Safe Disposal of Radioactive Waste for one Million Years – the Challenges

Gordon Turner,
Waste Package Research Manger
Nirex, UK

Presentation to FE-Net Technology Workshop on MPA

(Thursday 24 February 2005)

nirex

Contents

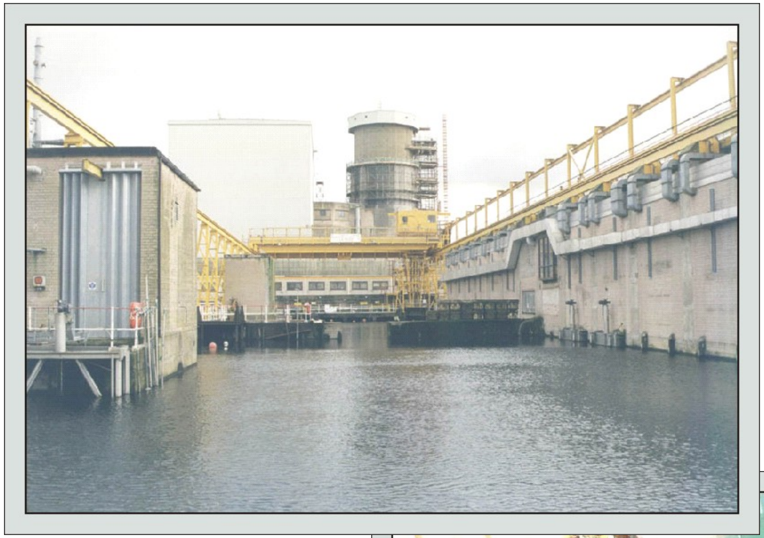
- Nirex Phased Geological Disposal Concept
- Operational Phase
- Backfilling
- Post-Closure Phase

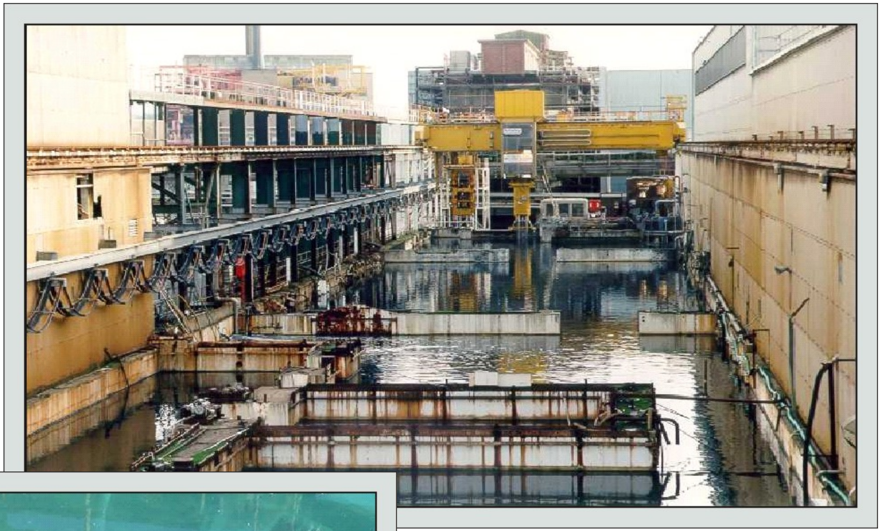
Magnox Fuel Cladding “Swarf”

Remote Dismantling of WAGR Core

nirex

Legacy Ponds





Redundant Submarines

nirex

Magnox Encapsulation Plant Sellafield

nirex

500 litre Drum Waste Package

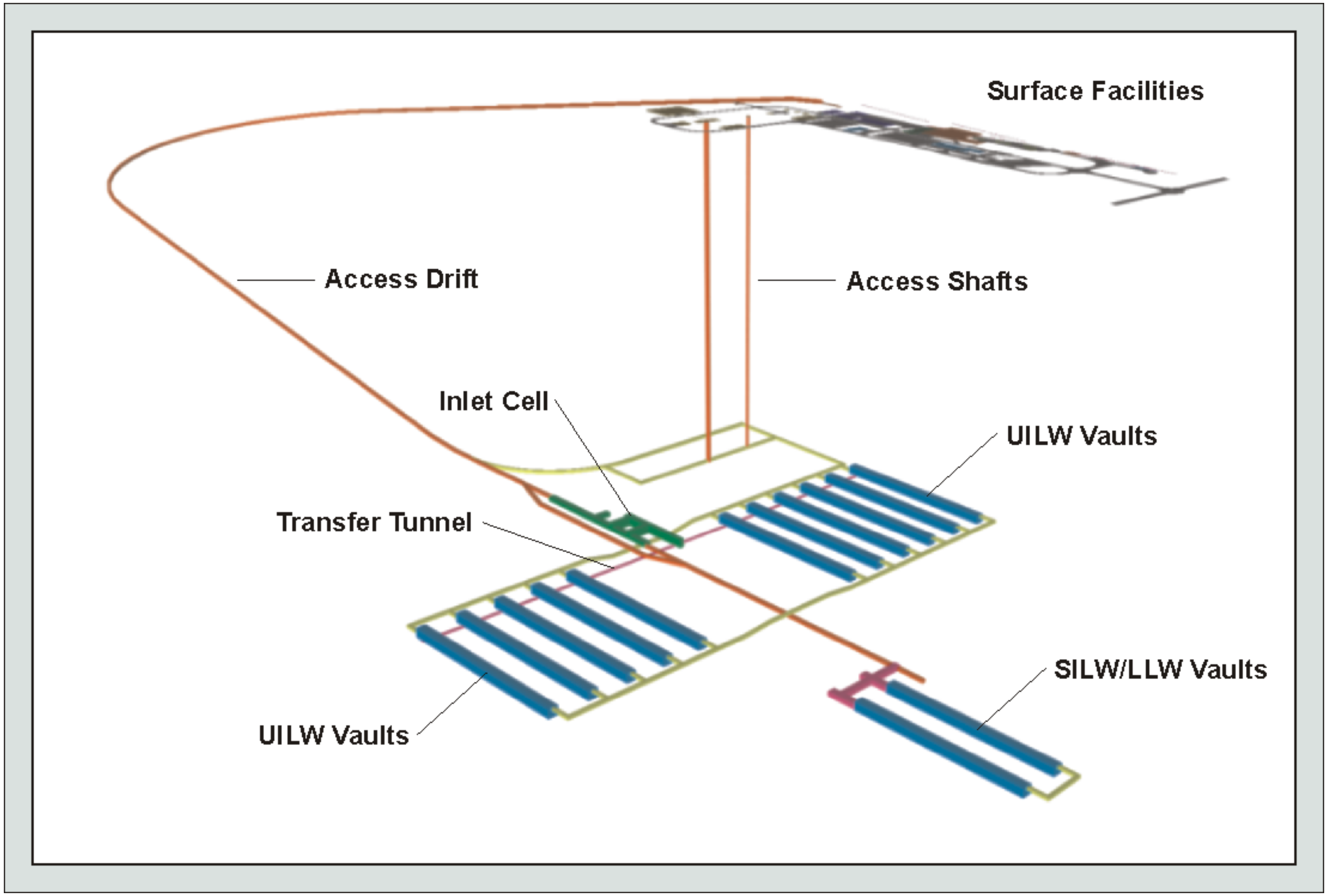
- 2001 Inventory reports 21,000 of these in engineered stores mainly at Sellafield, with smaller numbers at Dounreay and Harwell. Plants also under construction at Winfrith and power station sites.

$3m^3$ Box

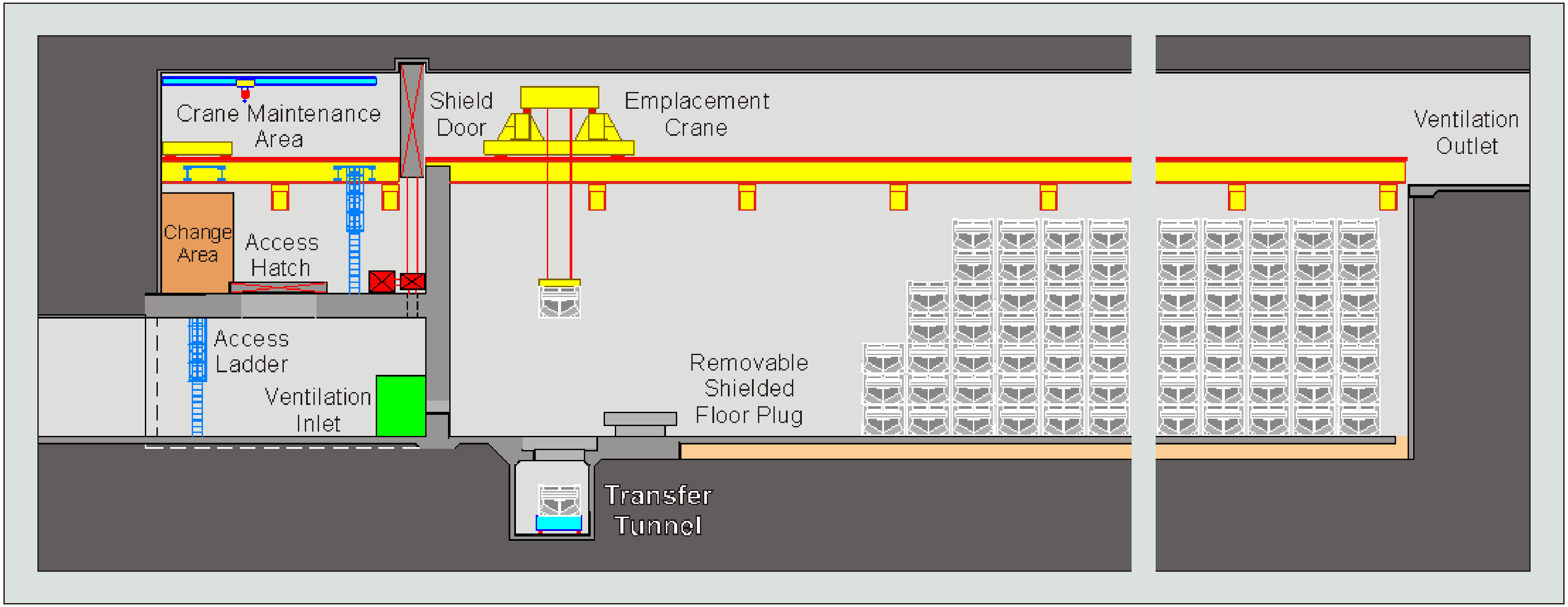
This container being used at Berkeley and Trawsfynydd (ideal for decommissioning).

Box being handled in the Berkeley store.

Phased Geological Repository Concept

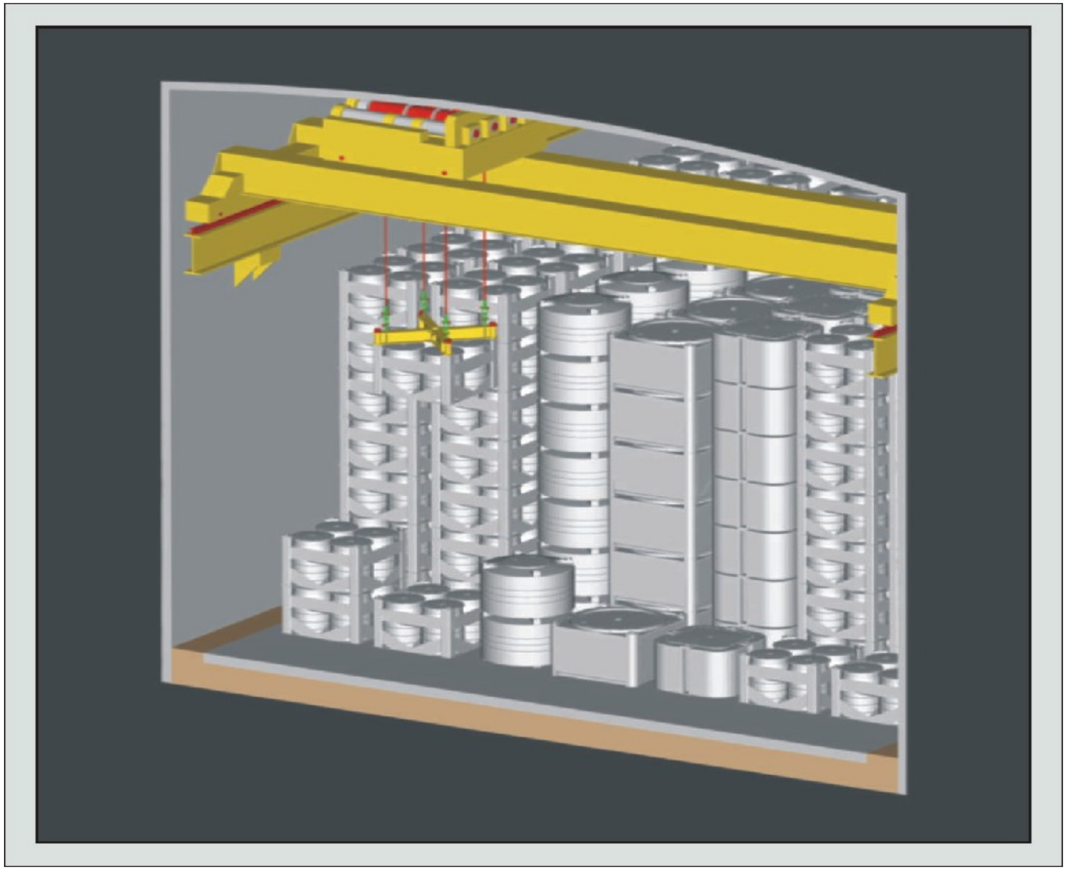


UILW Vault Emplacement/Retrieval Systems



nirex

Cross-section Through a Generic UILW Vault During Emplacement

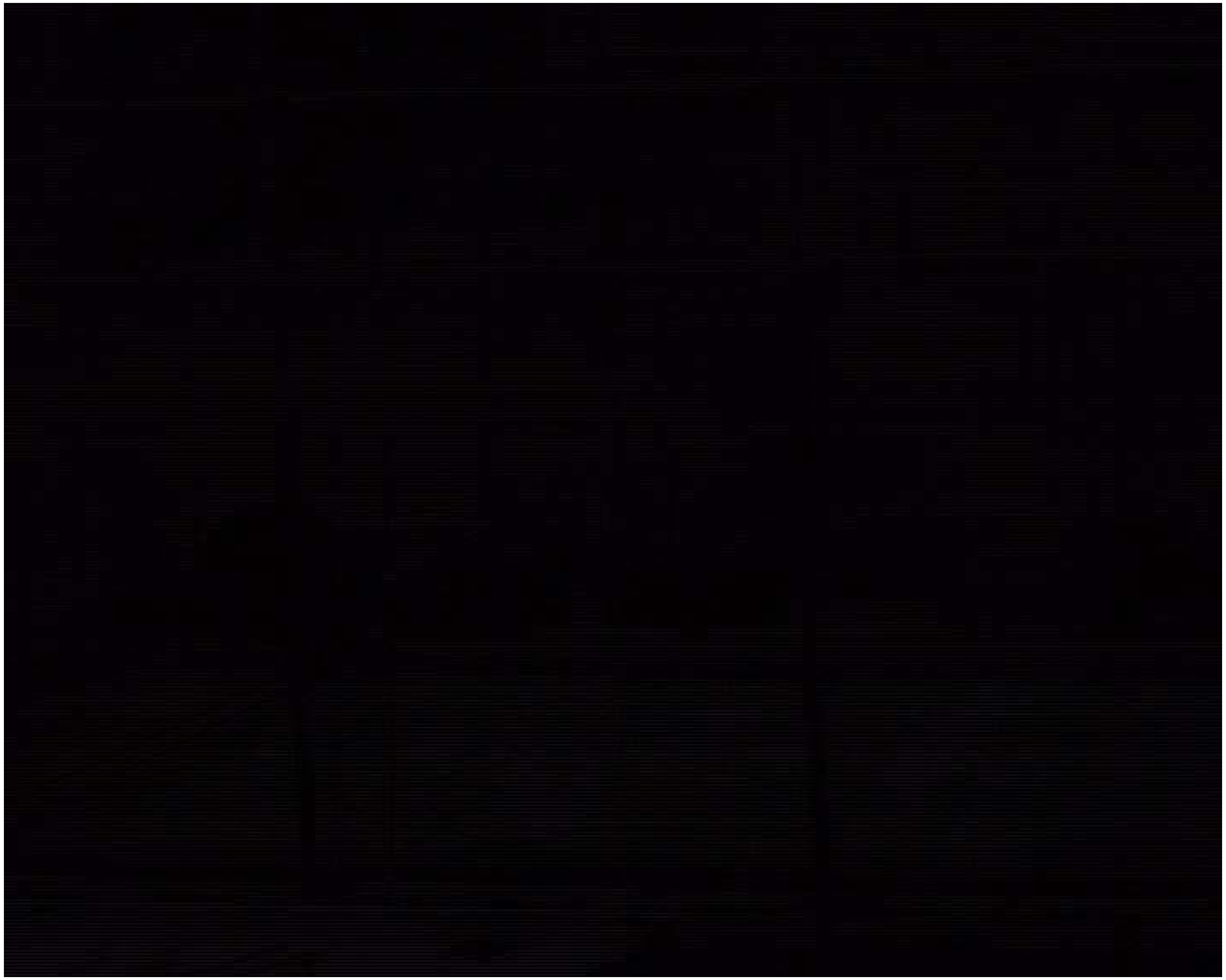


nirex

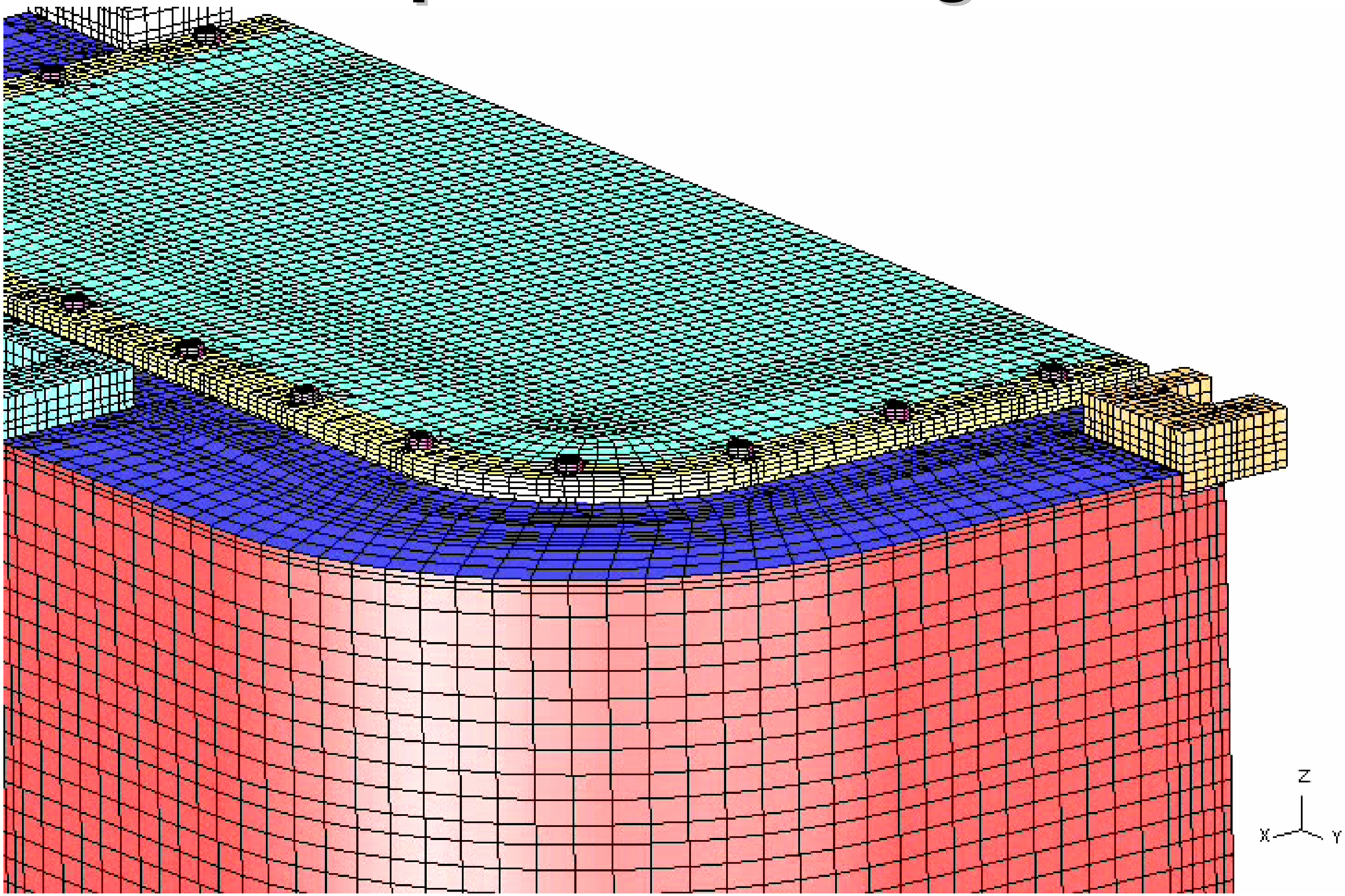
Impact Bounding Hazard

- Mechanical Damage (building / roof collapse, aircraft / train crash, explosives, crane failure, seismic)
- 25 metre
- flat / aggressive target
- 100 micron suspendible fraction

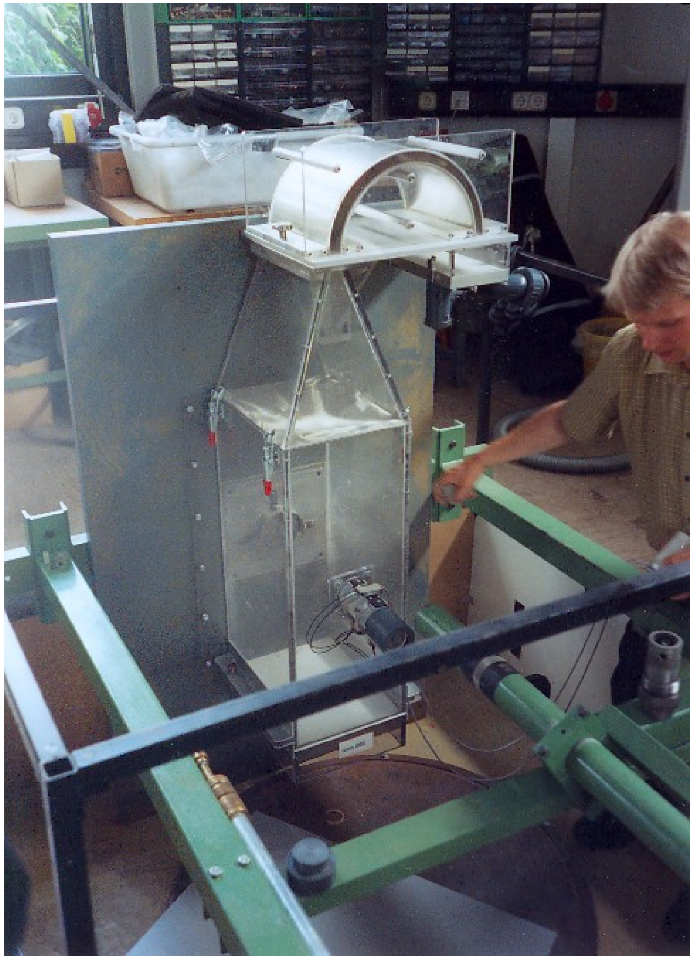
Drop Test



Impact Modelling

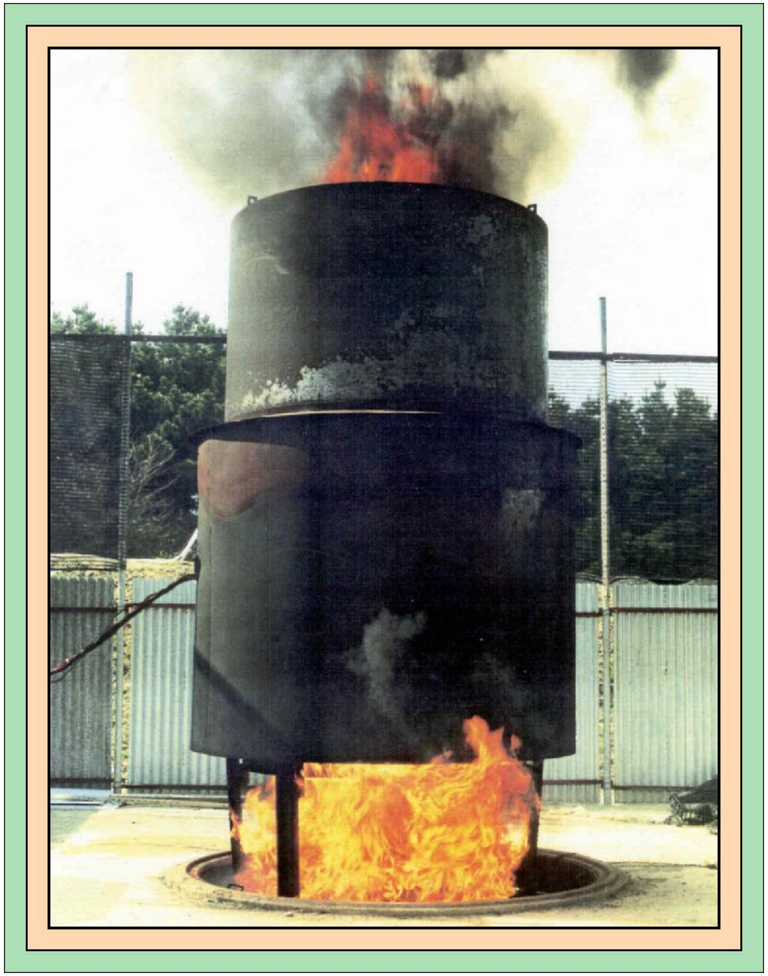


Polymer Sample Impact

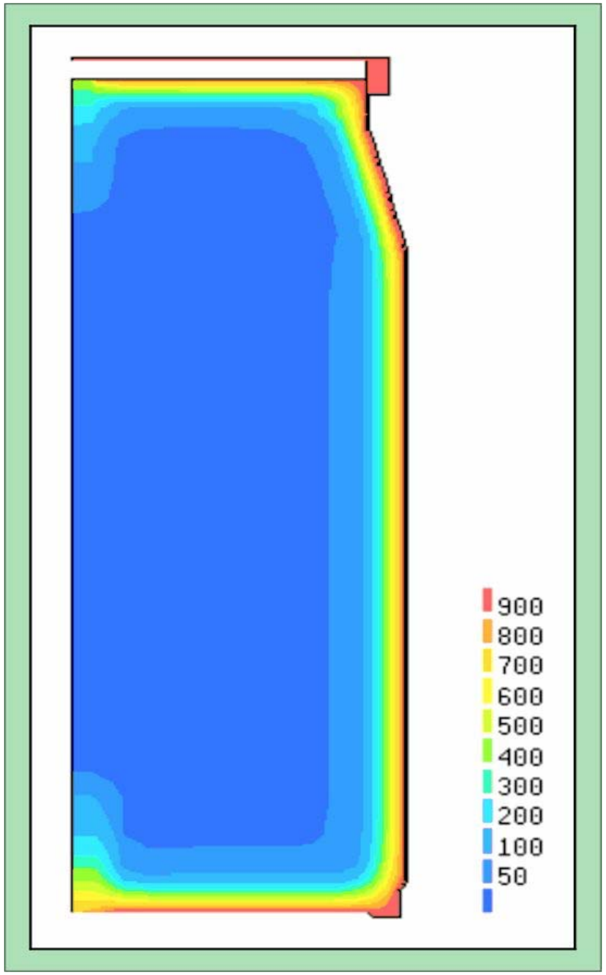


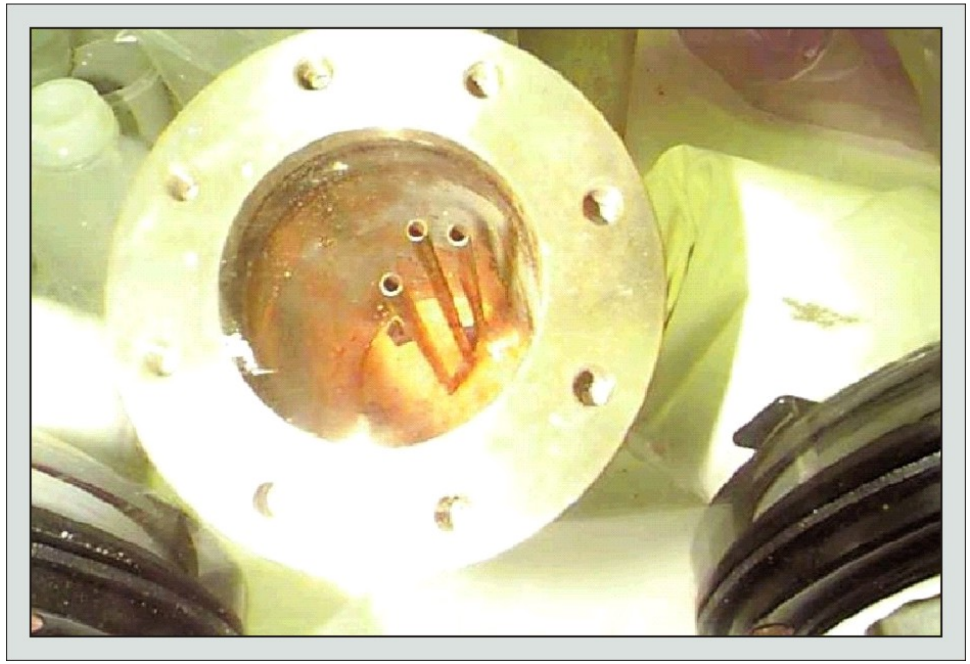
Fire Bounding Hazard

- Thermal Damage (train fire, flammable gas, explosion, electrical / package fire, overheating)
- 1000^{o}C for 1 hour
- fully engulfing
- gas and volatile releases



Fire Modelling Combined with Active Tests





Waste Package Engineering

Interim storage and transport

- Needs passively safe waste packages

Benefits of a cement matrix

- Immobilises the radionuclides
- Tolerant to chemically diverse wastes
- Suitable for solid, slurry & liquid waste (many are alkaline)
- Free flowing for good infilling
- Low voidage & low permeability when cured
- Cheap

⇒ But, gas means the steel container must be vented

Image of PFA / OPC Hydrated for 180 Days

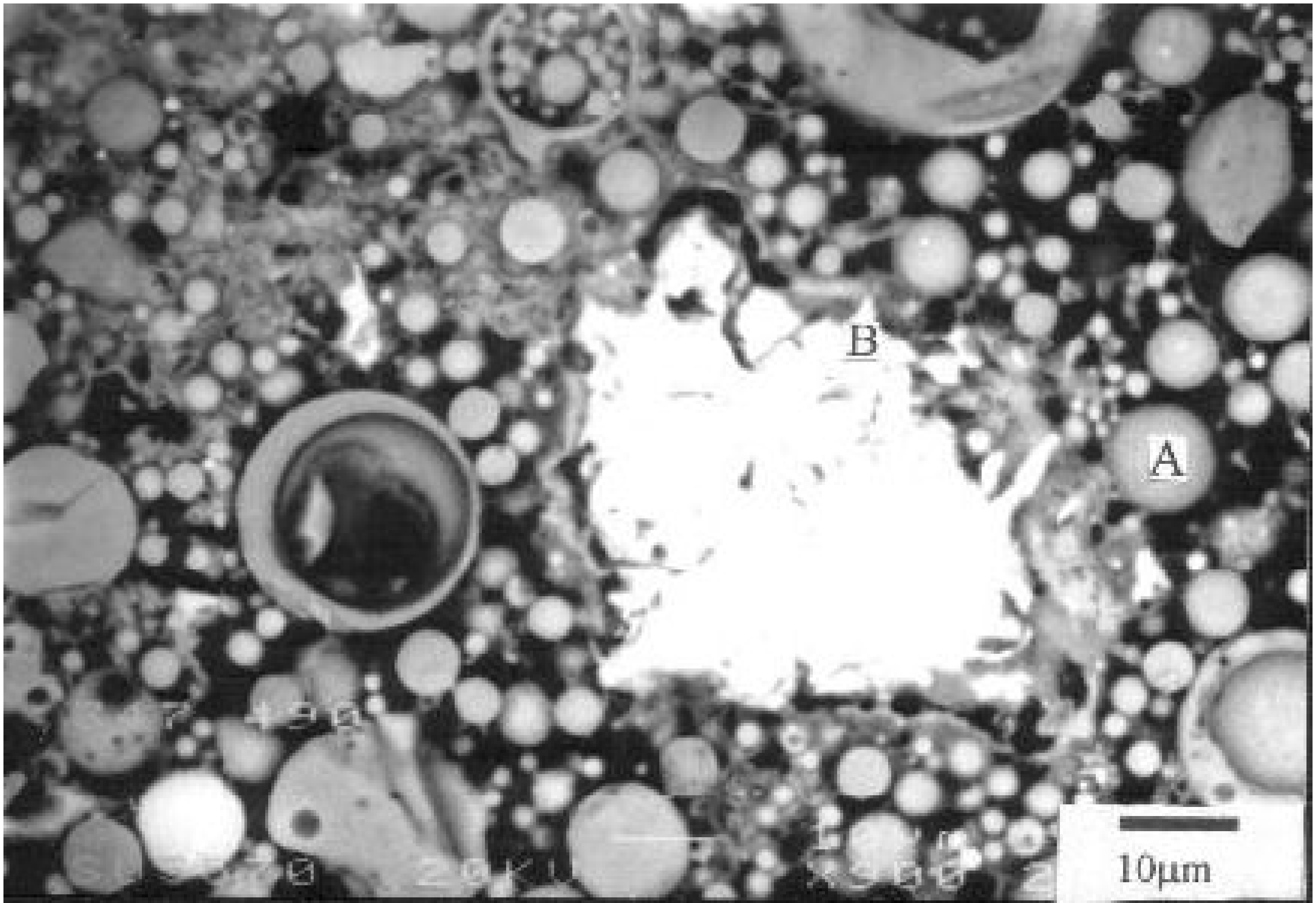
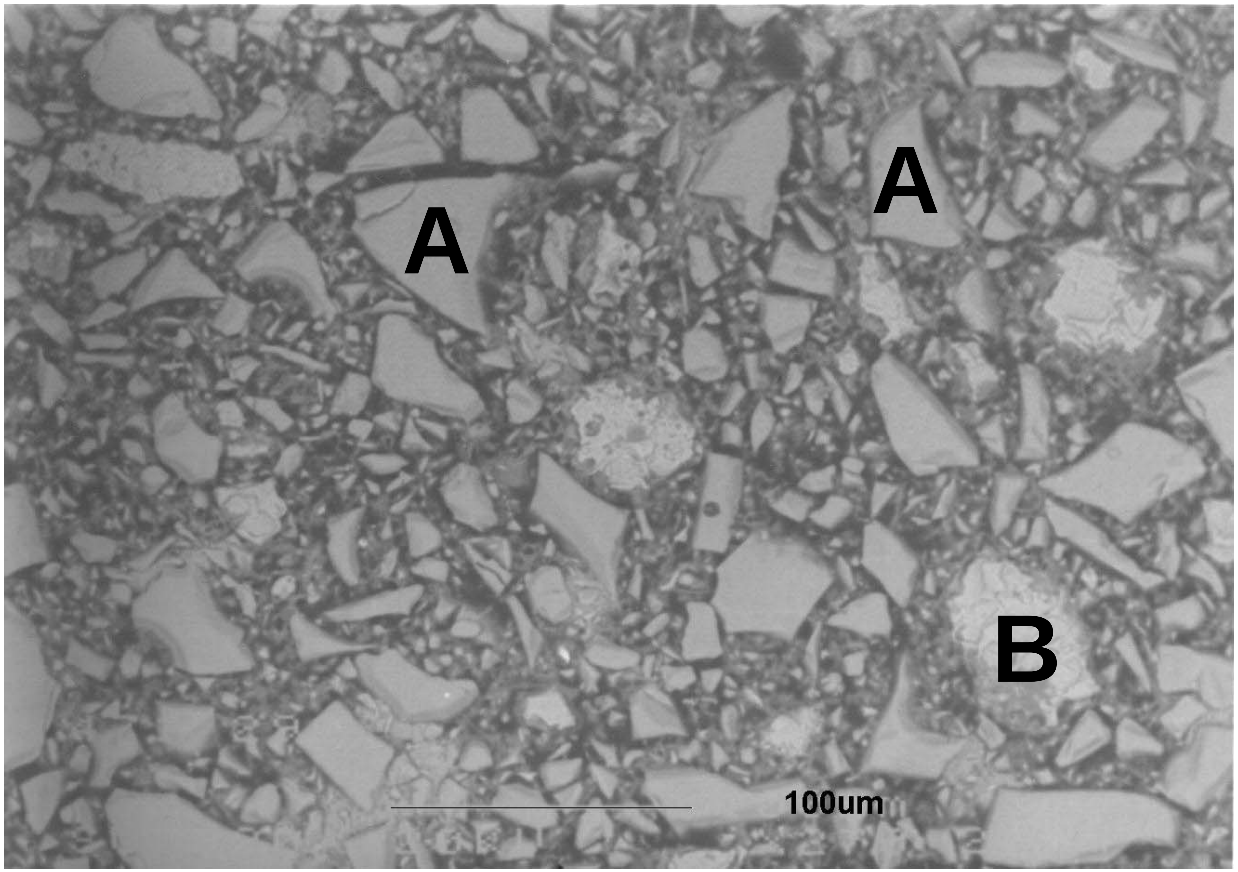


Image of BFS / OPC Hydrated for 90 Days

A = BFS grains
B = anhydrous cement grain



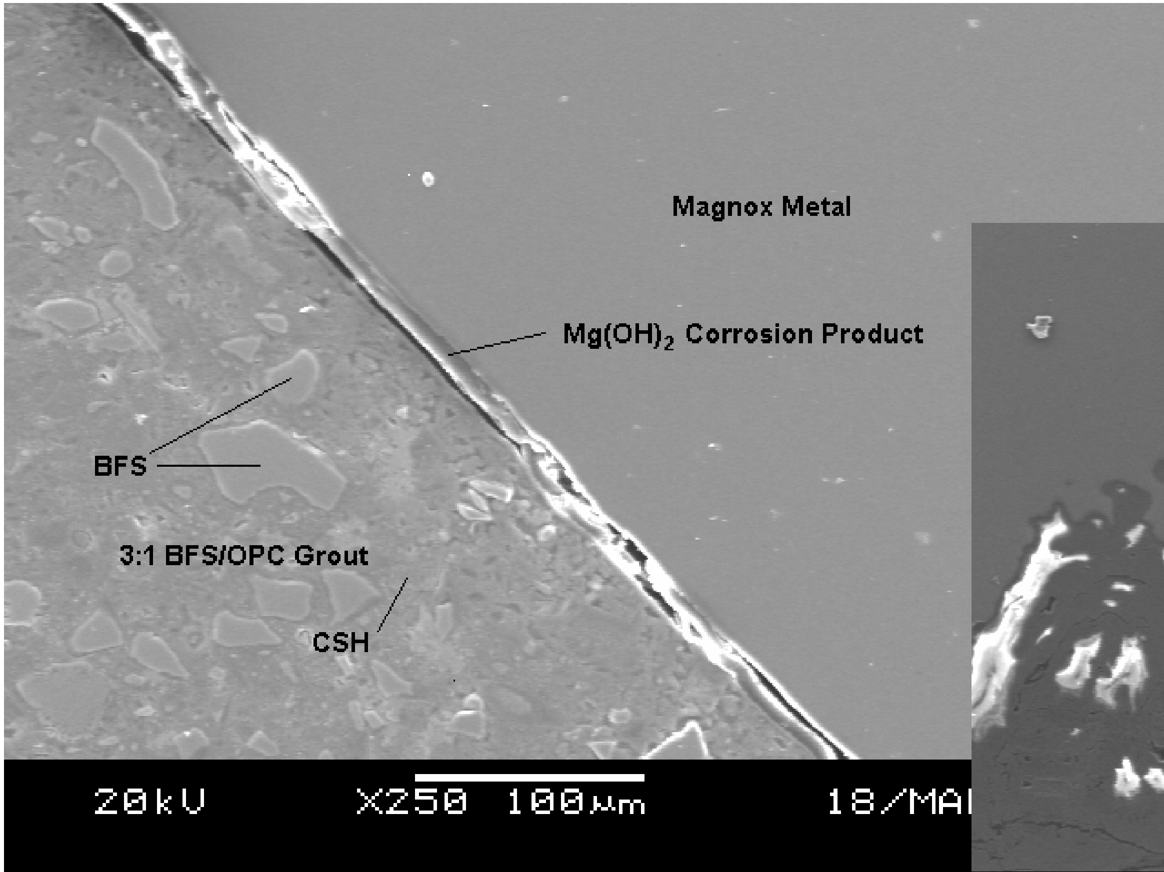
nirex

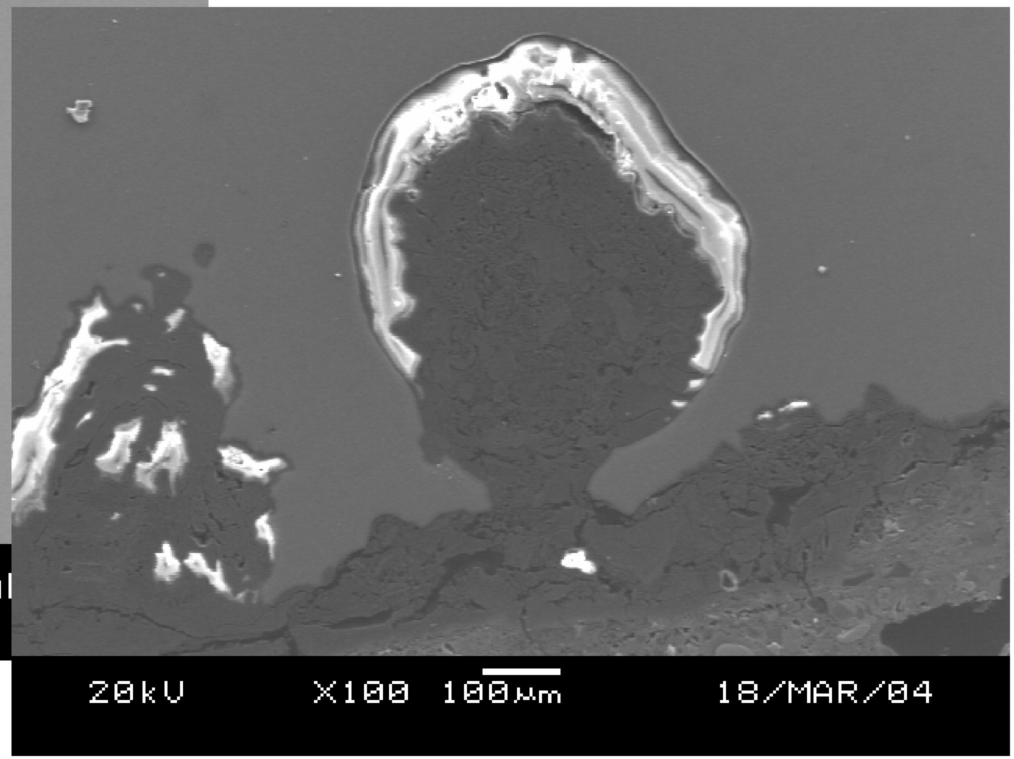
Magnox in Grout

Courtesy of NSTS

Corrosion of Magnox

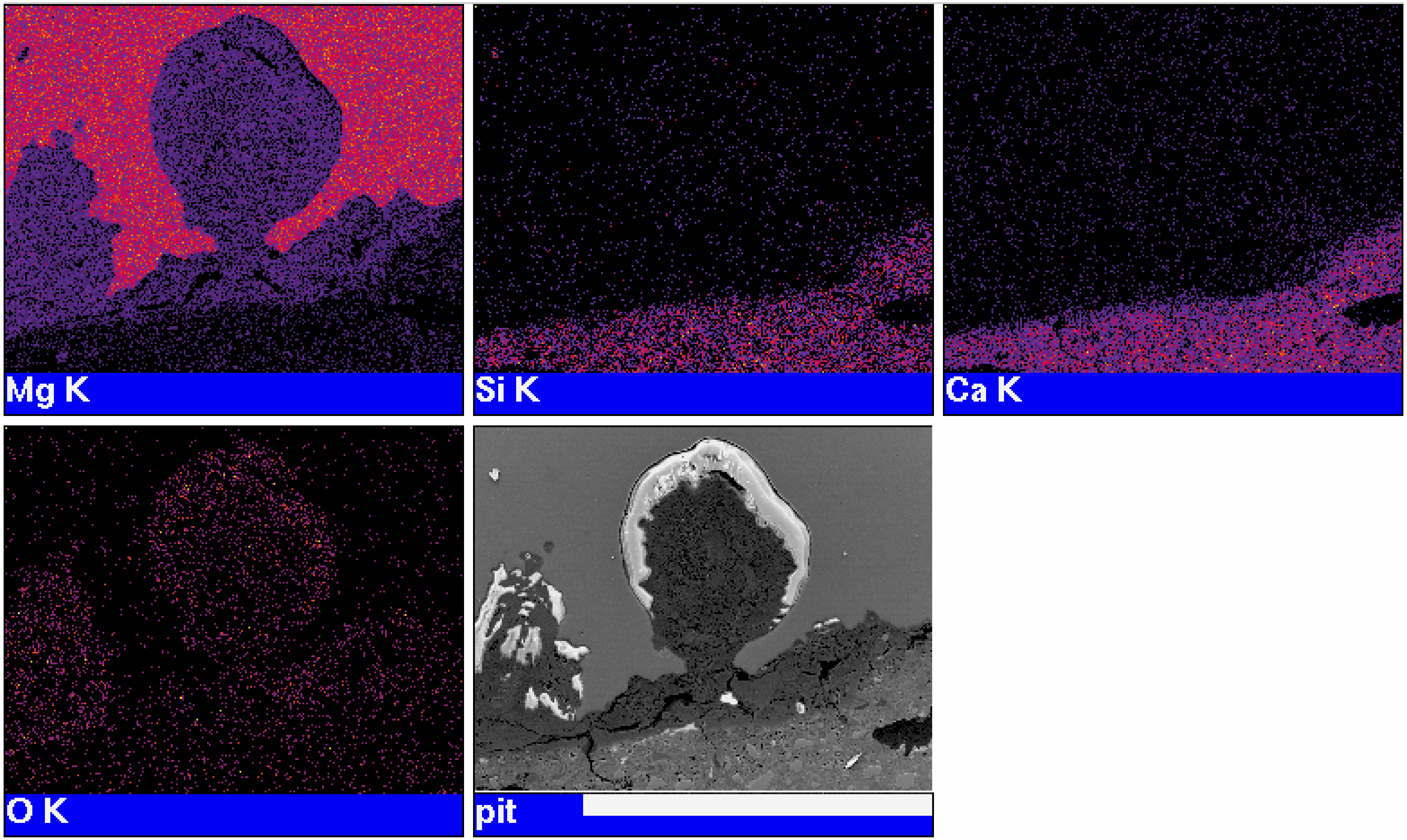
Fresh / Corroded





Courtesy of NSTS

Elemental Mapping



Courtesy of NSTS

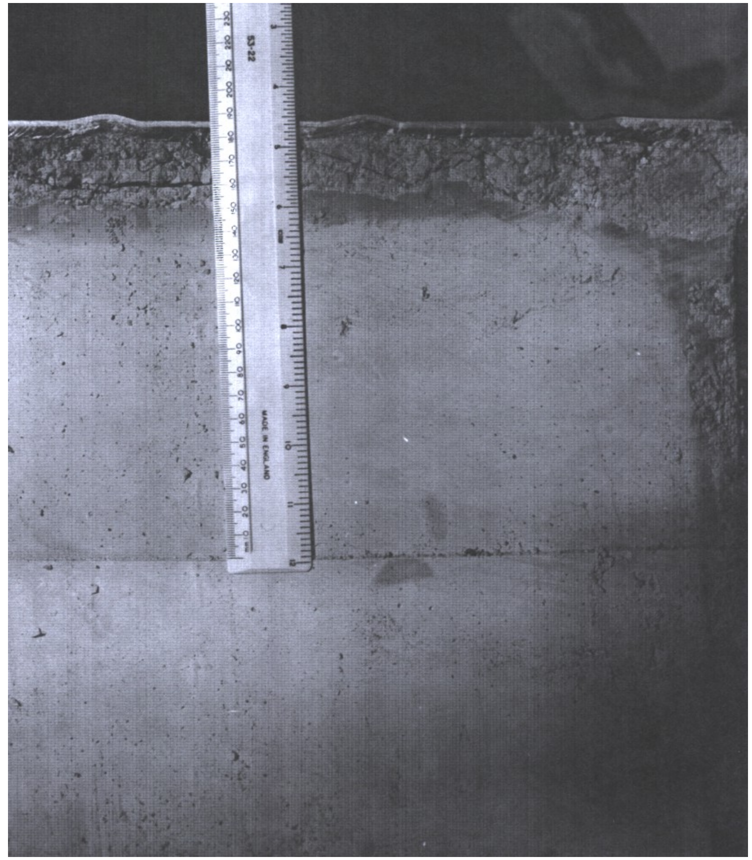
Issues for Impact Performance

- Strength of contents
- Location of activity:
  - in pores; or,
  - bound in the matrix
  - bound in waste e.g. activated steel
- Breach of containment
- Predicted release
- Age (400 years)

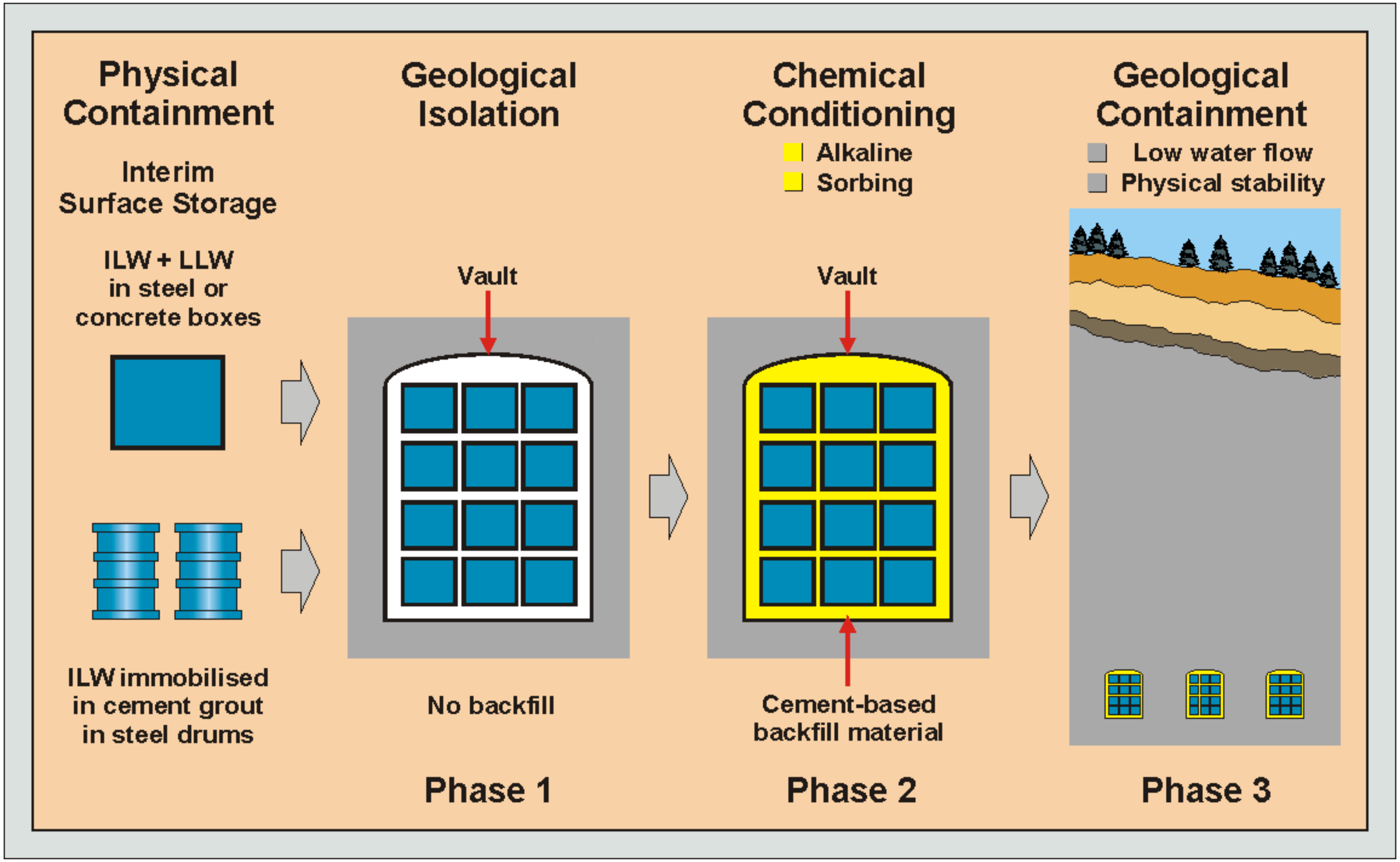
nirex

Issues for Fire Performance

- Thermal properties
- Degradation of waste
- Location of activity:
  - in pores; or,
  - bound in the matrix
- Chemical form
- Predicted release
- Age (400 years)



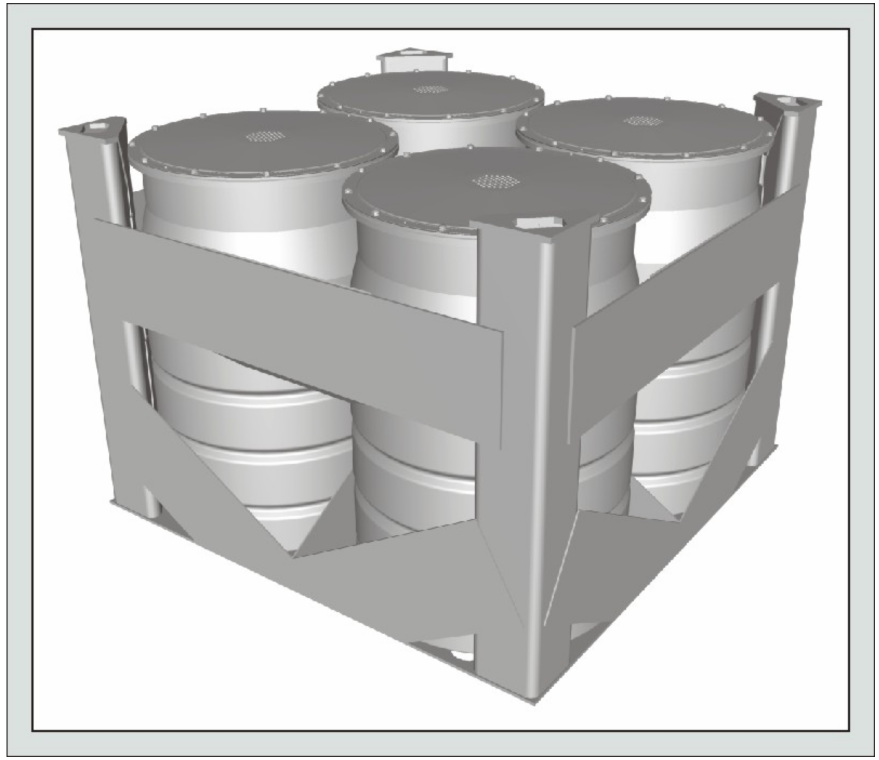
Phased Geological Repository Concept



nirex

Retrieval from the Backfill

Retrieval from the Backfill



nirex

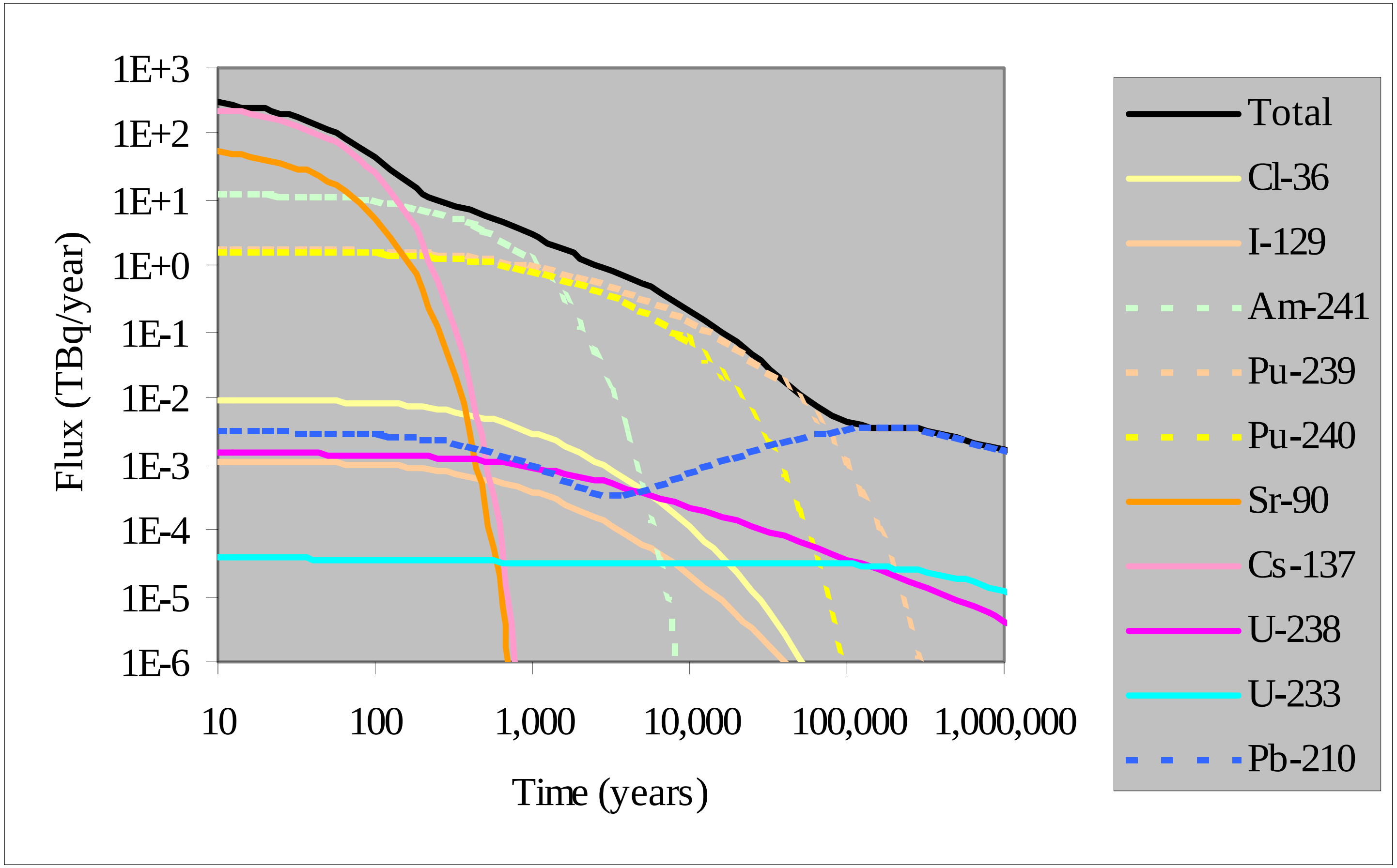
Physical Containment of the Waste Package

- High pH reduces container corrosion
  - but the container is vented
- Physical containment provided by the cement matrix depends on
  - the integrity of wasteform
  - mobility by diffusion of particular radionuclides
- Modelling for weakly sorbing radionuclide
  - Peak flux after 90 to 400 years
- For well sorbing radionuclides container corrosion is more significant

Modelling Assumptions for Performance Assessment

- Container degraded
- Vault contents homogeneous
- “Solubility-limited source term”
- Linear sorption
- Organic complexes represented by solubility enhancement and sorption reduction factors

Flux from Engineered System

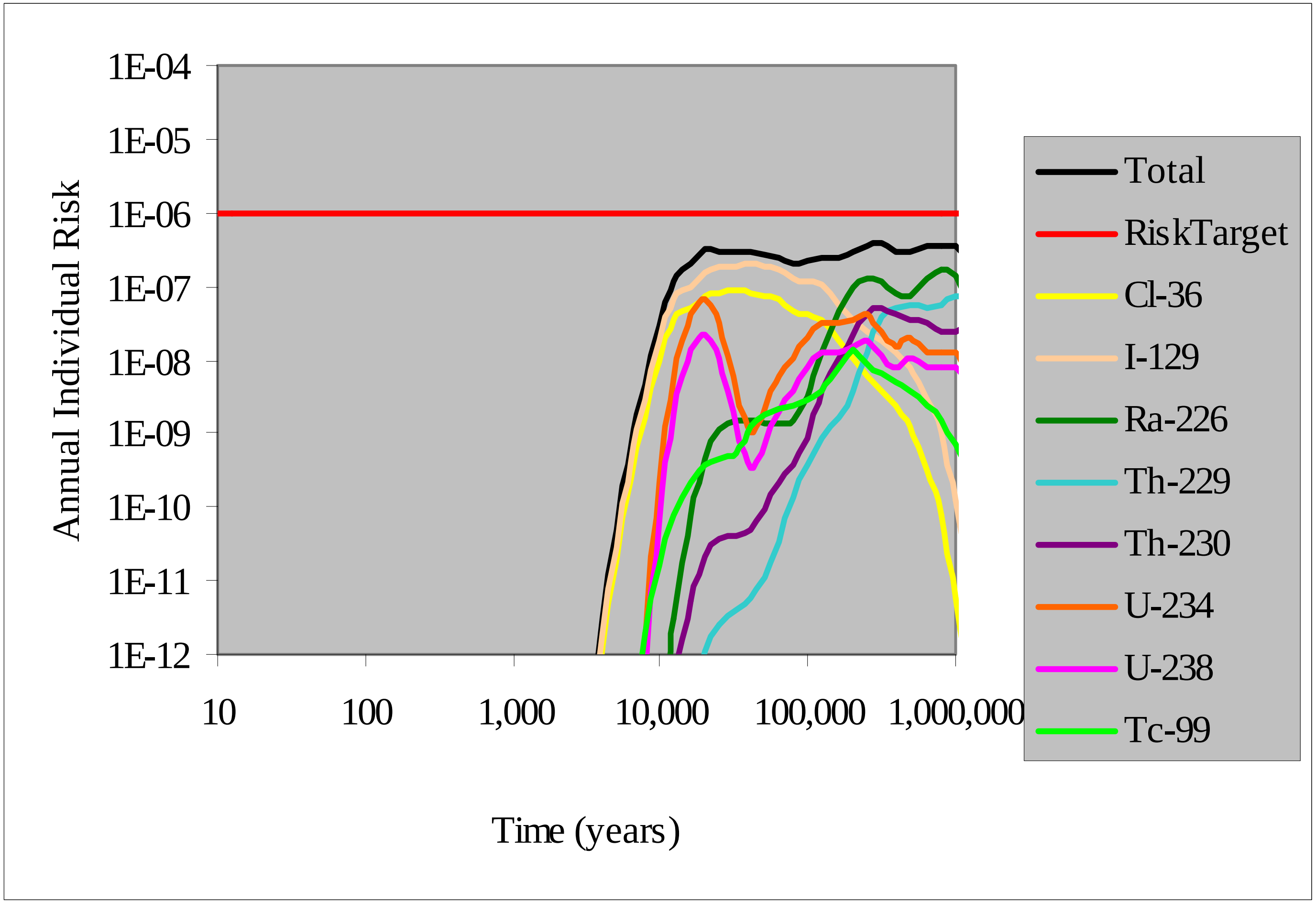


nirex

Challenges to the Use of a Cement Backfill

- The long timescale - how can you tell what will happen?
- The fact that wastes and groundwater flow rates will not be uniformly distributed (heterogeneity)
- Cement colloids could make radionuclides more mobile
- Cracking

Individual Radiological Risk



430655

nirex

Which Radionuclides Contribute to Risk?

- Cs-137, Sr-90, Am-241
  - Short half-life means these do not reach the biosphere
- Pu-239, Pu-240
  - Medium half life, low solubility and high sorption mean these do not reach the biosphere
- U-238
  - Long half life - decay products contribute to risk
- Cl-36, I-129
  - Very long half life and poor sorption means these contribute to radiological risk

Geosphere Issues

- What controls post-closure risk?
- What are the key radionuclides and how much can the repository tolerate?
- Base scenario
  - Groundwater pathway
  - Gas Pathway

Groundwater Pathway
What does Risk Depend On?

$$R_{\text{peak}} \propto \frac{I\,N\,G\;\;0.06B}{\sqrt{\sigma_s^2 + \sigma_g^2}}$$

R_{peak} = peak risk

I = inventory

σ_s = source term spreading time

σ_g = geosphere spreading time

N = fraction released from repository

G = fraction released from geosphere

B = biosphere factor

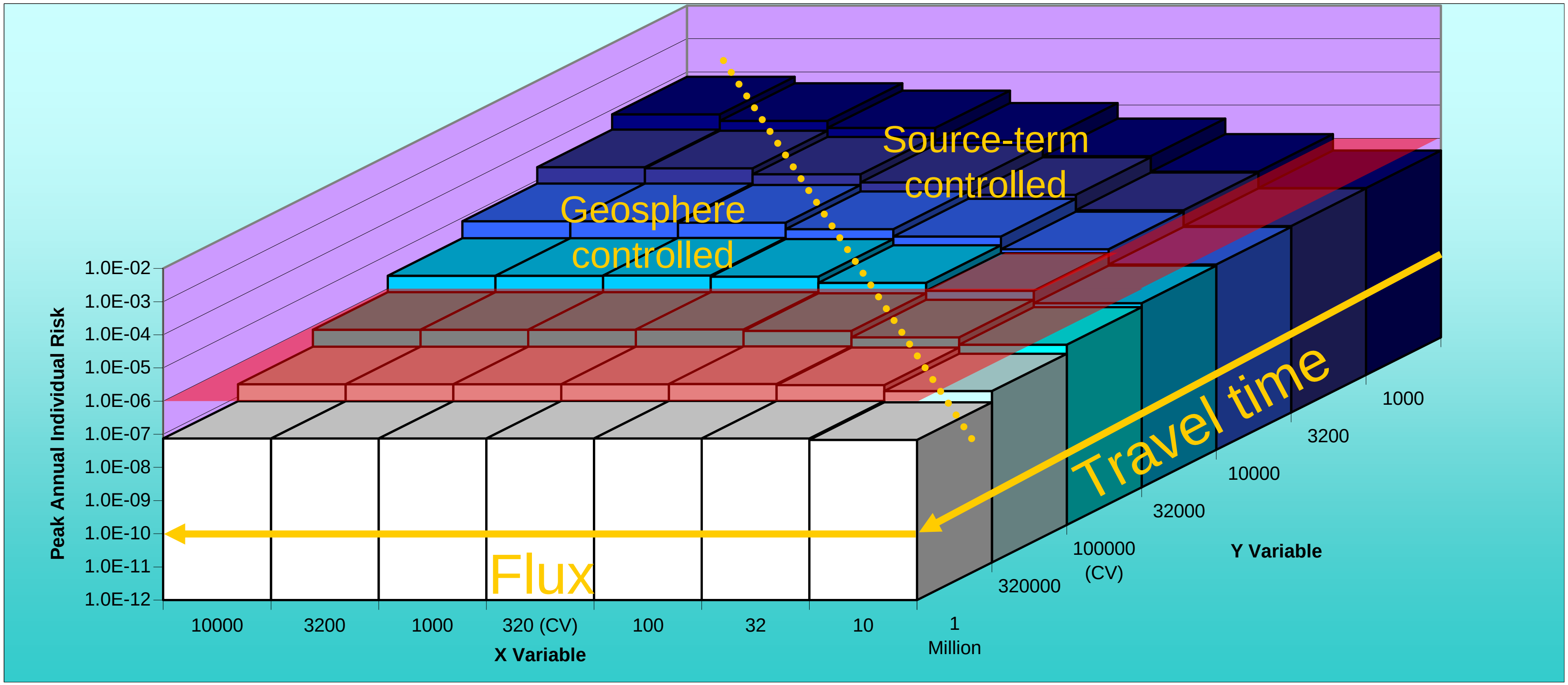
0.06 = dose to risk factor

Iodine-129

- Iodine-129 has a half life of 15.7 million years
- Inventory of iodine-129 is 1.5 TBq
- Iodine is very soluble and mobile
- Source term spreading time, σ_s, depends on flux through repository, Q
- Geosphere spreading time, σ_g, depends on travel time, T

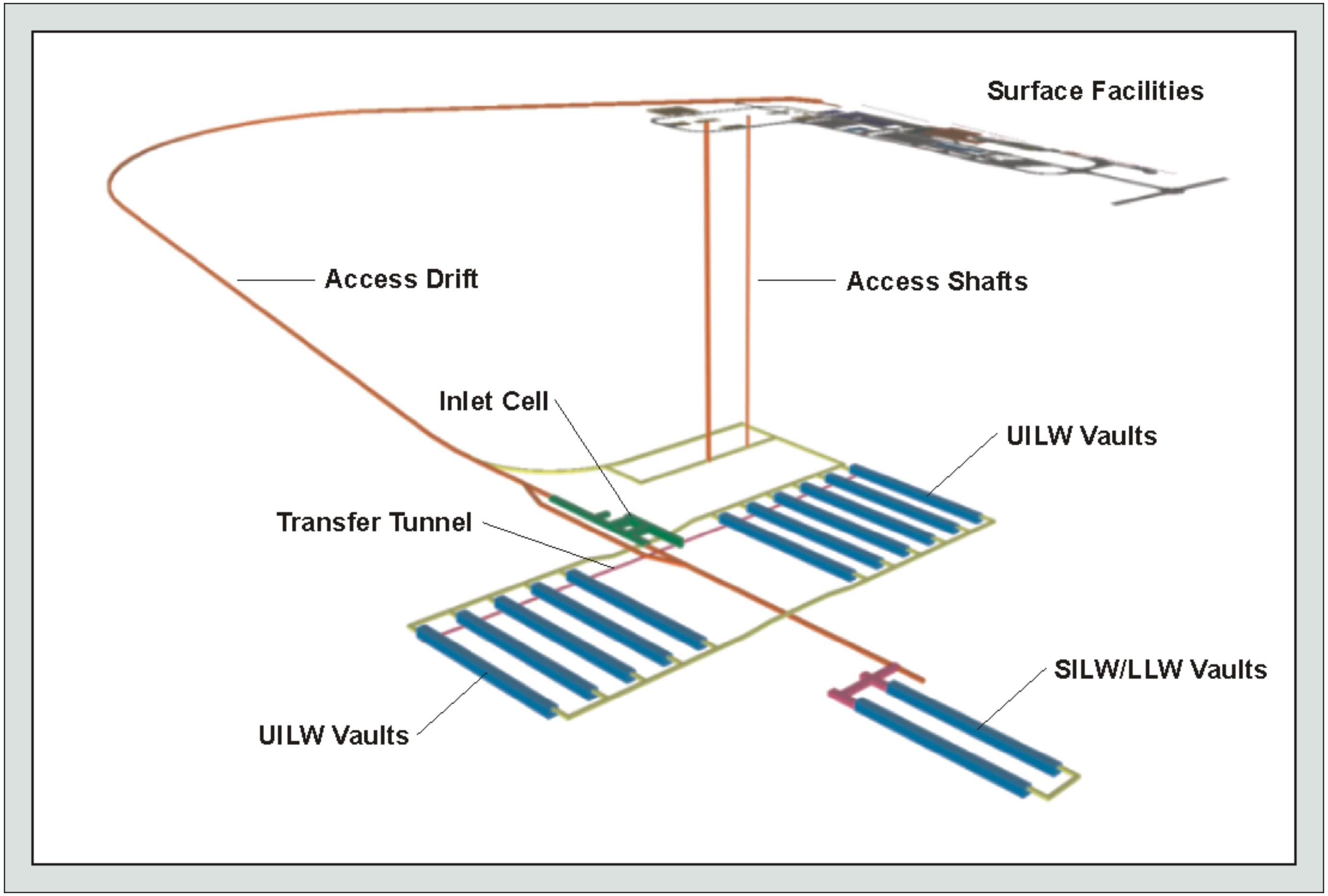
Iodine-129 Travel time v Flux

Worksheet:		Data			
Radionuclide:	(0-39)	14	OK	Radionuclide is:	I-129
Near-field solubility:	(1-7,X,Y)	3	OK	Near-field solubility:	Central values
Near-field sorption:	(1-7,X,Y)	3	OK	Near-field sorption:	Central values
Far-field sorption:	(1-7,X,Y)	3	OK	Far-field sorption:	Central values
Flux (Q):	(1-7,X,Y)	X	OK	Flux (Q):	Plotted on the X axis
Travel time (T):	(1-7,X,Y)	Y	OK	Travel time (T):	Plotted on the Y axis



nirex

Phased Geological Repository Concept



nirex