University of BRISTOL

Nuclear Waste Services

SOUTH WEST NUCLEAR HUB

Nuclear Energy Futures EPSRC Centre for Doctoral Training

Research Support Office

Disposal of heavily corroded spent MAGNOX fuel

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#SWNuclearHub

In partnership with NRC

The **South West Nuclear Hub** incorporates the **Bristol-Oxford Nuclear Research Centre** (NRC)
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What is MAGNOX?

MAGNOX reactors:

- *Gas-cooled and graphite moderated*
- *Unenriched metallic uranium fuel*
- *Produced electrical power and Pu239*
- *First Generation of nuclear reactors in the UK*
- *Operational between 1956 and 2015*

The name comes from the fuel cladding used:

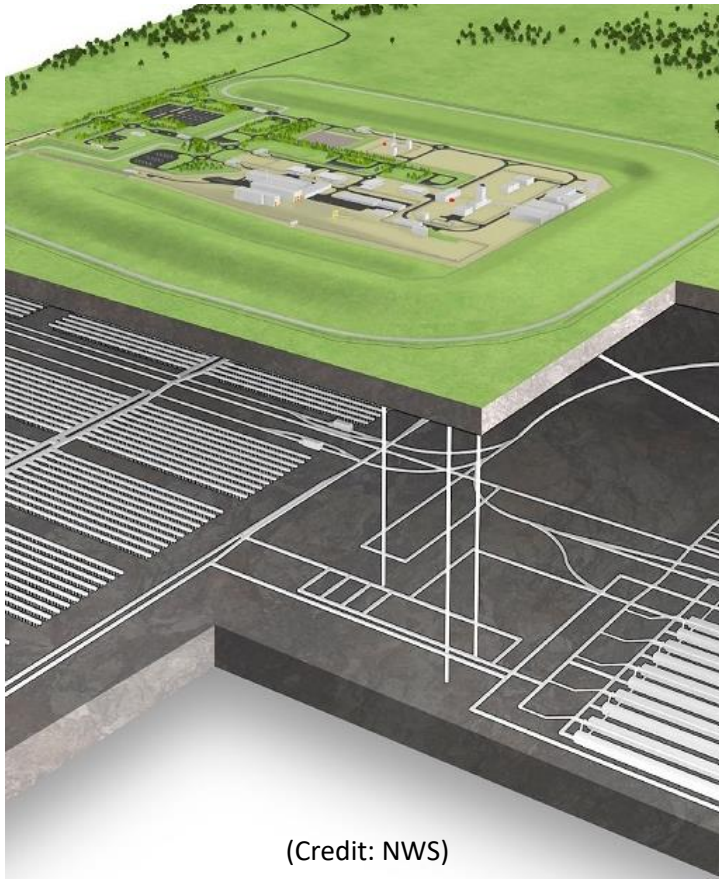
MAGnesium Non-OXidising is an alloy of magnesium and aluminium

Oldbury power station
(Credit: Horizon Nuclear Power)

MAGNOX fuel isn't just ordinary uranium!

Current metallic uranium science is not sufficient to model how corroded spent MAGNOX fuel will behave in a GDF.

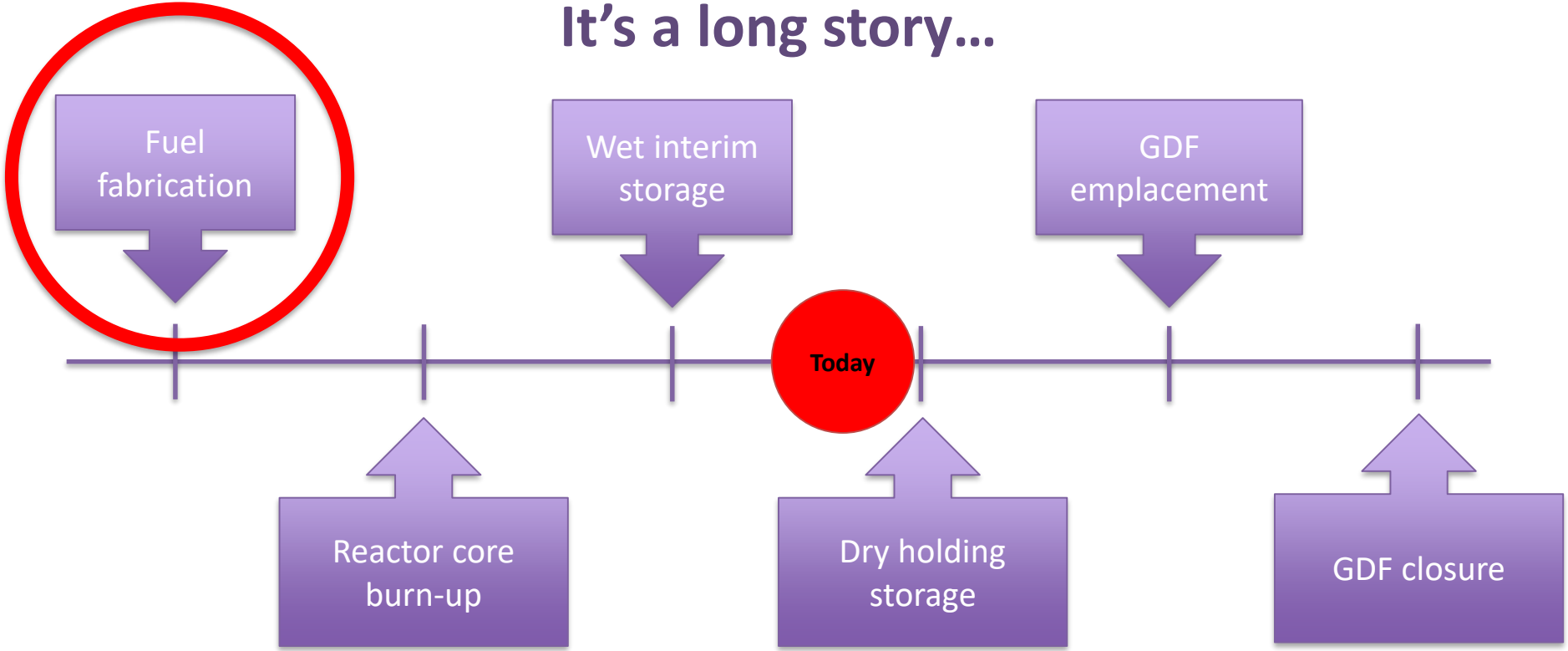
We care about much more than just the uranium in the fuel!



(Credit: NWS)

MAGNOX fuel isn't ordinary uranium!

It's a long story…



MAGNOX fuel isn't ordinary uranium!

Fuel Fabrication

- Metallic U cast into rods
- Dimensions & cladding fins vary
- Purity

→ **Carbide Impurities?**

(Credit: Camilla Parkes)

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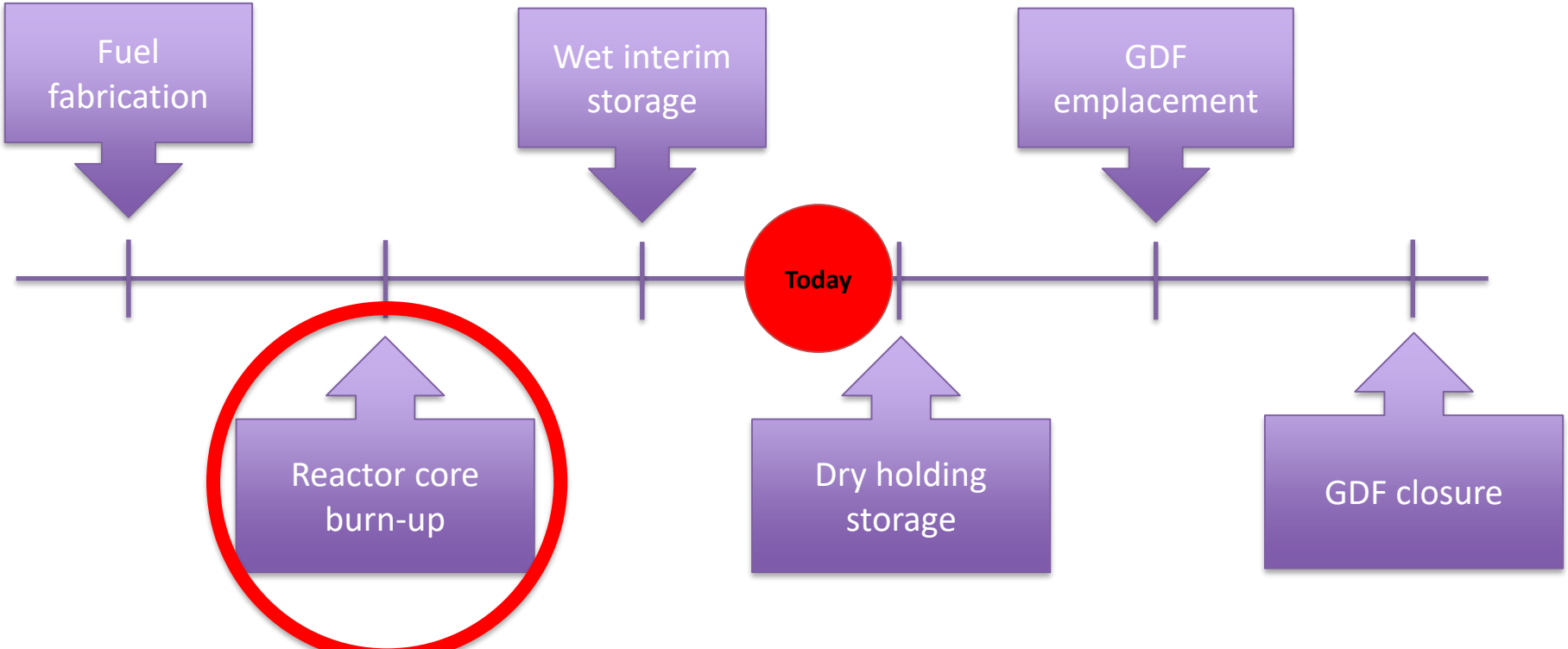


MAGNOX fuel isn't ordinary uranium!

Reactor Core Burn Up

- High temperature (360°C)
- Thermal cycles
- Irradiation
- Fission product generation

*Burn up **isn't homogenous** through the core or within the fuel rod! This is partly because uranium metal is very dense* ($\sim 19 g cm^{-2}$)

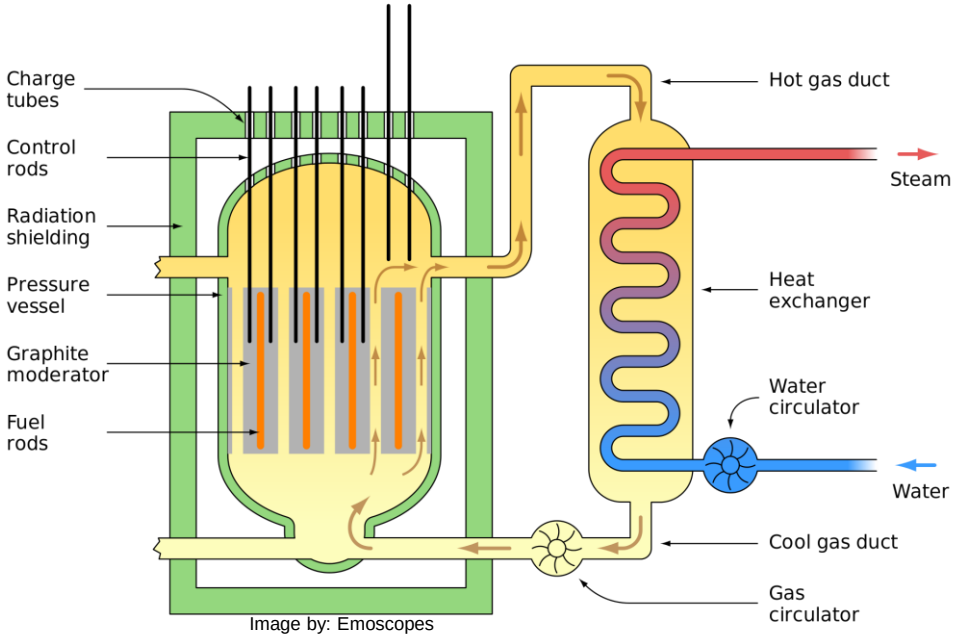
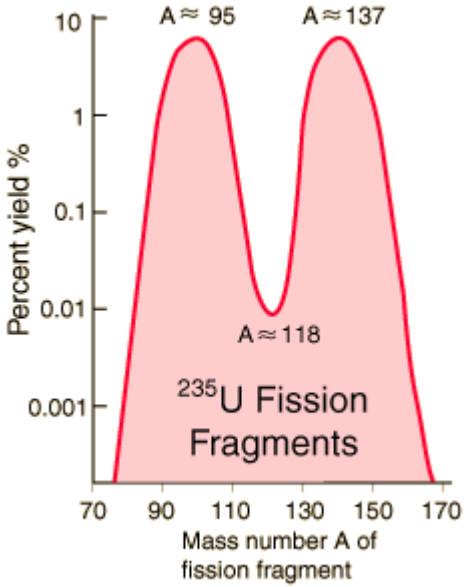


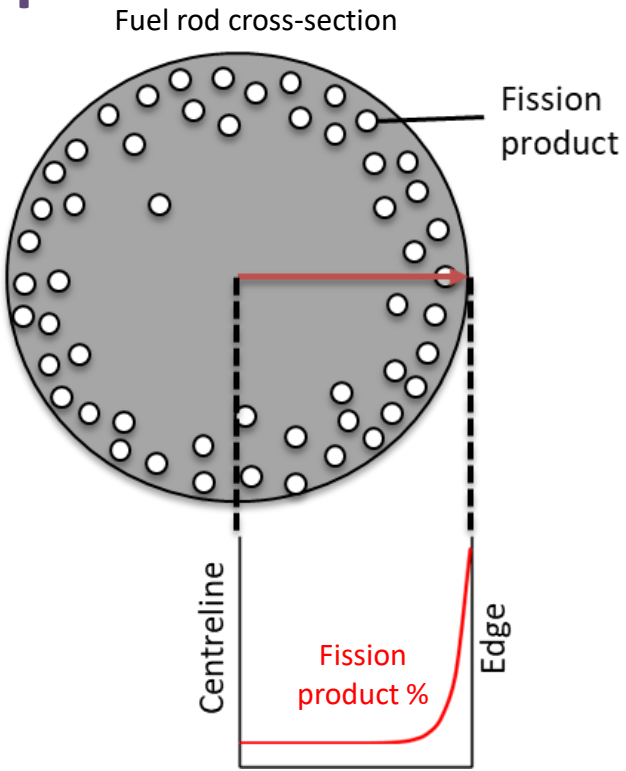
Image by: Emoscopes

MAGNOX fuel isn't ordinary uranium!

Reactor Core Burn Up



The fission product distribution (and porosity) is predominately near the fuel rod surface



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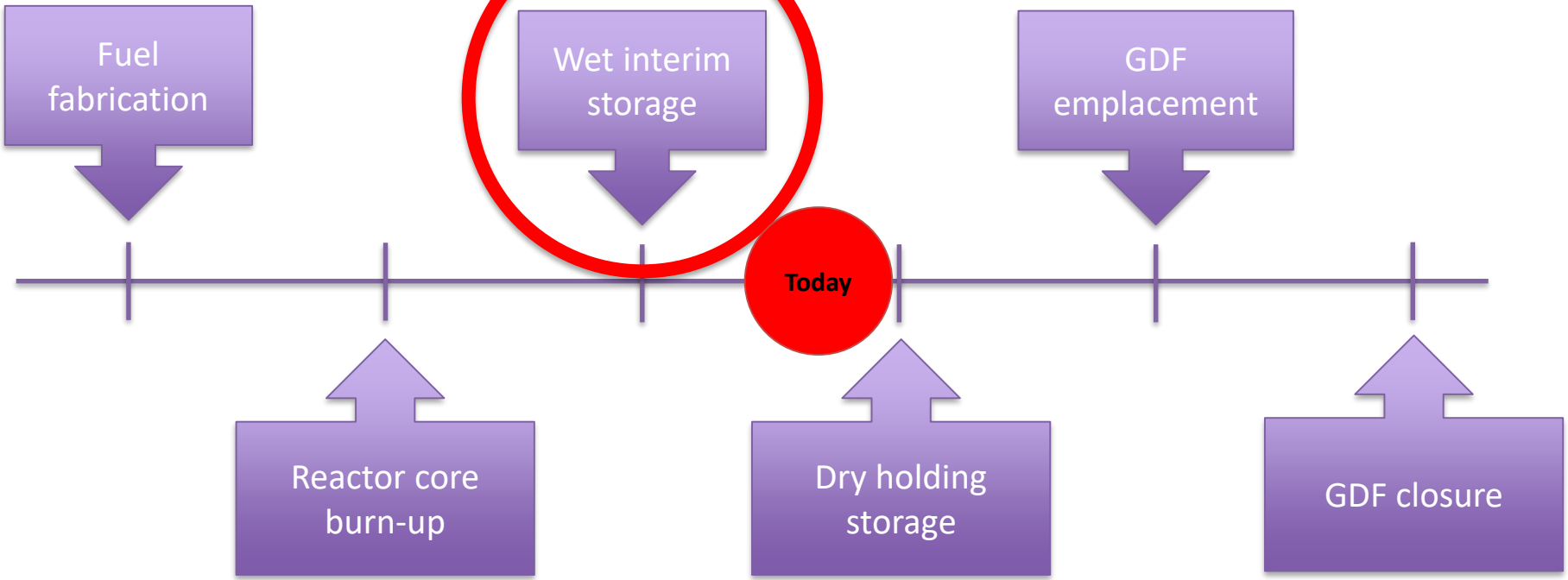


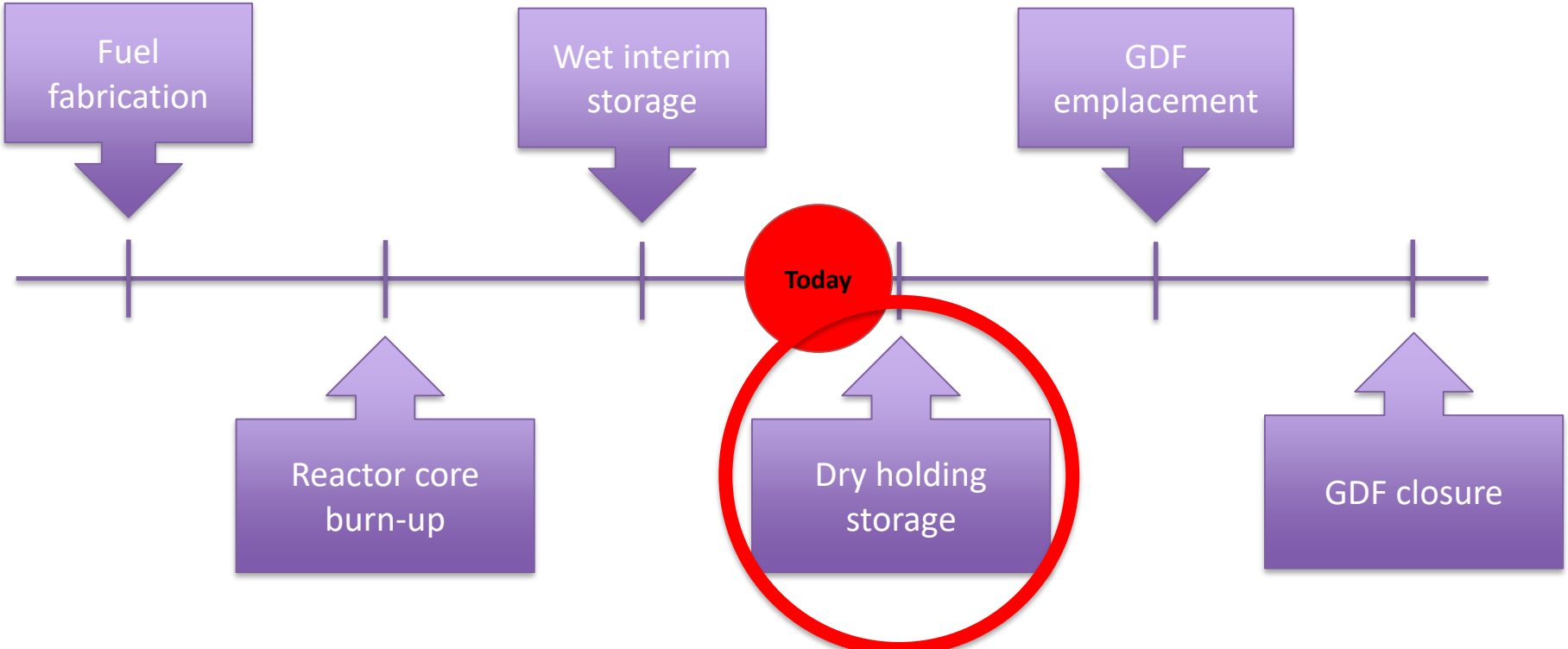
Wet interim storage – The FGMSP

- Built in 1950's
- Store, cool & recycle
- High pH of 11.5
- MAGNOX clad degradation
  → MAGNOX sludge
- Developed ecosystem

(Credit: Sellafield Ltd)

MAGNOX fuel isn't ordinary uranium!

It's a long story…

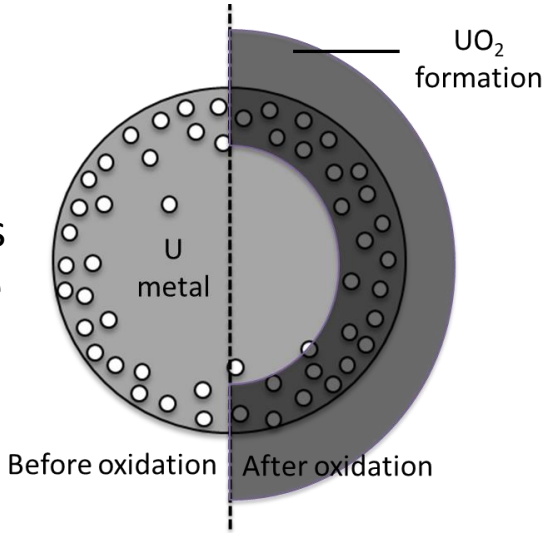


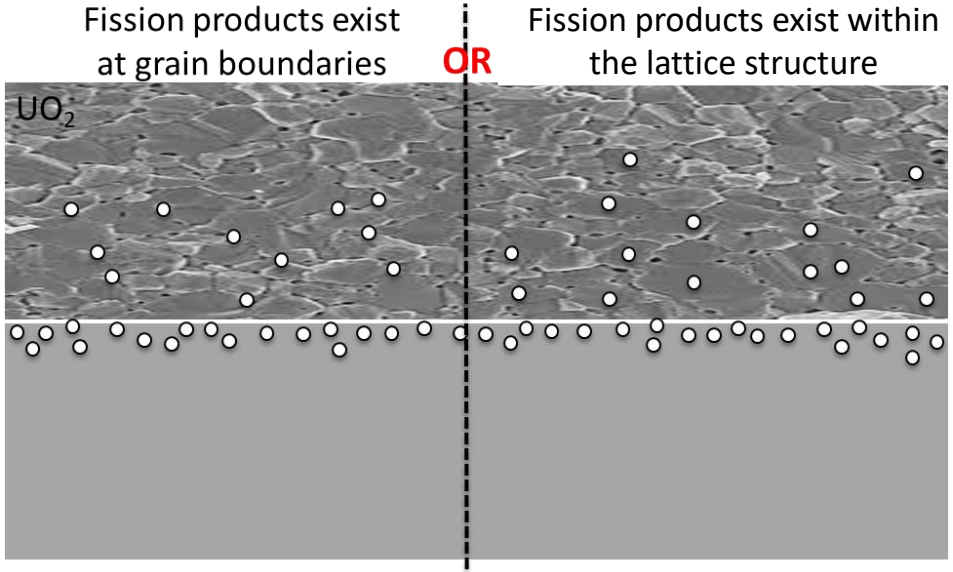
MAGNOX fuel isn't ordinary uranium!

Dry holding storage

How much has the fuel oxidised?

Where do the fission products go during oxide formation?





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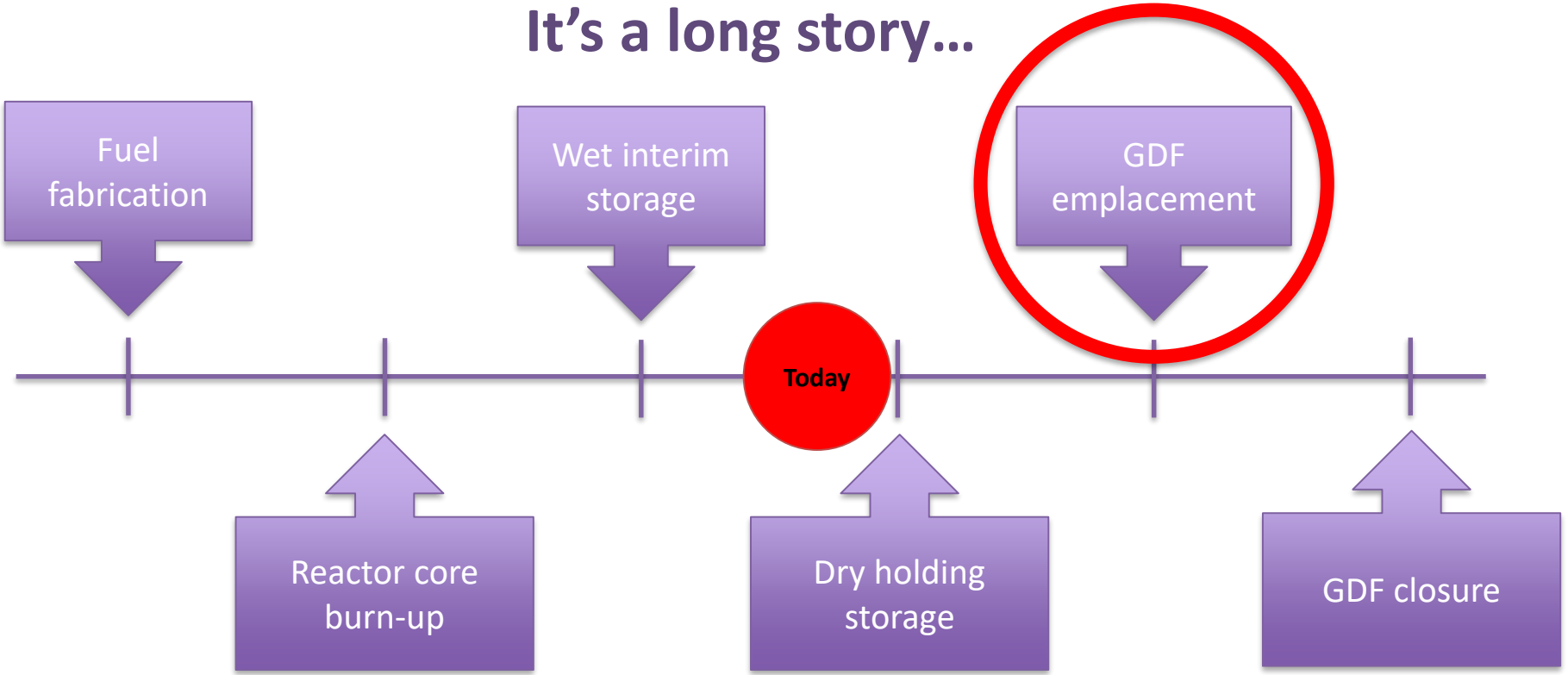
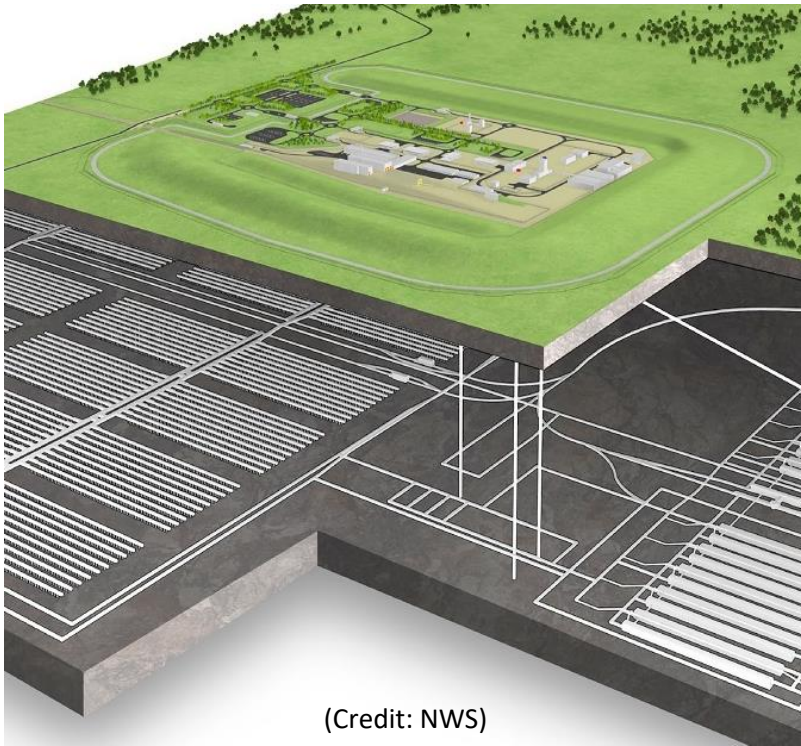


GDF Emplacement

- Transport
- Moisture within containers
- Packaging
- Relatively dry environment
- Oxic gaseous atmosphere



(Credit: NWS)

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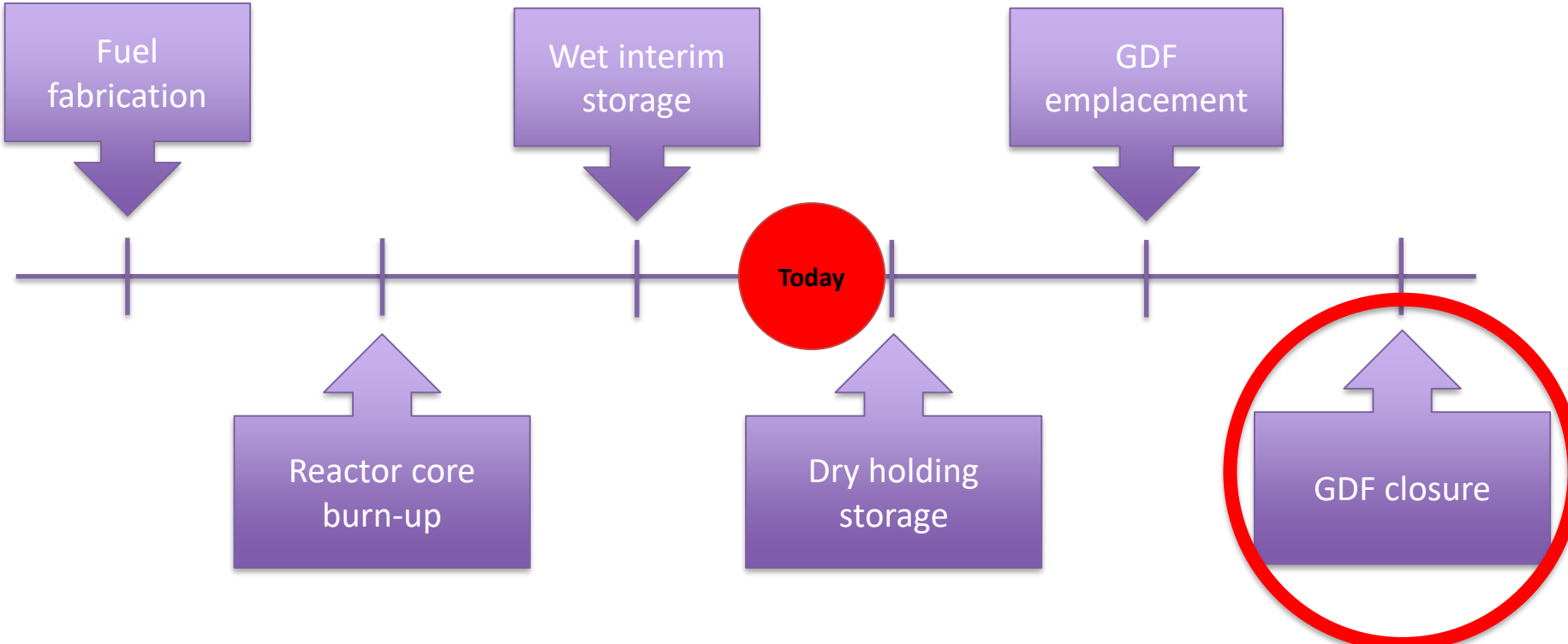


GDF Closure (LHGW Concept)

Conditions in the **HHGW** concept will be different to the **LLGW** concept.

For **HHGW:**

- Bentonite backfill
- High integrity, long-lived container
- GW re-saturation slower
- GW circum-neutral pH

- Groundwater (GW) re-saturation
  - Corrosive chloride & sulphate content (site rock-type-specific)
- GW reactions with host rock, grout, concrete and other GDF structures
  - High pH (~pH 13)
  - Carbonation of cement
    - Lowering of pH
    - Local increase to radionuclide solubility
- Residual ambient gas
  - Declining oxygen
  - And (later) hydrogen
- Radioactivity (albeit lower than in HHGW concept)
  - Radiolysis, He formation, photocatalysis?

The LHGW disposal concept is much cheaper than the HHGW concept

MAGNOX fuel isn't ordinary uranium!

Long after GDF Closure (LHGW Concept)

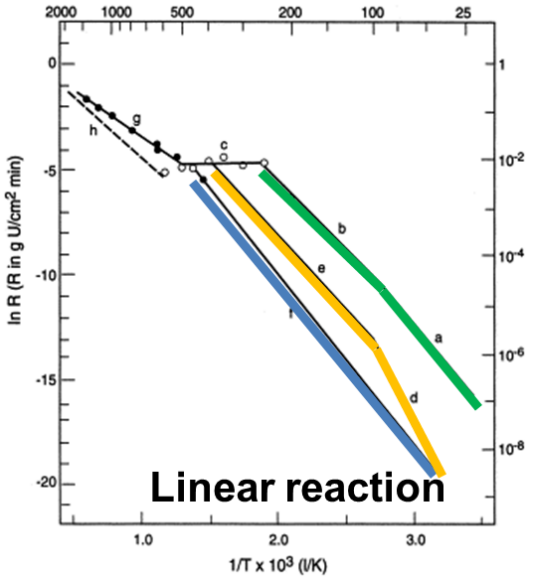
- Corrosive groundwater saturation
- Buffering capacity of cement used up
  - Lowering of pH
  - Increase in radionuclide solubility
- Gradually decreasing ambient temperature
- All oxygen consumed
  - Anoxic conditions
- Potential for hydrogen headspace
- Gradually declining radioactivity

$U + O_2 \rightarrow UO_2$

$U + H_2O \rightarrow UO_2 + H_2$

$U + H_2O + O_2 \rightarrow UO_2 + H_2O$

U corrosion fastest in wet anoxic conditions!



John M Haschke, **Corrosion of uranium in air and water vapor: consequences for environmental dispersal,** Journal of Alloys and Compounds, Volume 278, Issues 1–2, 1998, 149 - 160

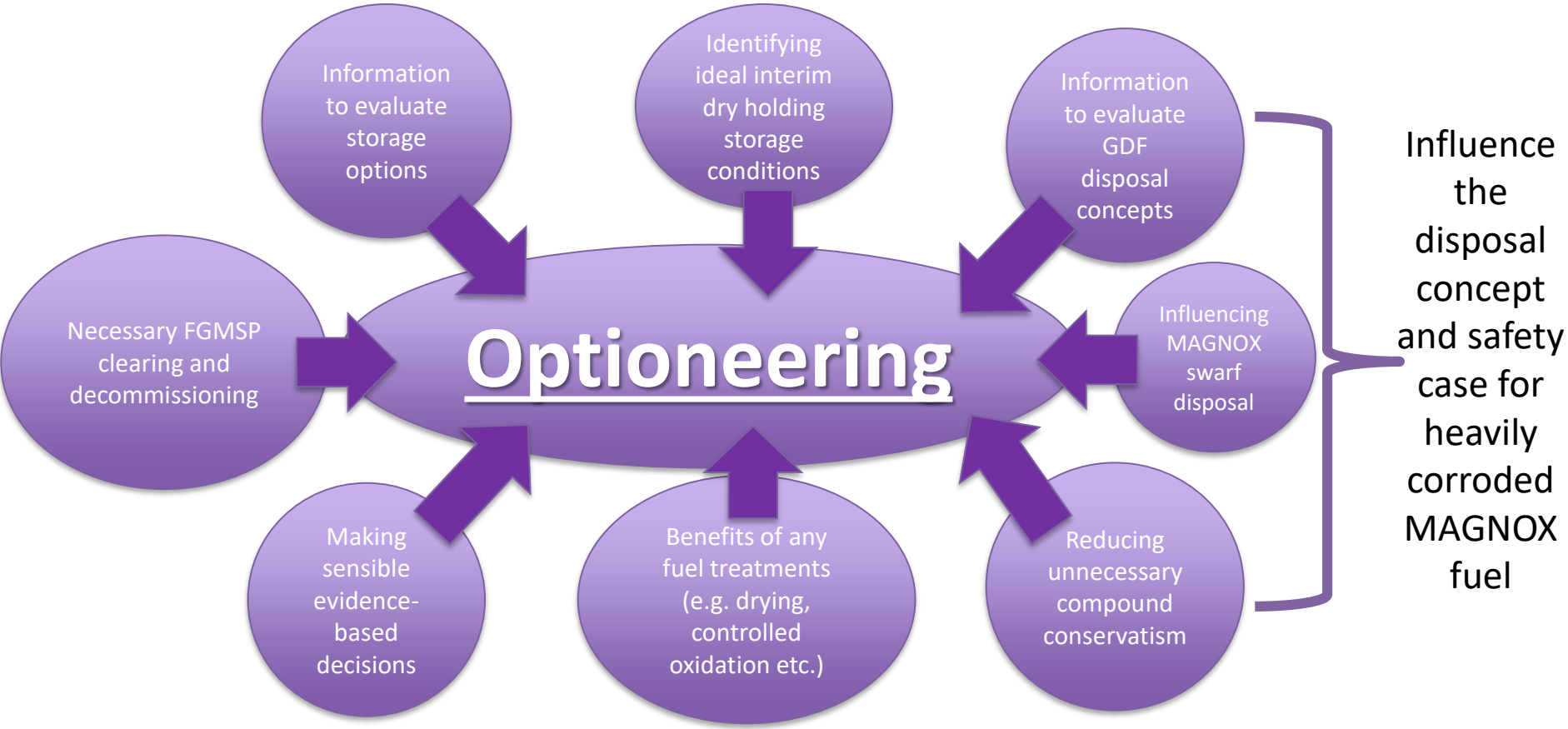
Objectives

- Understand the evolving GDF conditions and correlate these to how we expect metallic uranium to corrode
- Create MAGNOX ‘simfuel’ by adding in FP-simulant salts
- Understand partitioning of FPs from metal to oxide and their dissolution behaviour

Theoretically, we expect the solubility of UO_2 in GW to be **very** low

Could harmful FPs leach into the groundwater?

Application



Acknowledgements:
- Tom Scott
- Ross Springell
- Rosie Hibberd

Thank you!

But meanwhile…

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SOUTH WEST NUCLEAR HUB

My NWS secondment

Understanding each others' needs

Navigating restricted information

Knowing who to talk to

Understanding requirements & processes