

# Nuclear Fuel Waste Management

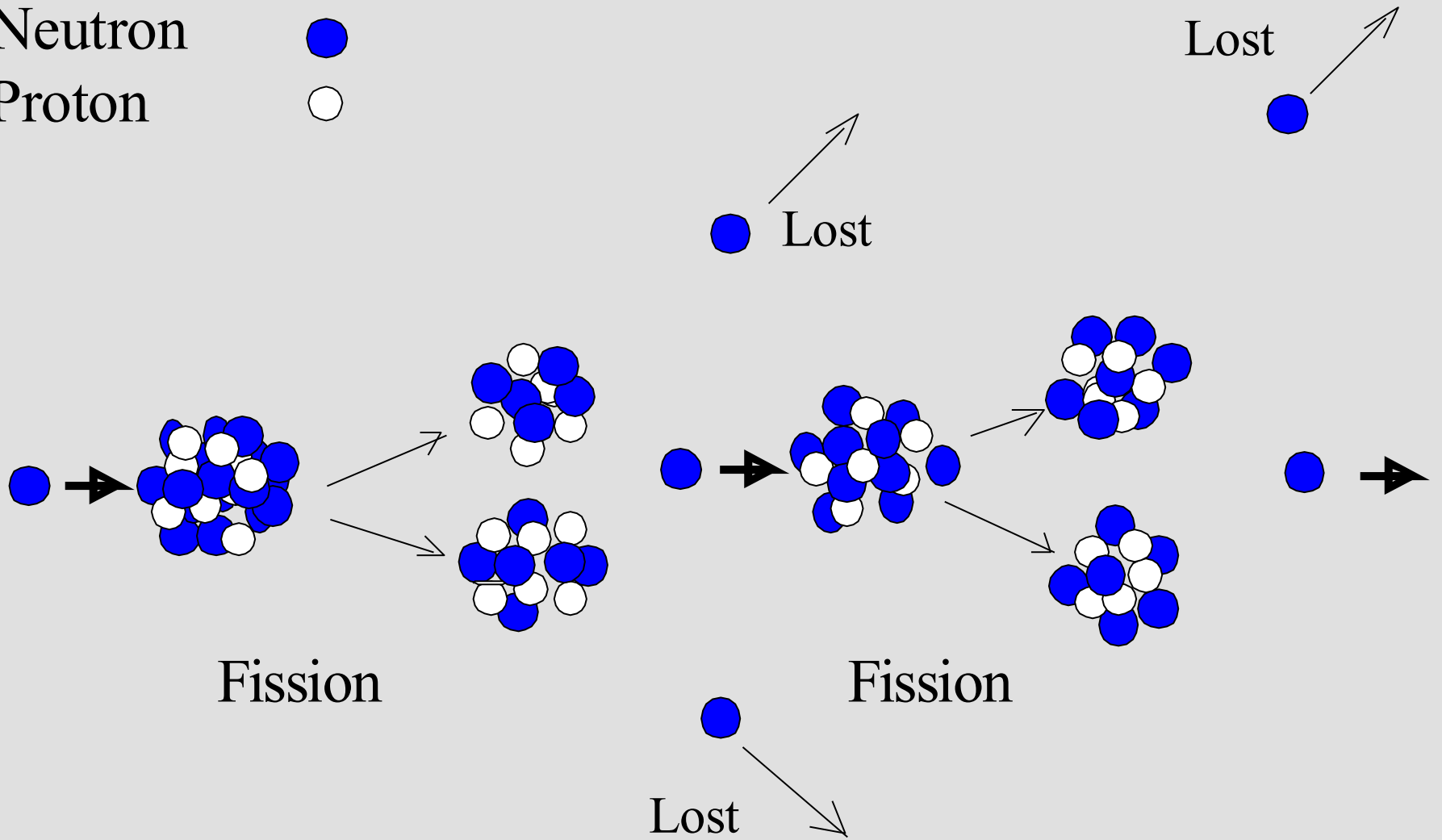
The Problem

The Proposed Canadian Solution

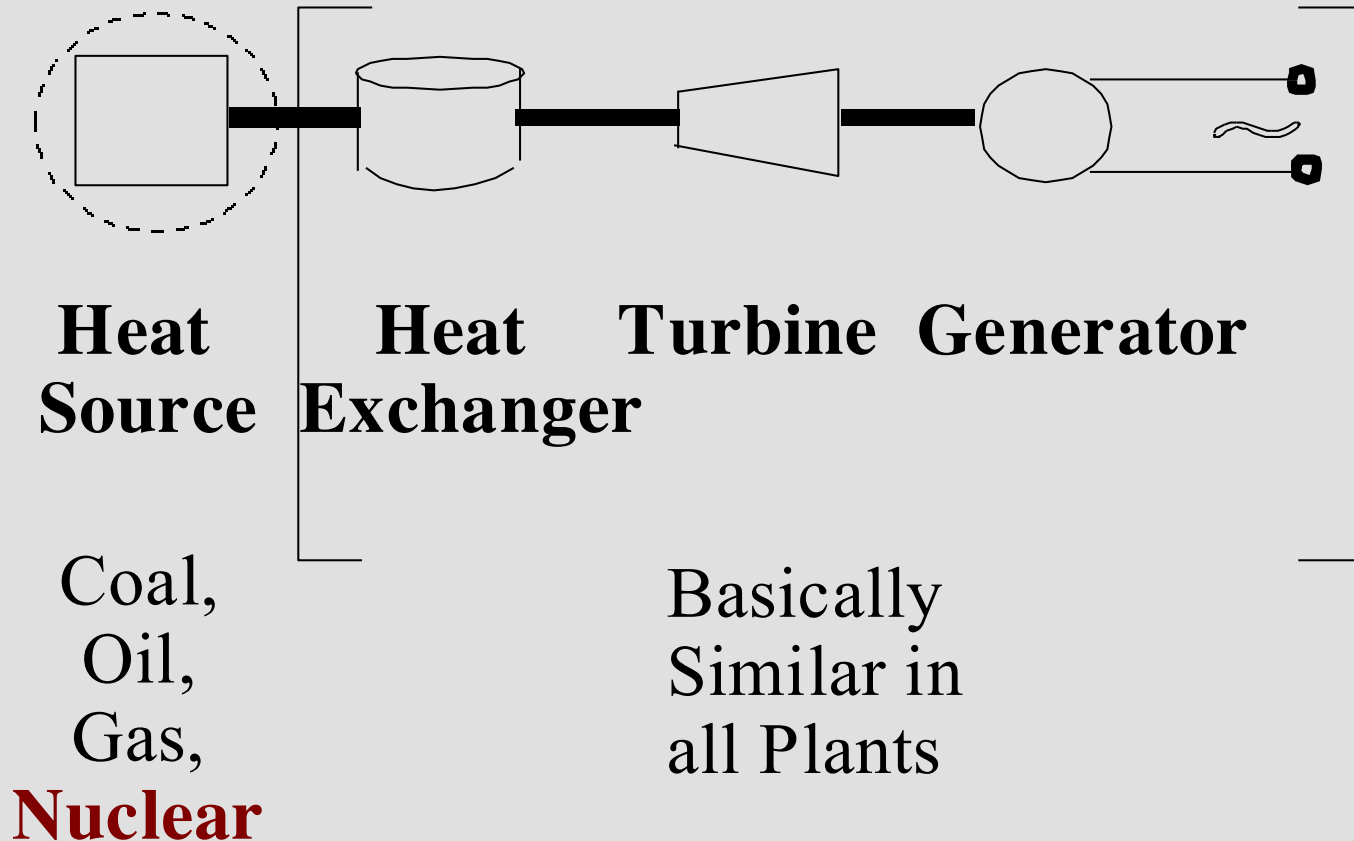
The Expected Results

# Nuclear Chain Reaction

Neutron  
Proton



# Generic Power Plant



# Nuclear Fuel Composition

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<u>Component</u>	<u>Initial</u> %	<u>After Use</u>
<b>Uranium</b>		
<sup>238</sup> U	99.2836	98.492 %
<sup>235</sup> U	0.7110	0.202
<sup>234</sup> U	0.0054	0.004
<b>Total Uranium</b>	100.00 %	98.698 %
<b>Stable Fission Products</b>	-	0.654
<b>Radioactive Fission Products</b>	-	0.158
<b>Activation Products</b>	-	0.490
<b>Total</b>	100.00 %	100.00 %



The Fuel is Uranium Dioxide

**Where is the Used Fuel Now?**

**In Storage at the Reactor Sites.**

# Some Problem Nuclides

<u>Nuclide</u>	<u>Half Life</u> (years)	<u>Radiation,</u>	<u>Energy</u> (M e V)
<b>Sr, Y -90</b>	28.8	$\beta^-$	0.55, 2.3
<b>Tc-99</b>	$2.1 \times 10^5$	$\beta^-$	0.29
<b>Sn, Sb-126</b>	$1.0 \times 10^5$	$\beta^-$	0.06, 1.9
<b>I-129</b>	$1.7 \times 10^7$	$\beta^-$	0.15
<b>Cs-135</b>	$2.3 \times 10^6$	$\beta^-$	0.21
<b>Cs, Ba-137</b>	30.0	$\beta^-$	0.51 $\gamma$ 0.66

# **Where are the Radionuclides?**

**Some match the structure of the  $\text{UO}_2$**

Actinides, most fission products

Remain in the  $\text{UO}_2$  crystal

**Some form at crystal boundaries and other gaps**

Mo, Pd, Rh, Ru, Tc, Te.....

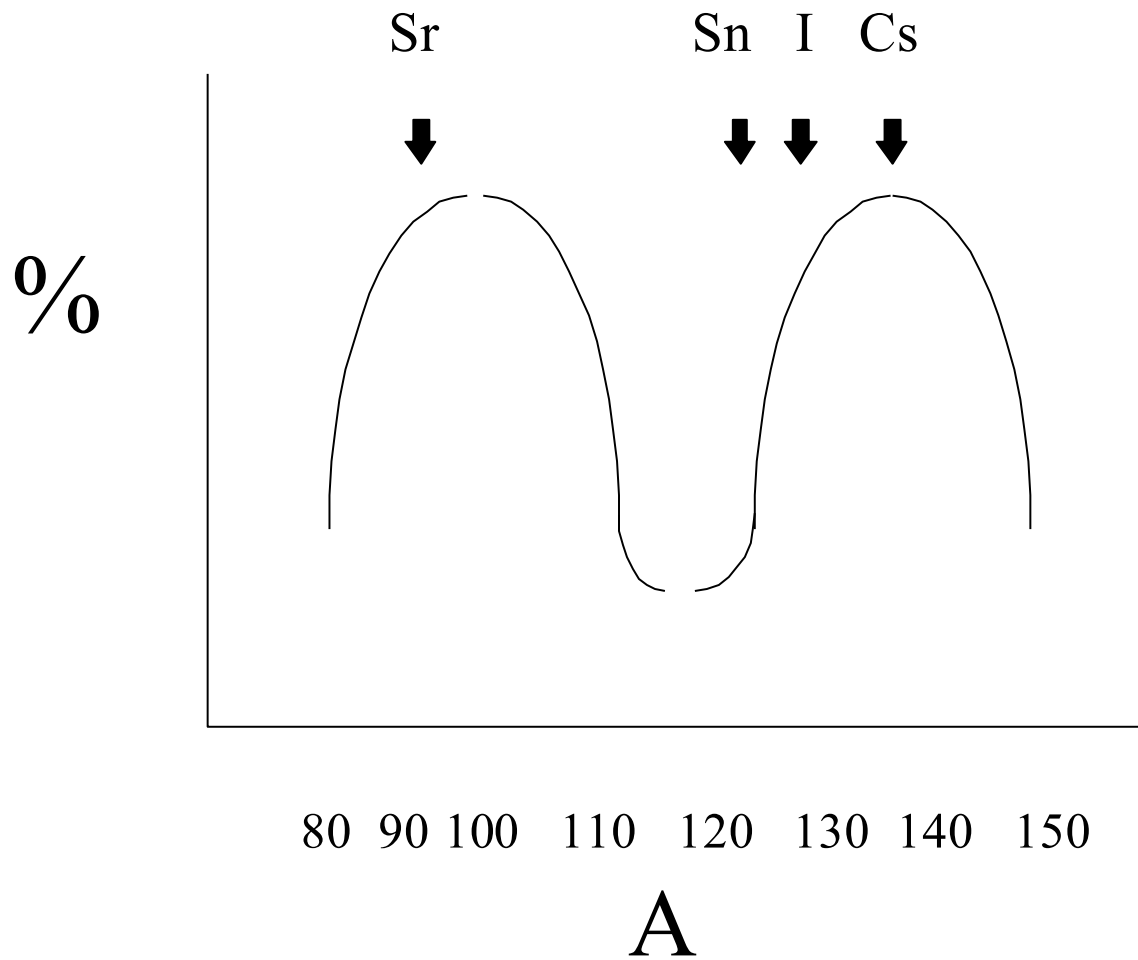
**Some may migrate to the edge**

Cs, Sr, I, Sn, Se

# The Instant Release Nuclides

- A few of the more volatile elements are found on the outside surface of the fuel
- About 8% of each of:
  - $^{36}\text{Cl}$ ,  $^{99}\text{Tc}$ ,  $^{129}\text{I}$ ,  $^{135}\text{Cs}$
  - and a few others





# **Health Effects**

## **External Sources:**

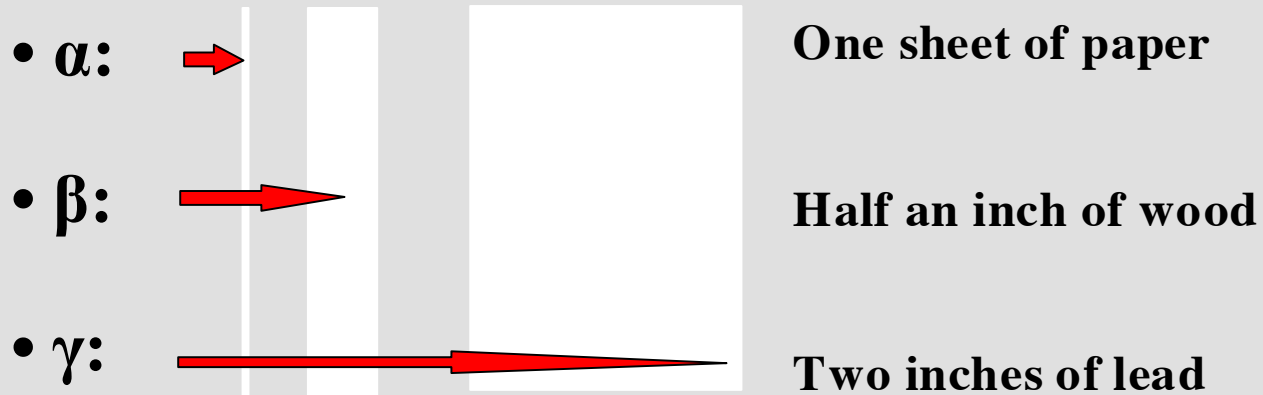
**General, Topical, Radiation Sickness**

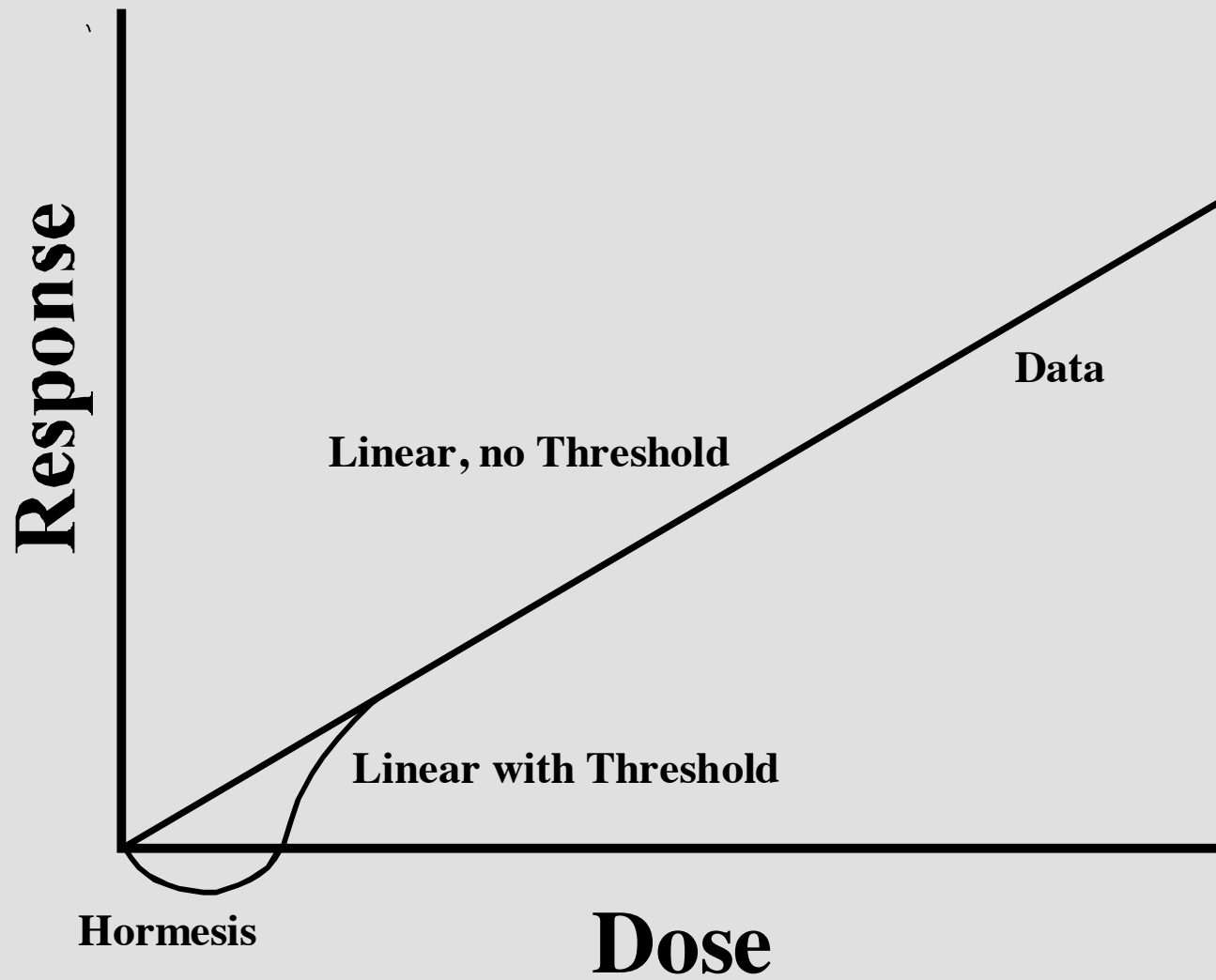
## **Internal Sources:**

**Organ-specific:**

**Thyroid, Bone Marrow, Liver, Others**

# How far will radiation go?





# **Canadian Inventory of Used Fuel**

Currently: > 2.6 Million bundles

Adding about 90,000 per year

# Natural Background Radiation

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Source	Dose Rate (mSv/a)
Cosmic Radiation	0.3 - 0.5
Concrete House	0.5 - 1.5
4-hour Jet flight	0.01
Radon (outdoors)	0.2
Medical x-rays	0.3 - 0.4
Human Body ( $^{14}\text{C}$ , $^{40}\text{K}$ )	0.2
<b>Total (Average)</b>	<b>2 - 3 mSv/a</b>

# UN and CNSC Regulations

- **For up to 10,000 years**
- **Current standards of exposure limits**
- **Risk of cancer less than 1 in a million**

**(Using a Dose-Conversion ratio 0.02 per Sv)**

**(∴ Dose Rate less than 0.05 mSv/a)**

# **Some Unacceptable Solutions**

- **Storage Forever**
- **Burial at Sea or in Space**
- **Burial in the Polar Ice Caps**
- **Transmutation**
- **Shoot it into the Sun**
- **Bury it in old Mines**



# **The Multi-barrier Concept**

- **Any barrier will eventually fail**
- **A failed barrier can be backed up by another**
- **Each barrier provides delay**
- **Delay leads to decay**

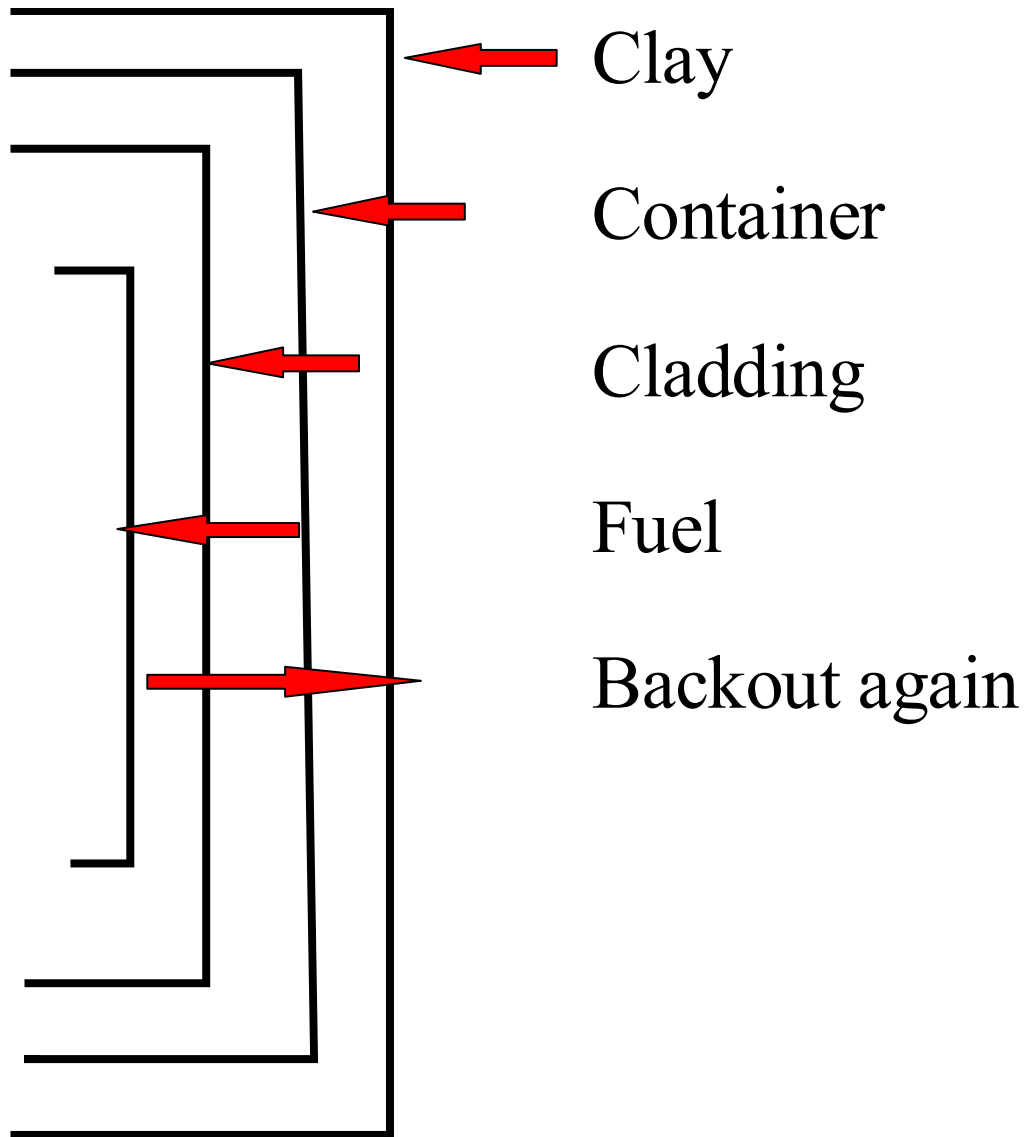
# **Revised AECL Proposal**

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- **The Fuel Bundles to be held in a Metal Container**
- **The Container should be Steel coated with Copper**
- **To be buried deep (500 - 1000 m) in intact rock**
- **To be packed in a bentonite clay 'box'**
- **To be backfilled with rock and cement**
- **Surrounded by at least 50 m of intact rock.**

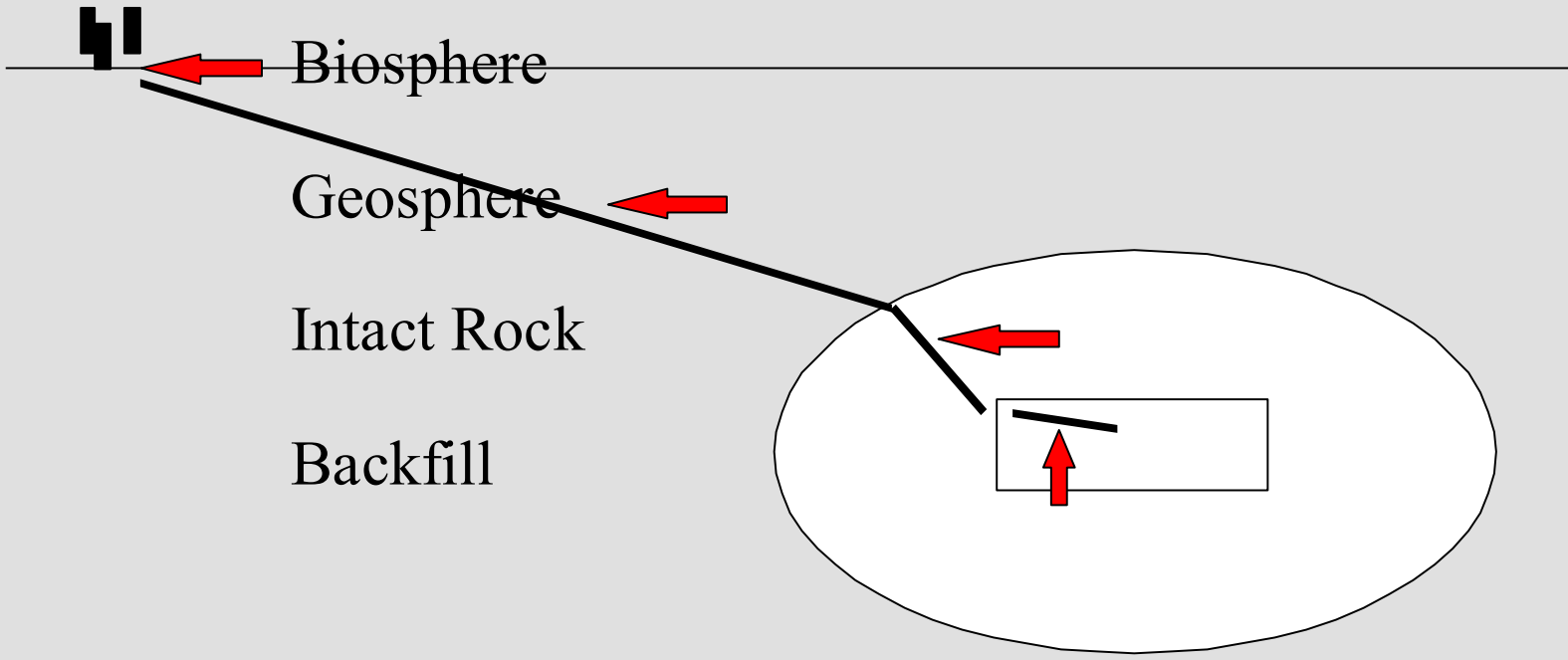
# **The Engineered Barriers**

- **The Fuel form itself**
- **The Cladding of the Fuel Bundle**
- **The Fuel Container**
- **The Clay Buffer Box**



# **The Natural Barriers**

- **The Backfill**
- **The Intact Rock**
- **The Geosphere**
- **The Biosphere**



**Of these: The Inact rock  
is likely the greatest barrier**

# The Processes

- **Resaturation**
- **Container Failure, Cladding Failure**
- **Radionuclide Release**
- **Radionuclide Migration**
  - **The Buffer**
  - **The Backfill and The Intact Rock**
  - **The Geosphere**
  - **The Biosphere - Isotope dilution**



# **Nothing Happens Until**

**Water corrodes the container  
and the sheathing**

**and dissolves the Instant Release Nuclides**

# My Estimates

<b>Resaturation</b>	<b>100 years</b>
<b>Container Failure</b>	<b>30,000</b>
<b>Sheath Failure</b>	<b>1,000</b>
<b>Instant Release</b>	<b>0</b>
<b>Migration: Buffer</b>	<b>100</b>
<b>Intact Rock</b>	<b>15,000</b>
<b>Geosphere</b>	<b>10,000</b>
<b>Total</b>	<b>56,000 years</b>

# **Where are we now?**

**OPG and the Industry has set up**

**Nuclear Waste Management Organisation**

**Annual Reports**

**Frequent News Reports**

## Adaptive Phased Management:

Store at a central site

Above ground or shallow burial

Test and Improve the science

Finally bury

# **Site Selection Criteria – Social**

**Acceptable to the local people**

**Acceptable to nearby communities**

**Acceptable to the wider public**

# **Site Selection Criteria – Technical**

**Absence of Seismic Activity**

**Absence of mineral values**

**Intact rock with adequate thickness and low porosity**

**Rock that is strong enough**

**Ground water that is and will remain reducing**

**Recharge zone with very old water**

Phase 2 January, 2016

Continuing:

Blind River, Elliot Lake, HornPayne,  
Central Huron, Huron Kinloss, Ignace, Manitouwadge,  
South Bruce, White River

Recent Book

The  
Chemistry of  
Nuclear Fuel Waste  
Disposal

Donald R. Wiles

Polytechnic International Press  
2002



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