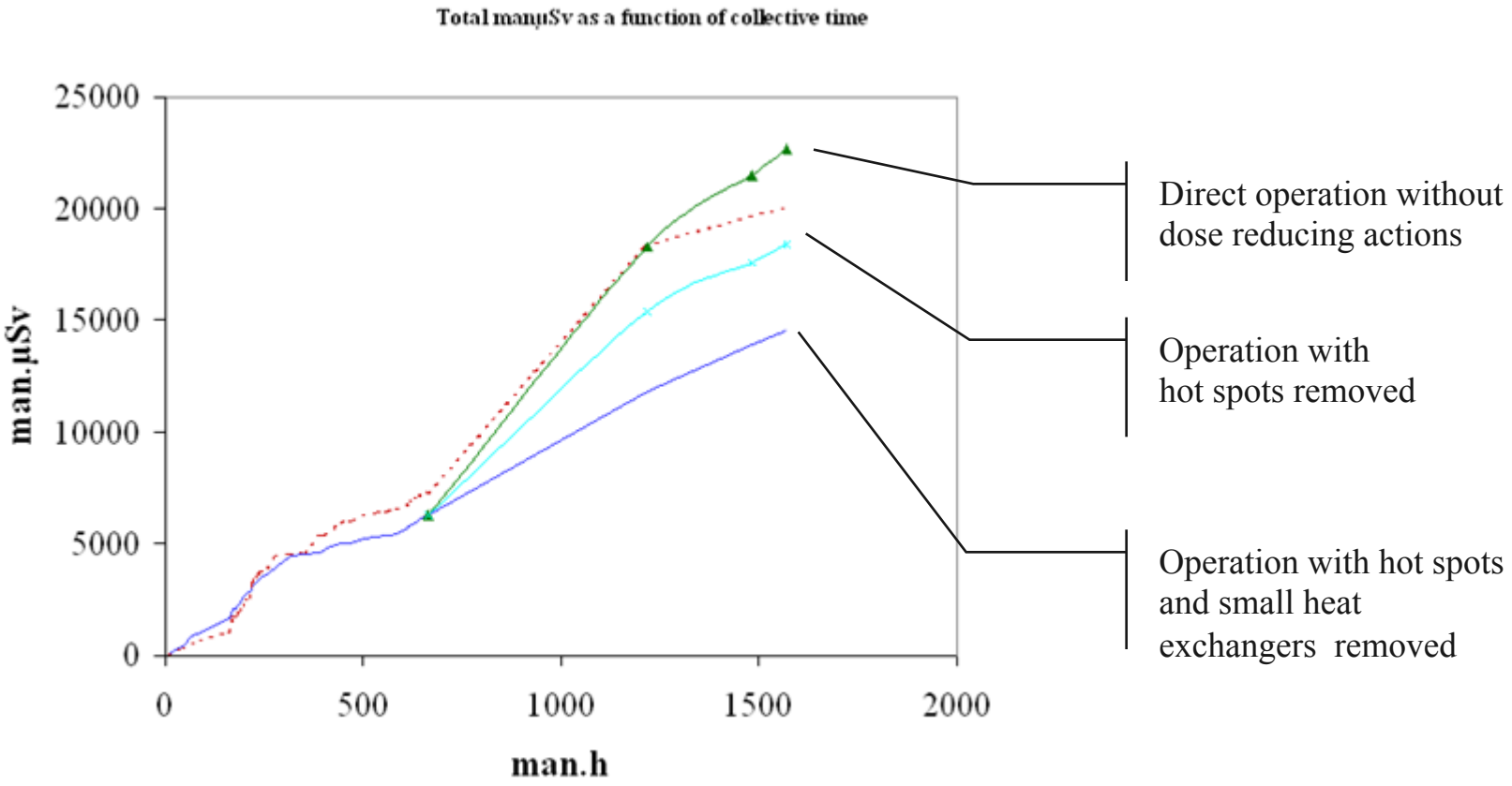






Example decommissioning activities at BR3 (4)

Scenario comparison



The REBUS project

The REBUS project

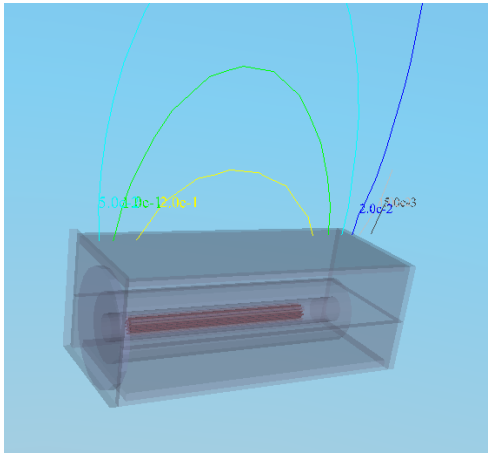
- Loading of a spent fuel bundle in a critical facility
  - First of a kind
  - Need for radiation protection
  - Technical boundary condition
    - Limited lifting power of the hoist → 1500 kg

Basic risk
The spent fuel bundle

- Spent fuel adequate shielding is needed
- Source term determined through Origin calculation based on the irradiation history
- Photon spectrum generated for dose calculations with VISIPLAN 3D ALARA planning tool
- Cross verification of dose calculation with MicroShield

Design of the shielding

- Shielding in two parts
  - Double shielding for slow operations
  - Single cylindrical shielding for fast operations and lifting
- Cross verification of the shielding calculations
  - Point-kernel → 4.3-5.5 mSv/h in contact
  - MCNP → 3.4 mSv/h in contact



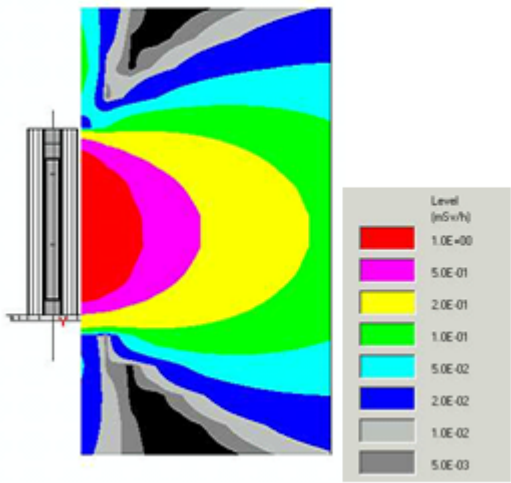
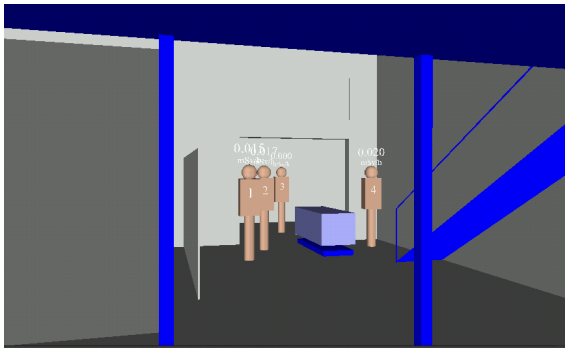
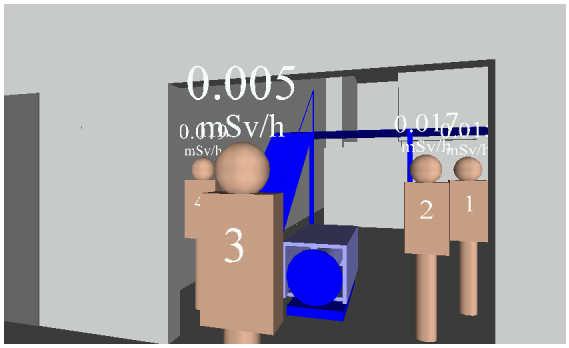
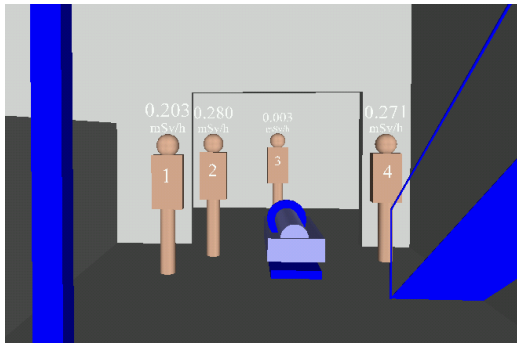


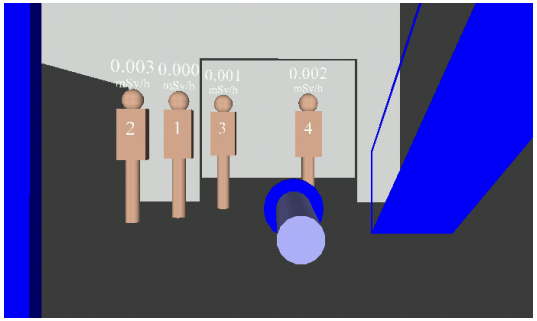
Fig Dose rate around REBUS container (25 pins of 1 m, 60 GWd/ton burn-up, 5 year cooling time

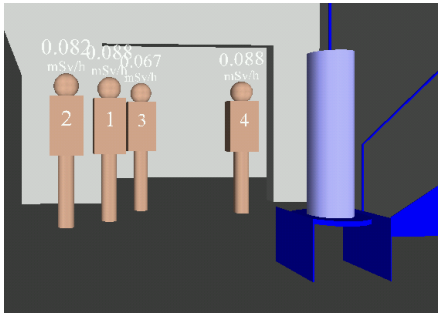
Loading of spent fuel in a critical facility
Simulation in VISIPLAN

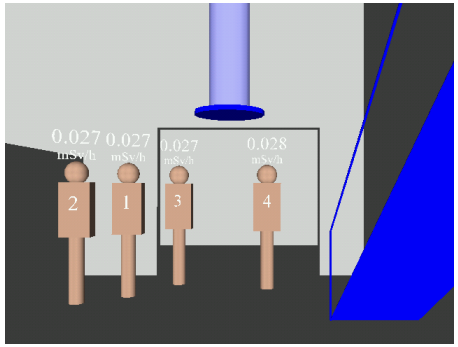


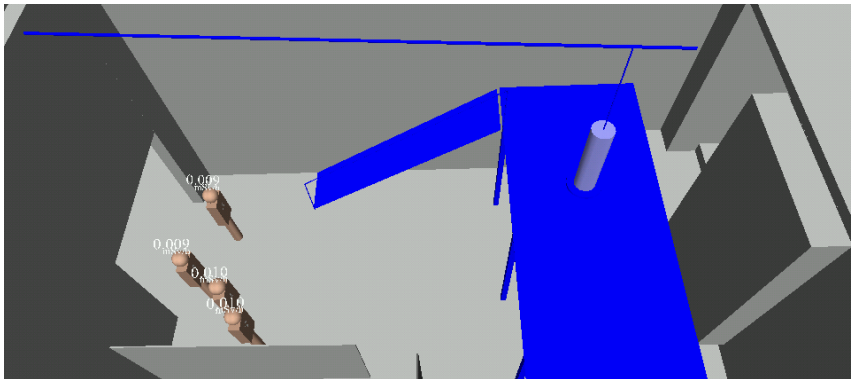


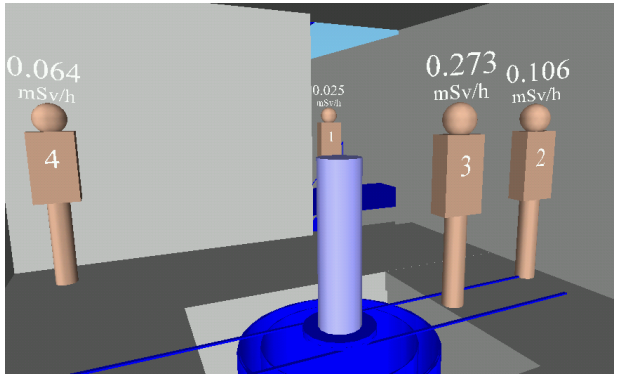












Loading of spent fuel in a critical facility
Reality

Spent fuel is shielded by a lead container. The inner container is lifted to the reactor top.

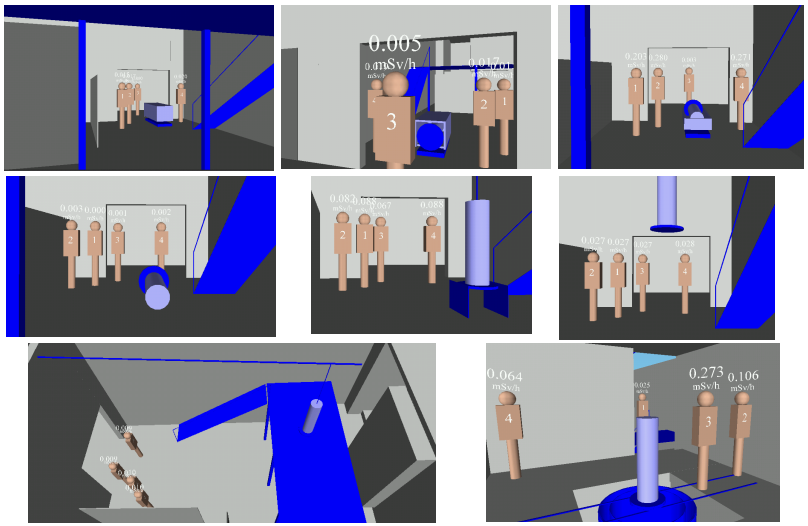
Sequence of events

Different geometries

Different exposure rates

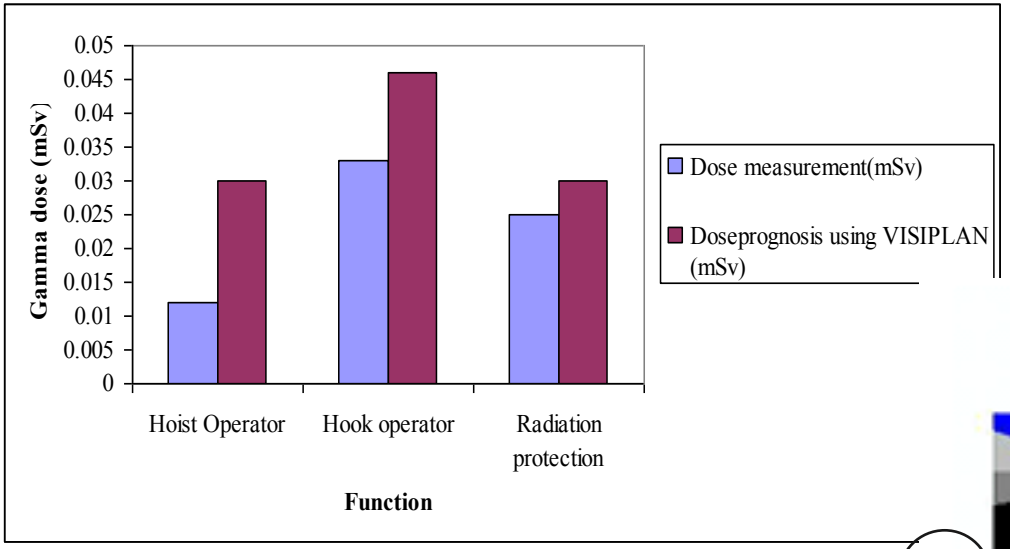
Loading of spent fuel in a critical facility
Dose prognoses

Dose evaluation could be made beforehand.



Function	Pers.	Average dose rate (mSv/h)	Duration (man.min)	Duration (man.h)	mSv
Fork lift driver	F	0.008	3	0.050	0.000
Crane operator	A	0.086	16	0.267	0.023
Man attaching the hooks	B	0.131	16	0.267	0.035
Moving the container	C	0.0004	0.6	0.010	0.000
			35.6	**0.593**	**0.058**
			man.min	**man.h**	**man. mSv**

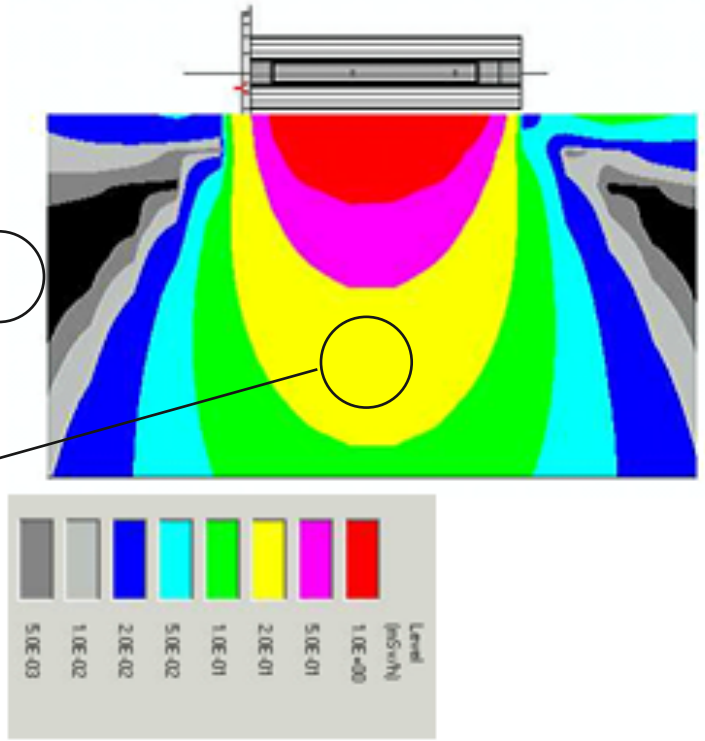
Loading of spent fuel in a critical facility
Dose Results for the loading



- Why the difference for the hoist operator

Real position, Decided by the operator based on the visualization of the risk

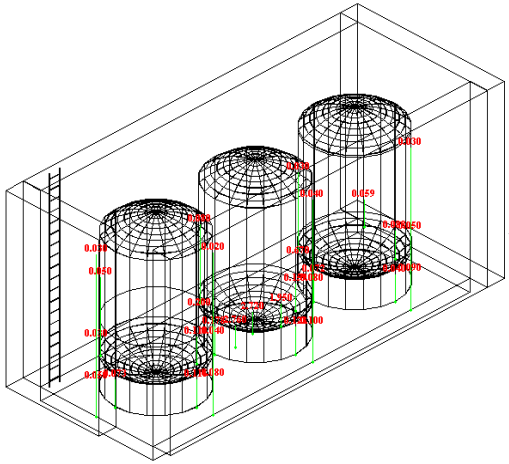
Calculated position



- Visualizing the risk enables the workers to make decisions on their protection

Cleaning the HLLW tanks

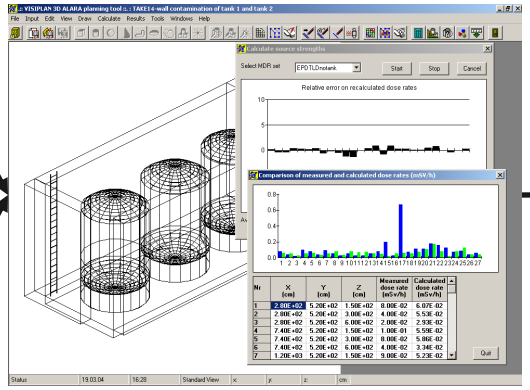
Cleaning the HLLW tanks
Modeling the sources (1)



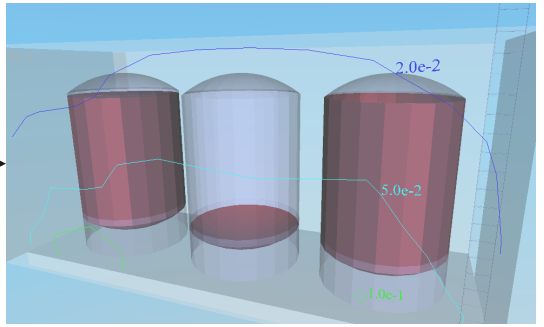
Dose measurement

HLLW: High Level Liquid Waste tanks need to be cleaned before decommissioning.

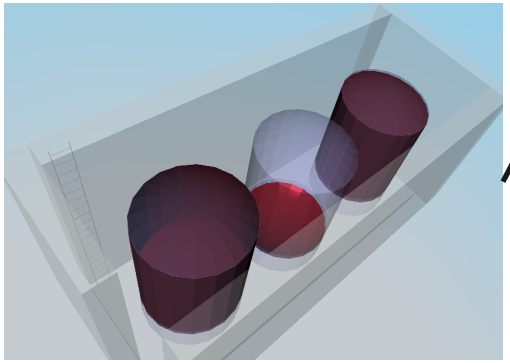
Source inference technique based on measured dose rates and 3D modeling of the sources and the site.



Source strength calculation

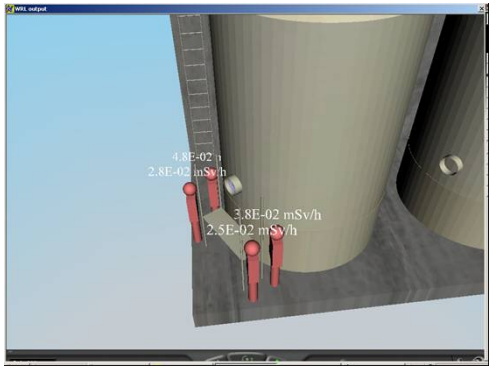


Dose calculation

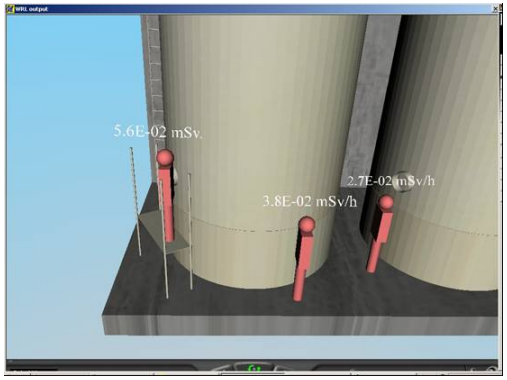


Source model

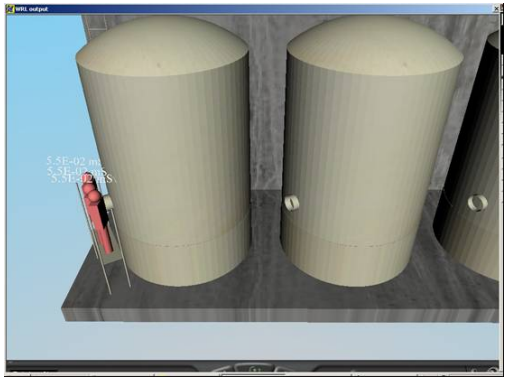
Cleaning the HLLW tanks
Modeling the Cleaning scenario (2)



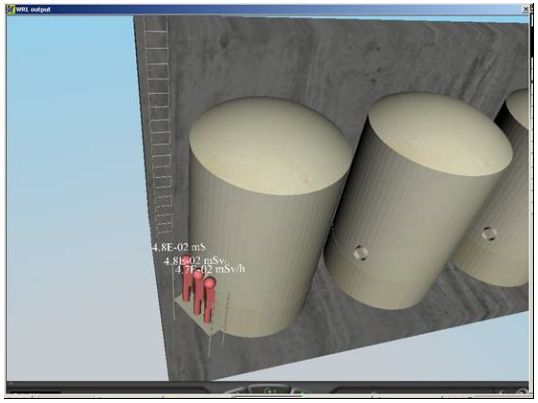
Placement of the scaffolding



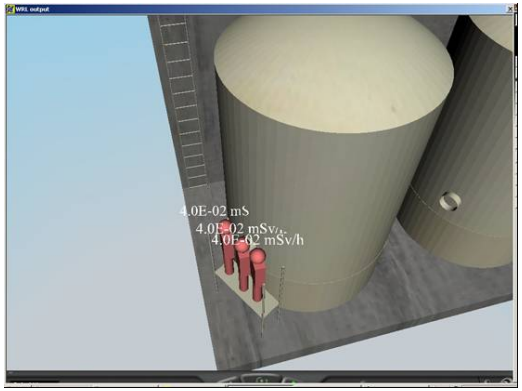
Placement of the hose



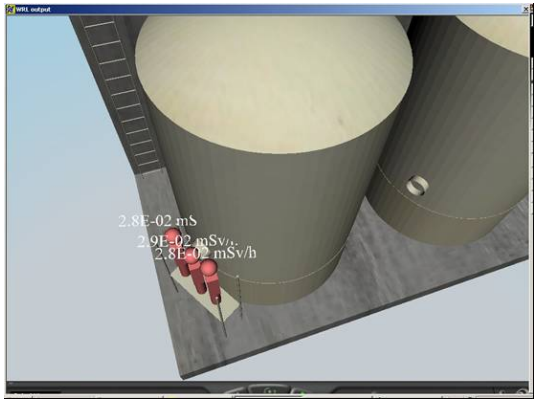
Cleaning source in tank



Cleaning source at 75 %



Cleaning source at 50%



Cleaning source at 10 %

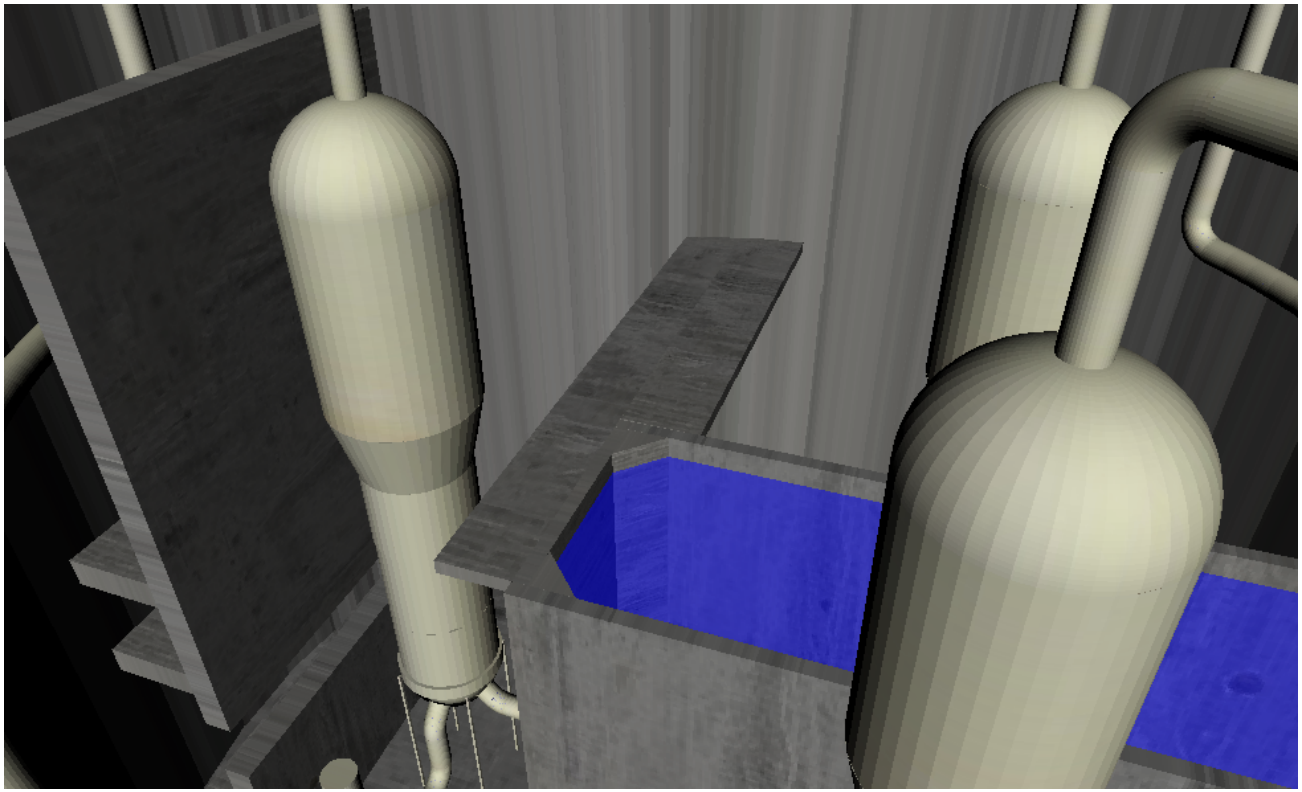
Cleaning the HLLW tanks
Scenario dose assessment (3)

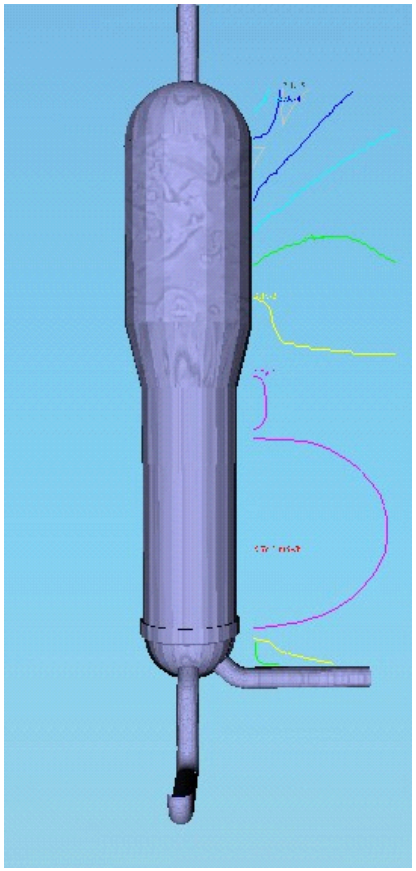
Result from the simulation in VISIPLAN

Nr	Workers	Take	Trajectory	SSA set	Work Time (min)	Collective Dose (mSv)	Minimum Work Time (min)	Minimum Coll. Dose (mSv)	Maximum Work Time (min)	Maximum Coll. Dose (mSv)
1	ABC	TAKE28	Installing the hose	FitValues	15	3.03E-02	12	2.42E-02	18	3.64E-02
2	AB	TAKE28	Cleaning source 100%	FitValues	15	2.75E-02	12	2.20E-02	18	3.29E-02
3	AB	TAKE28	Cleaning source 75%	Percent75	15	2.38E-02	12	1.90E-02	18	2.85E-02
4	AB	TAKE28	Cleaning source 50%	Percent50	15	2.01E-02	12	1.61E-02	18	2.41E-02
5	AB	TAKE28	Cleaning source 10%	Percent10	15	1.42E-02	12	1.13E-02	18	1.70E-02
6	AB	TAKE28	Removing the hose	Percent10	15	1.05E-02	12	8.39E-03	18	1.26E-02
Total					**90**	**1.26E-01**	**72**	**1.01E-01**	**108**	**1.52E-01**

Simulation of the dose rate near a steam generator

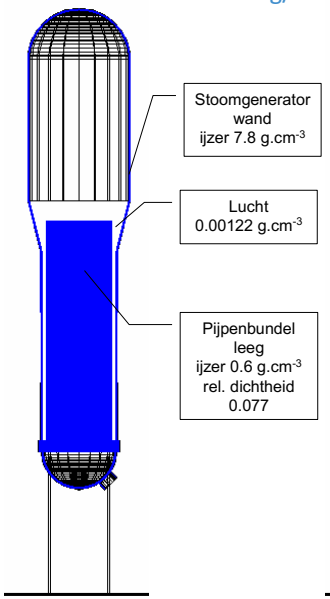
Steam generator
Evaluation of the dose in different situations





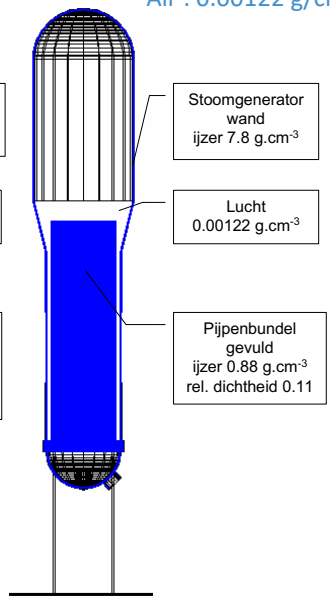
Dose evaluation

Translation:
Steam generator
wall Iron 7.8 g/cm³
Air : 0.00122 g/cm³



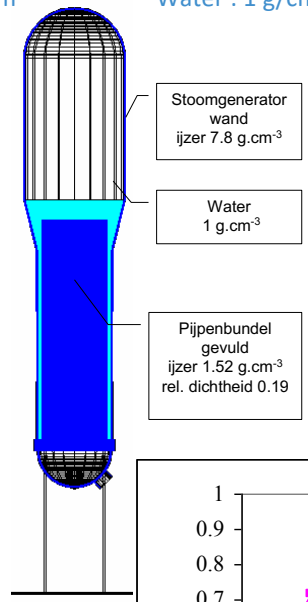
Translation :
Pipe bundle empty
Iron 0.6 g/cm³
Relative density : 0.077

Translation:
Steam generator
wall Iron 7.8 g/cm³
Air : 0.00122 g/cm³

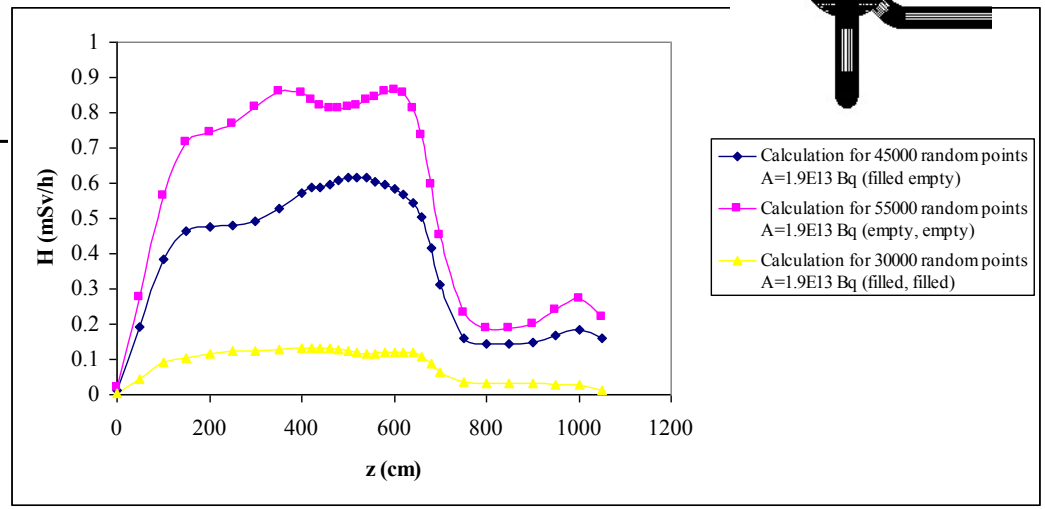


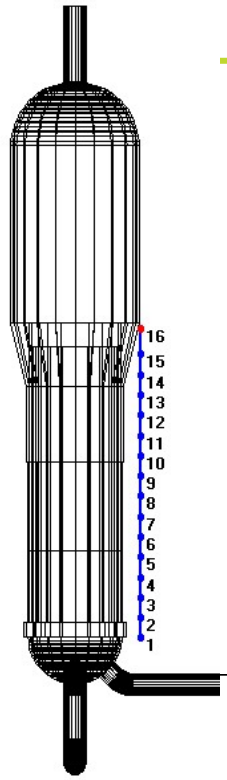
Translation:
Pipe bundle filled
Iron 0.88 g/cm³
Relative density : 0.11

Translation:
Steam generator
wall Iron 7.8 g/cm³
Water : 1 g/cm³



Translation:
Pipe bundle filled
Iron 1.52 g/cm³
Relative density : 0.19



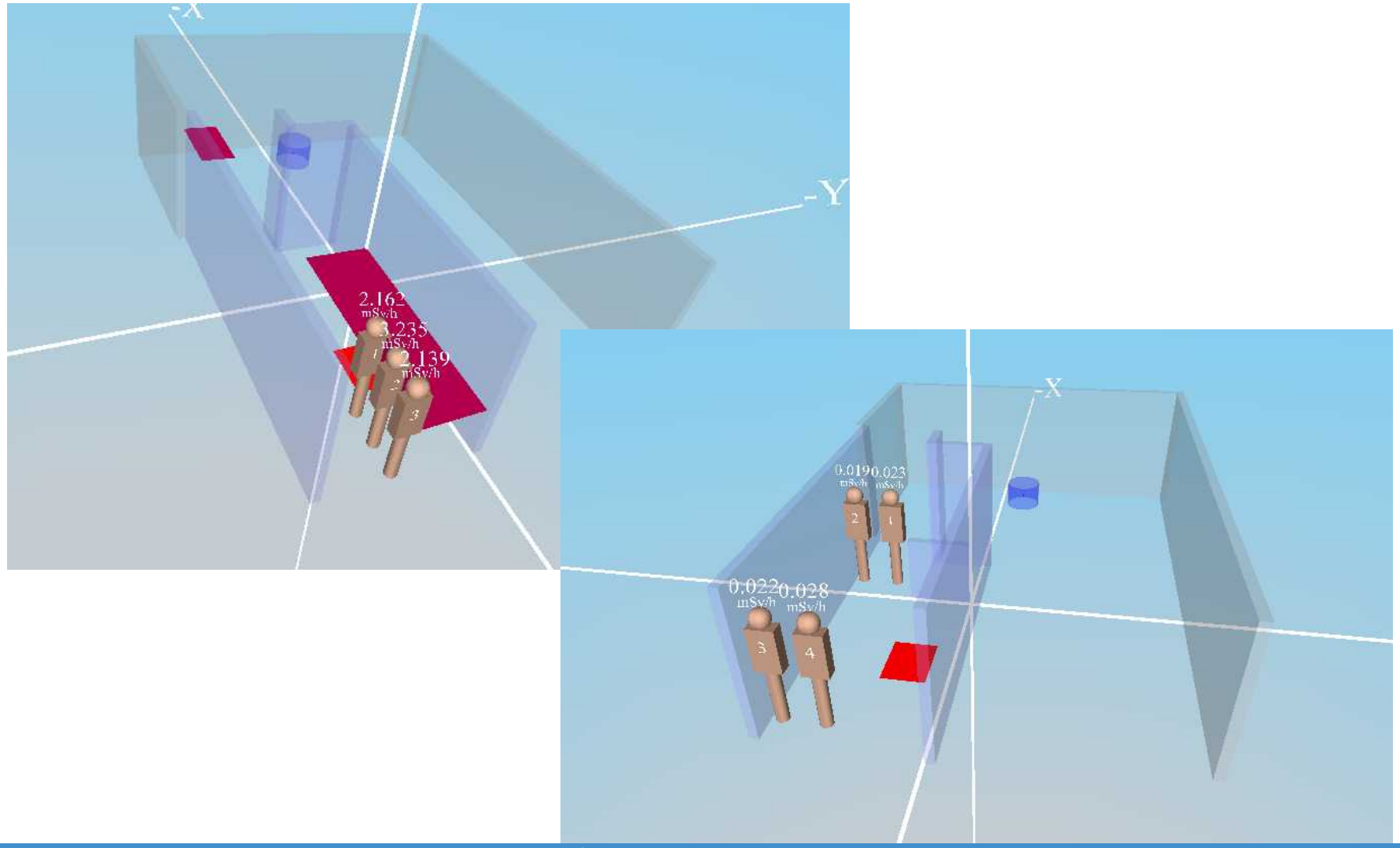


Decommissioning of the hot cell 41

The dismantling campaign of cell 41 started in 2000

- Steel profiles
- Working table
- Vertical wall
- Tanks
- Shielding walls in Pb
- Remote handling arm
- Travelling crane
- Several wastes

Dose prognoses with VISIPLAN



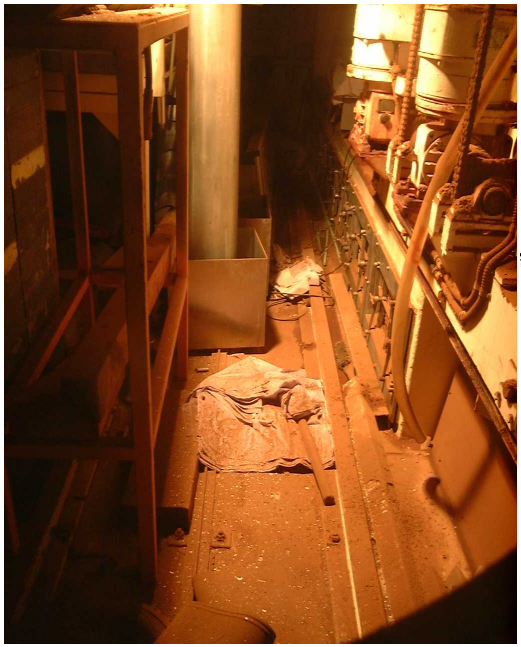
Different procedures were written

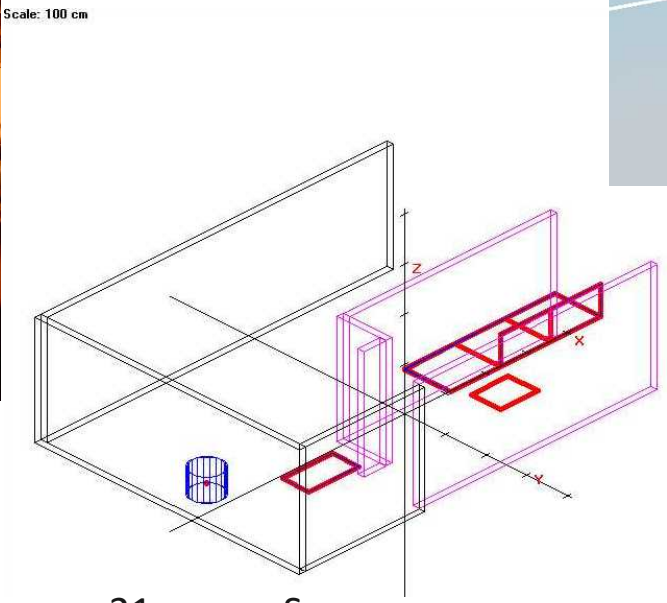
- Intervention zone before the entrance of the cell
  - Working zone
  - Waste docking station
  - Passage for the personnel

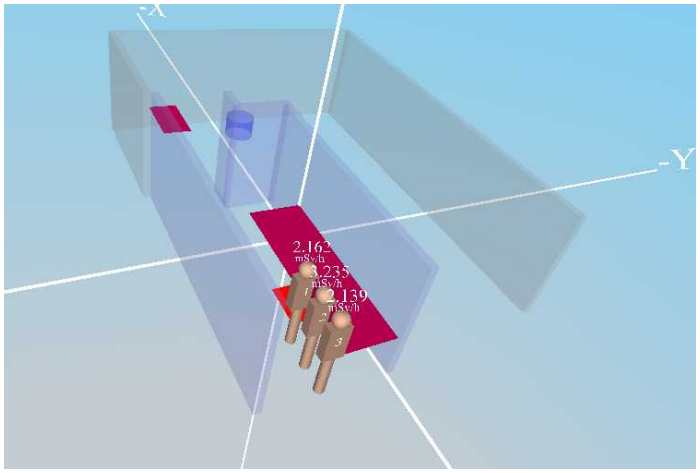
Different procedures were written

- Means of protection
  - Ventilated pressurized suit
  - Mask filter P3
  - TLD
  - Electronic Dosimeters EPD
- Procedure
  - Nose-blow
  - Measurement Whole Body Counter

Decommissioning Cell 41







VISIPLAN Dose prognoses : 21 man.mSv

Measured : 26 man.mSv

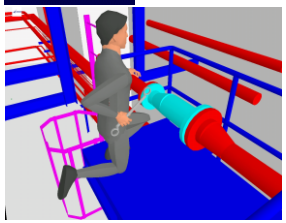
difference is related to additional waste management and cleaning operations that were not taken into account in the VISIPLAN assessment

Almaraz (Spain) site characterization in the VRIMOR project

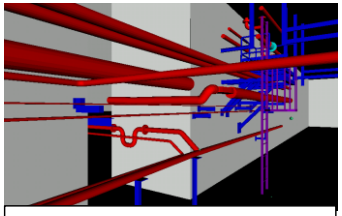
Virtual Reality in Maintenance Outage and Repair

To show the viability of an integrated approach to minimise occupational exposure through the combination of different technologies including gamma scanning, geometrical scanning, human motion simulation tools and a radio-geometrical modelling tool.

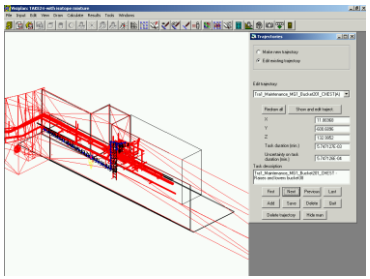
Research and development Internationale projects VRIMOR FP5



ErgoDose from NNC ltd UK human motion simulation tool (VRIMOR)



Geometric environment determined using the laser scanner and the LFM tool of Z+F ltd UK (VRIMOR)



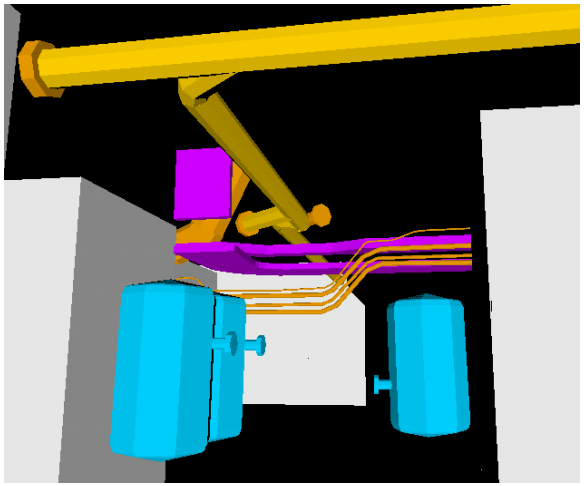
SCK•CEN's VISIPLAN 3D ALARA planning tool performing dose assessment in a 3D multi-source environment on trajectories and work scenario's

HesPI human motion simulation tool from UPM, Spain (VRIMOR)

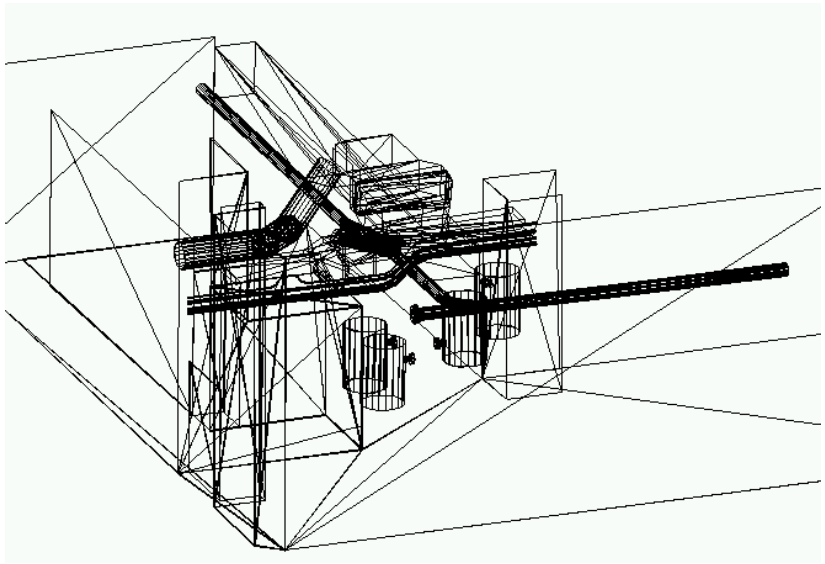
EDR gamma scanner from CIEMAT, Spain (VRIMOR)

Geometric Information

ZF UK Ltd LFM



SCK•CEN VISIPLAN 3D ALARA planning tool



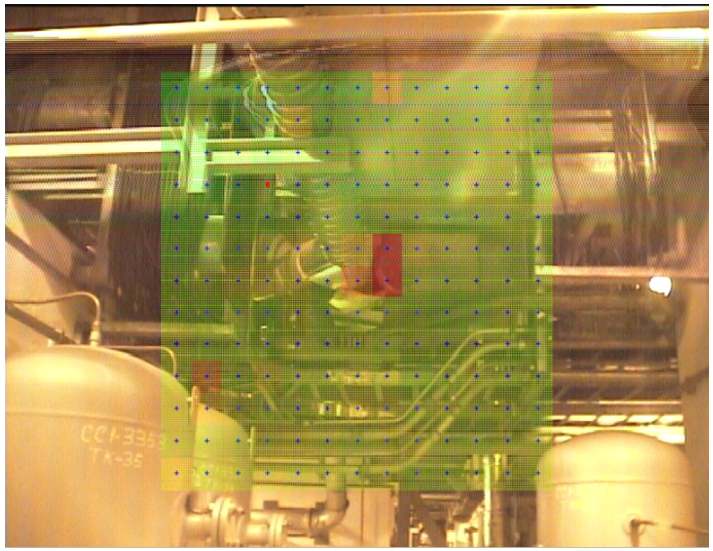
Geometry interface

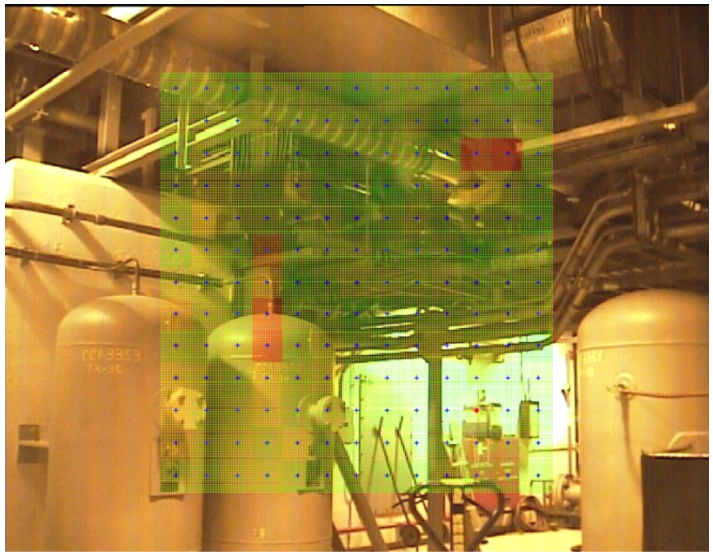
Application on site
Gamma Scans

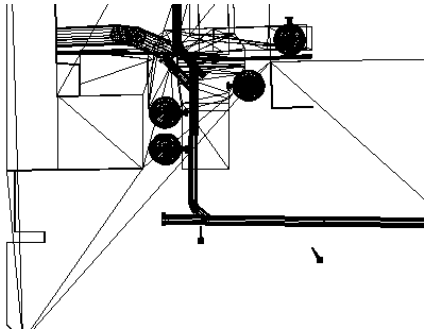
MINISTERIO DE CIENCIA Y TECNOLOGÍA

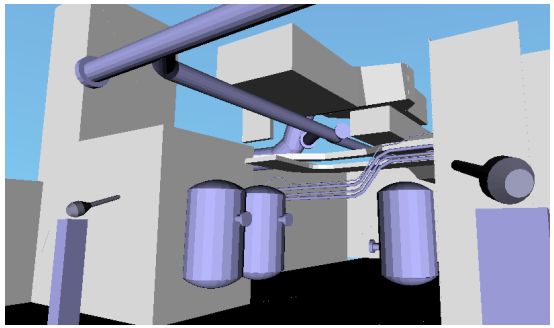
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Two scans from different positions

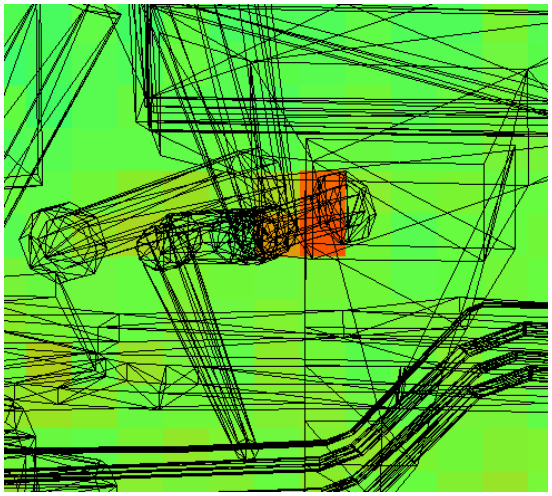




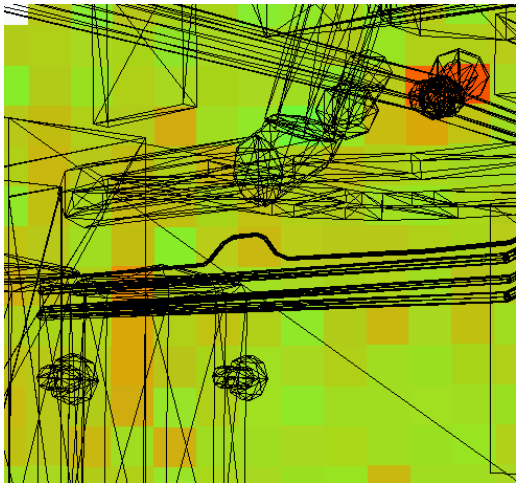




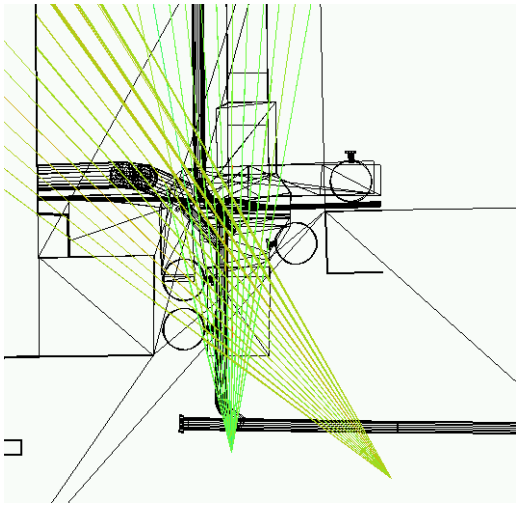
Gamma Scan Analysis



Scan 1



Scan 2

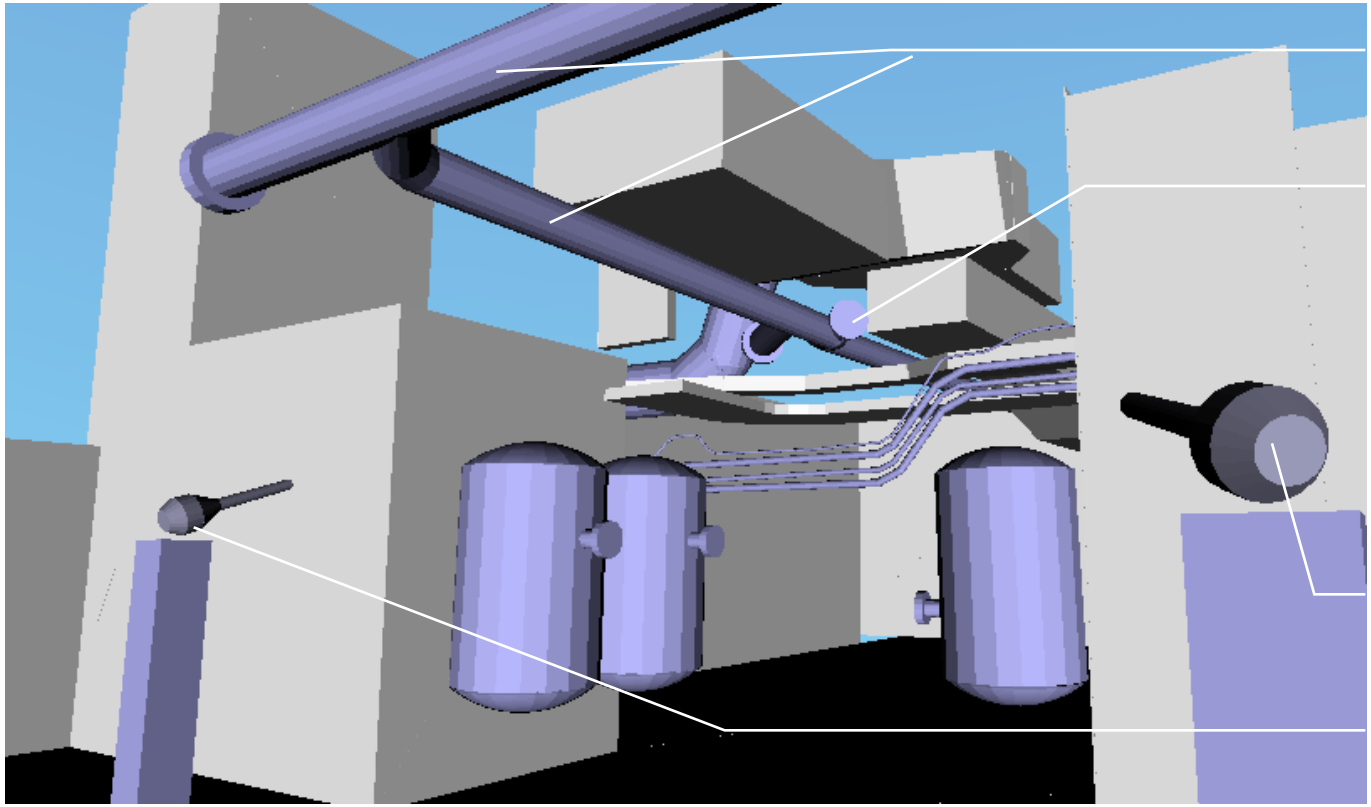


VISIPLAN plan view

of the two scans

Interpretation and analysis based on the geometric, gamma scanning and technical information acquired.

Gamma scan taken from two locations



Drain pipe shielded with lead

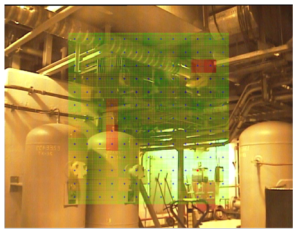
Position of a hot spot confirmed in the two scans

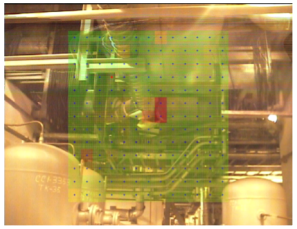
Scan position 2

Scan position 1

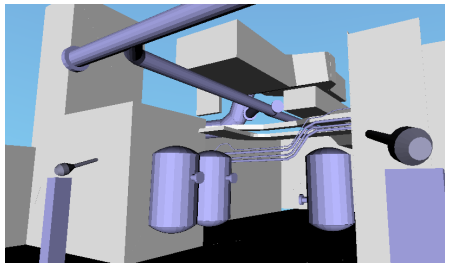
Research and development
VRIMOR FP5 Almaraz (SPAIN) site characterisation

Development of a method to analyse gamma scans

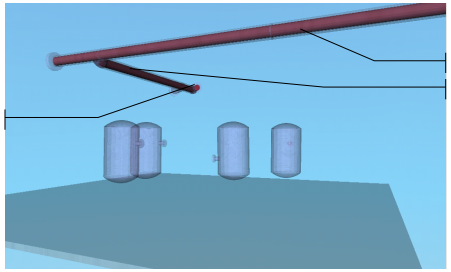


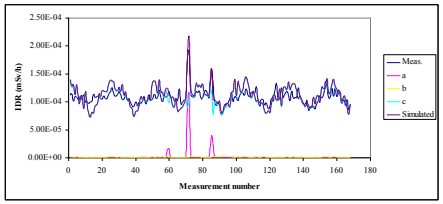


Measurement

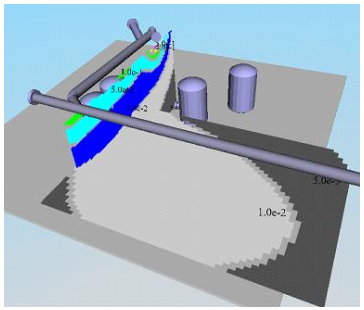


Geometric model

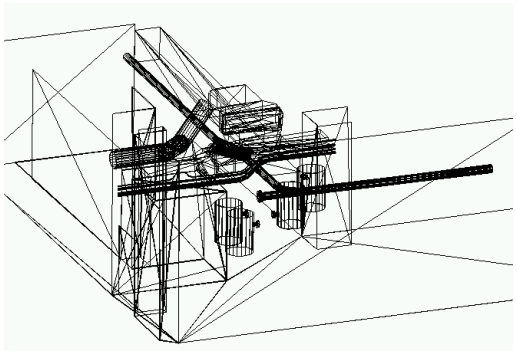




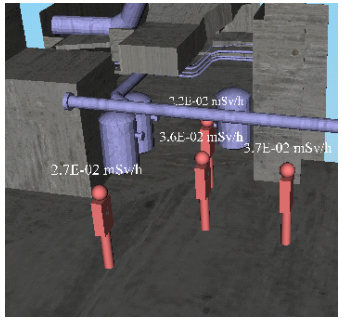
Source strength determination



Dose rate maps - Dose plot based on the fitted sources



Dose evaluation



Main dose contribution is not caused by the hotspot.

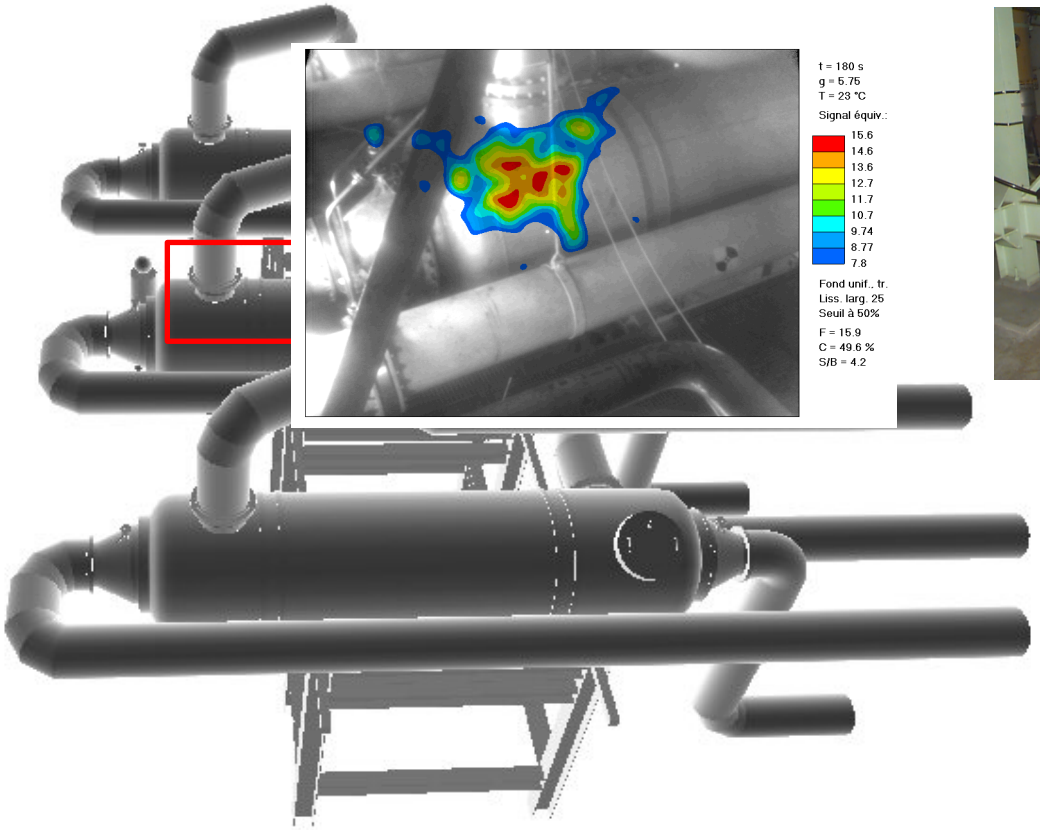
The main contribution is due the contaminated drainage lines.

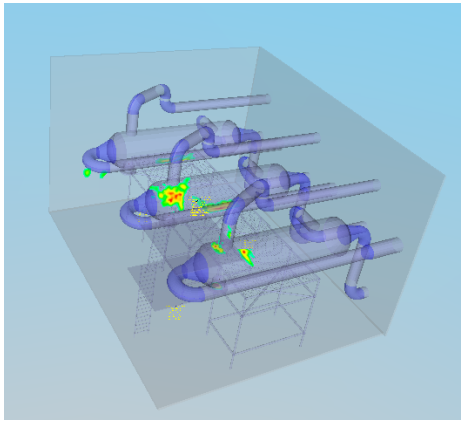
BR2 heat exchangers

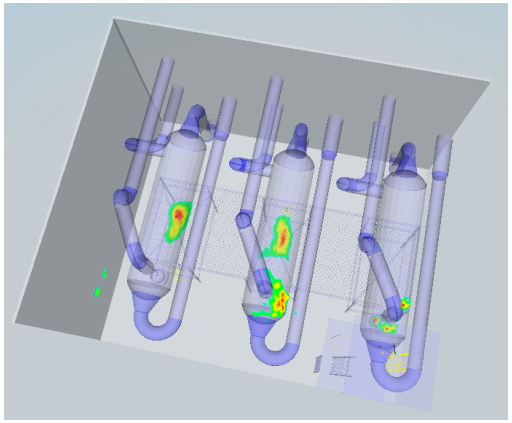
Research and development International projects
INTAS #401

Aim : Gamma imaging using coded aperture and pin hole gamma camera

SCK•CEN :Interfacing to VISIPLAN 3D ALARA planning tool.





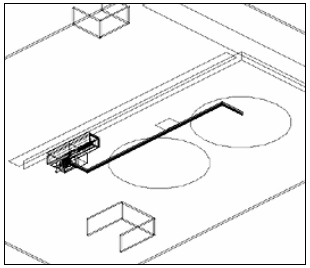


Partners: CEA – MEHPI – KI – SCK•CEN

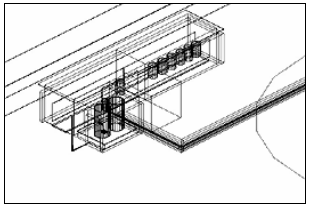
International projects
Services

International projects Services

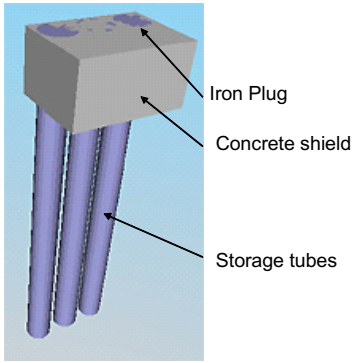
- IAEA mission Lithuania
  - Training of the regulators
  - Training of the radiation protection managers of Ignalina NPP
- IAEA mission Slovakia
  - Training of the ALARA team VUJE Trnava
  - Training of the ALARA team, Bohunice A-1 NPP
  - Advise and help in ALARA and shielding problems



General view showing the sludge pipeline (dark line), the cimentation facility and the nearby road (top right corner).



Close-up of the sludge pipeline arriving to the cimentation facility and the six 200 litre waste drums.



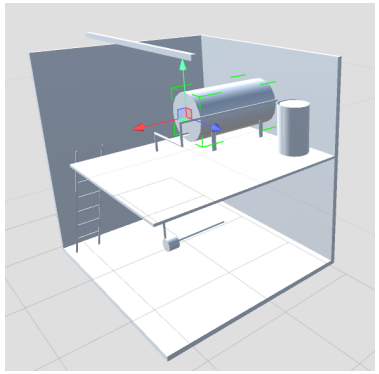
International projects Services

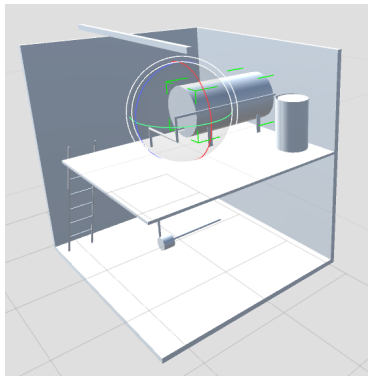
- IAEA mission CHINA
  - Training of 5 persons at CIAE Beijing
  - ALARA and use of VISIPLAN
  - Training of 20 persons at CNPE Beijing
  - 2 training sessions basic & advanced VISIPLAN
- JAPAN
  - Training of MNEC staff at Yokohama
  - Training of 15 persons

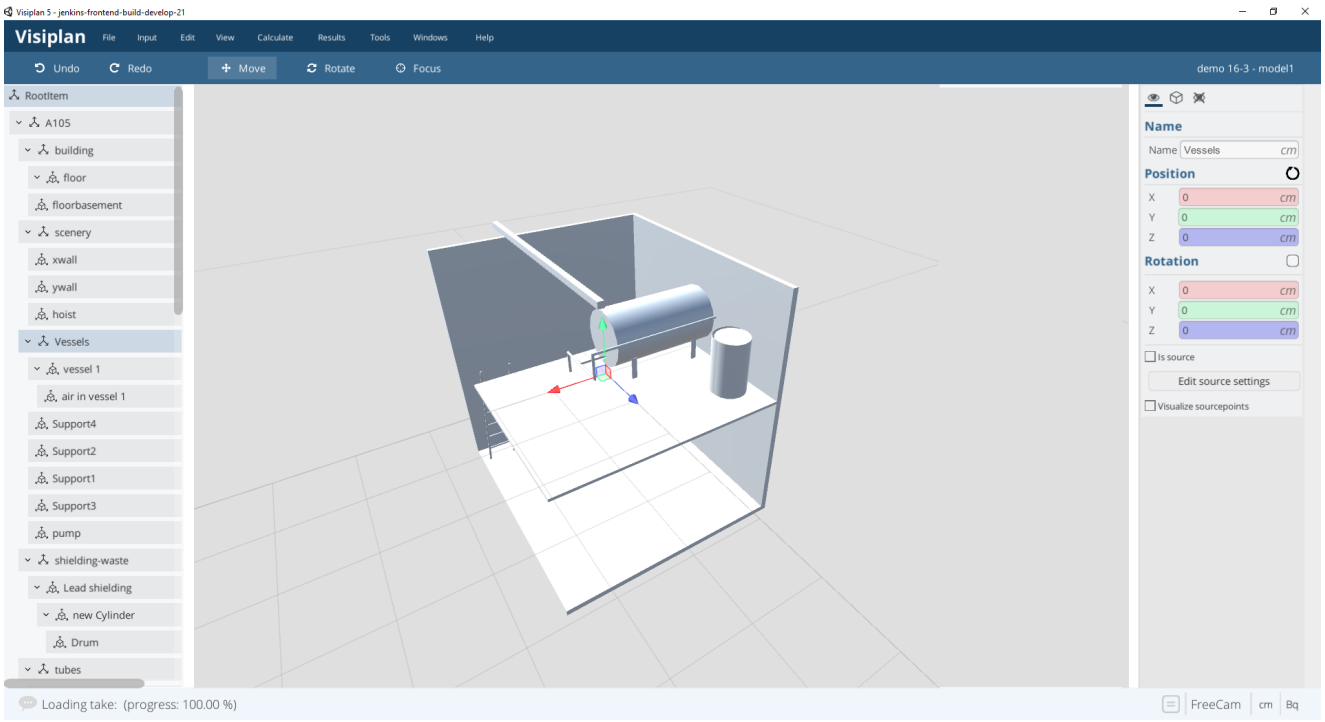
Sneak preview of VISIPLAN 5.0 (under development)

VISIPLAN 5

- Calculation kernel → point-kernel + buildup
- Improved graphical user interface

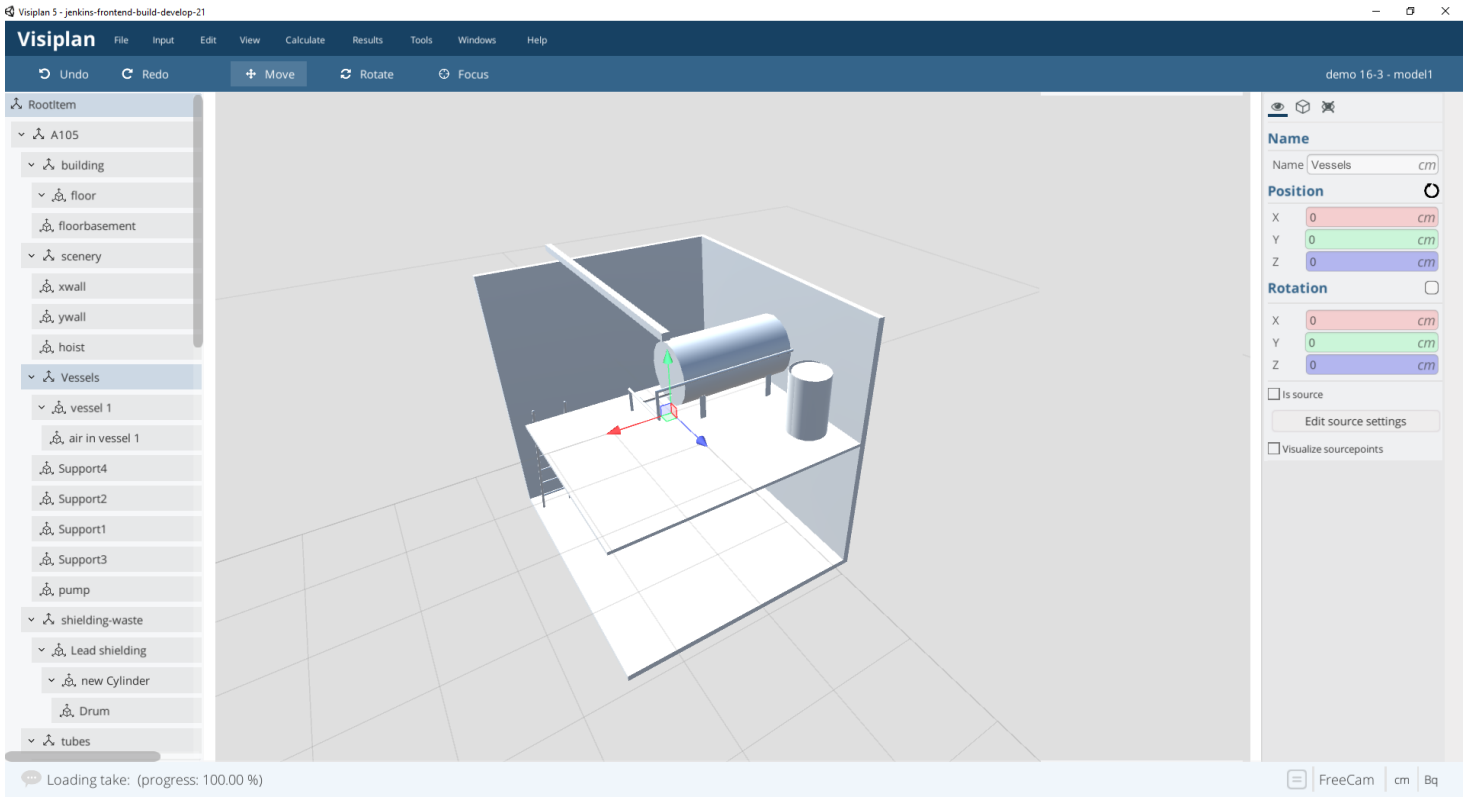






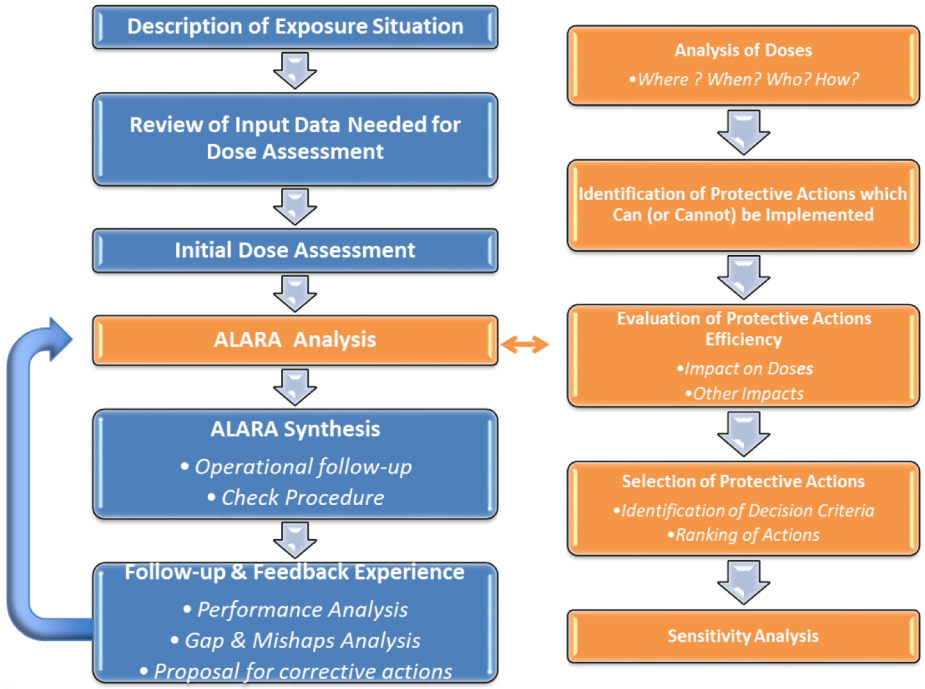
VISIPLAN 5

- Interface with forms, selecting items via root item or via selecting on screen
- GIZMO functionality for focus, rotate and move actions



Conclusion
VISIPLAN 3D ALARA planning tool

- Developed to support the ALARA analyst in applying the ALARA procedure
- Used in small to medium ALARA projects
- Used in scoping calculations
- Used in risk communication with the stakeholders
- Tool and methodology allows a comprehensive application of the ALARA procedure



SCK•CEN
Studiecentrum voor Kernenergie
Centre d'Etude de l'Energie Nucléaire
Belgian Nuclear Research Centre

Stichting van Openbaar Nut
Fondation d'Utilité Publique
Foundation of Public Utility

Registered Office: Avenue Herrmann-Debrouxlaan 40 – BE-1160 BRUSSEL
Operational Office: Boeretang 200 – BE-2400 MOL