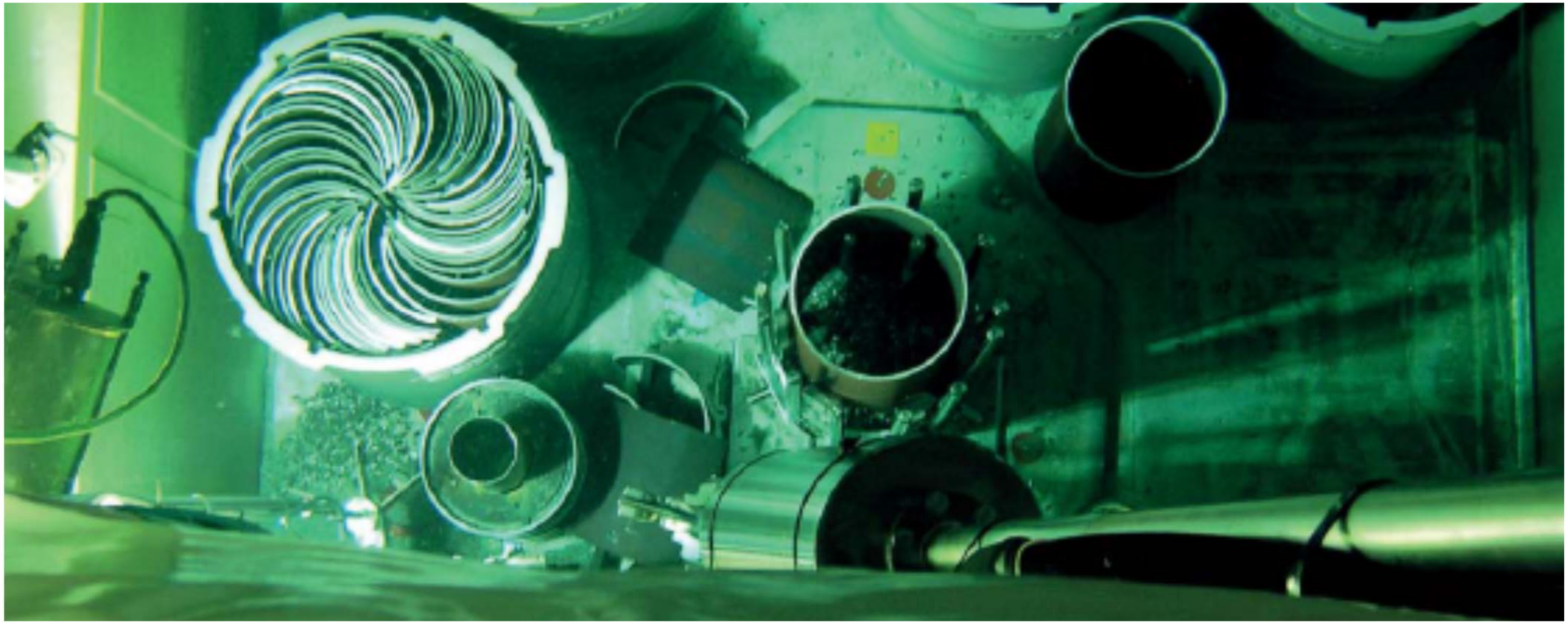


INTRODUCING A STRONG ALLIANCE FOR OPTIONEERING OF INPP REACTOR DISMANTLING

15 November 2018, Ignalina NPP

Mon Tindale, Mott MacDonald

Oliver Rabe, TÜV NORD

AGENDA

- TÜV-NORD Capability and References
- Mott Macdonald Capability and References
- Principles of Optioneering
- TÜV NORD / Mott MacDonald Team
- Information share: WAGR Case study
- Key Takeaways

- Questions?

TÜV-NORD and Mott MacDonald Nuclear Capability

TÜV NORD NUCLEAR CAPABILITY

- Established TSO in licensing and regulatory oversight with some 450 nuclear experts. Comprehensive safety assessment and inspection portfolio. One-stop shopping for all aspects of nuclear safety.
  - Core company TÜV NORD EnSys with a 50+ year record as an independent nuclear expert organization dealing with a wide range of nuclear facilities
  - Since 1980s special focus on waste management and disposal;
since early 1990s dealing with D&D of large power reactors
  - TÜV NORD Nuclear is an international network of entities with pronounced specific experience

TÜV NORD SELECTED REFERENCES

- Principal TSO in D&D of some 12 large power reactors (Map)
- Safety assessment in licensing and inspections in regulatory oversight over 10+ storage facilities for LILW + all German ISFSI; includes characterization and storage of graphite fuel from THTR and AVR
- QA for all German NPP waste packages destined for disposal
- TSO for all German final disposal projects
- Prominently positioned in all relevant expert panels on graphite reactor dismantling (GRAPA, CARBOWASTE, EPRI)

MOTT MACDONALD NUCLEAR CAPABILITY

- Established Tier 2 supplier to nuclear decommissioning programmes under NDA control in the UK.
  - Significant track record in decommissioning at Sellafield, Dounreay, Magnox and UK research reactor sites.
  - Over 400 nuclear SQEP staff actively engaged on projects at any time.
  - Recent winner of NDA award for working on Sellafield projects.
  - Substantial experience in graphite moderated, gas cooled reactors in the UK –Magnox & Windscale AGR prototype.

MOTT MACDONALD DECOMMISSIONING TRACK RECORD

- Mott Macdonald staff were integral to the design and implementation of the decommissioning of the Windscale Advanced Gas-Cooled Reactor (WAGR) on the Sellafield site in the UK
- Option assessment and mechanical design studies for movement of low-level waste containers at the UK's national radioactive waste disposal site.
- Option assessment and design services for two Magnox reactors undergoing decommissioning and long-term asset care requirements.
- Design studies undertaken for new LLW waste facilities at Dounreay, Scotland under direction of Scottish government.
- Design studies undertaken for the construction of the Bataapati radioactive waste repository (Hungary)

APPROACH TO OPTIONEERING – UK EXPERIENCE

- Identify key constraints in advance to bound options e.g. schedule or cost driven, immediate dismantling vs. deferred.
- Regulatory framework is a given – don't waste time debating exemptions to safety, security and environmental requirements.
- Concepts of ALARA and BAT – reasonableness is a good test for options.
- Radioactive waste needs to be a quality product – work backwards from your chosen endpoint of waste in disposal facilities of passively safe interim storage.
- Understand the waste acceptance criteria for each waste stream so that the options are technically validated.
- Options for each waste stream to be based upon best practice for waste assay, waste segregation & minimisation and final disposal options.
- Interim storage of higher activity wastes needs to be driven by final waste route to avoid double handling and increased dose to workers.

APPROACH TO OPTIONS APPRAISAL – LESSONS LEARNT (THE HARD WAY)

- Brainstorm all available options with given constraints but need to create a short list of those which meet key drivers e.g. if immediate dismantling is the chosen national policy then deferred decommissioning can be excluded from the short list.
- Scope out infeasible options before adding cost, effort or schedule data to accelerate the process.
- Bring key stakeholders into the decision making early. In the UK, the "Decide, Announce & Defend" approach has never succeeded in nuclear projects.
- Key stakeholders have had the power of veto in several cases e.g. Cumbria County Council for the UK higher activity waste repository and Scottish Government for low-level waste arisings from Dounreay.
- Mott MacDonald project staff have painful experience from such vetoes.

RADIOACTIVE WASTE MANAGEMENT PRINCIPLES

- The following principles are adapted from UK guidance for management of radioactive waste but would be relevant to the INPP options appraisal:
  - Radioactive waste should be subject to accurate characterisation and segregated to facilitate subsequent safe and effective management.
  - Radioactive waste should be stored in accordance with good engineering practice and in a passively safe condition.
  - Radiological hazards should be reduced systemically and progressively.
  - The waste should be processed into a passively safe state as soon as is reasonably practicable.
  - Information that might be needed for the current now and future safe management of radioactive waste should be recorded and preserved.

MOTT MACDONALD LEAD TEAM

- Mark Liddiard –Mott MacDonald's global practice leader for nuclear;
- 20 years+ in the nuclear industry covering decommissioning and radioactive waste management;
- Technical specialism in environmental assessment and permitting.

- Mon Tindale — Mott MacDonald Nuclear project Director and Reactor Decommissioning Consultant
- 30 years + in the nuclear industry – full project lifecycle for high hazard projects
- Engineering Manager for the WAGR project
- Mott MacDonald Nuclear Projects Director and Consultant

.

- Phil Gerrard — Technical Principal, Project Management
- 20 years + in the nuclear industry – full project lifecycle
- Project Manager for the WAGR project during Lower Structures and Pressure Vessel Dismantling

.

TÜV NORD LEAD TEAM

- Jörg Aign – TÜV NORD cluster manager International Nuclear Projects;
- Former Director DD&R EMEA (Europe Middle East & Africa) Operation at Westinghouse Electric Company
- Previously Nuclear Regulator in Germany on Waste Management

- Anthony Wickham - Leader of IAEA GRAPA Team
- Characterization of Windscale Pile I Graphite in Core
- Peer Review of Wigner Energy Data for BGRR Dismantling
- Visiting Professor at the University of Manchester (Nuclear Graphite Research Group)

- David Bradbury — Work Package Leader in EU CARBOWASTE Project
- EPRI Report on "Graphite Decommissioning: Options for Graphite Treatment, Recycling or Disposal including a discussion of Safety-Related issues."
- Over 50 publications on Igraphite

Reference Case Study : WAGR Core Dismantling

REFERENCE CASE STUDY: PROJECT WAGR

Windscale Advanced Gas Cooled Reactor (WAGR)

Prototype design or the UK AGR fleet; located at Windscale (Cumbria) and used as the test bed for performance optimisation.

Operations: 1963 to 1981:
Graphite moderated (Pile Grade A)

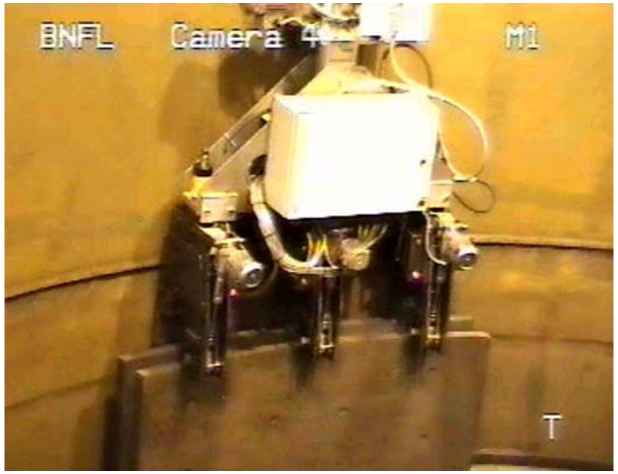
- CO_2 coolant
- 100 MW Thermal / 33MW Electrical
- Core ~ 6m high / 6m diameter

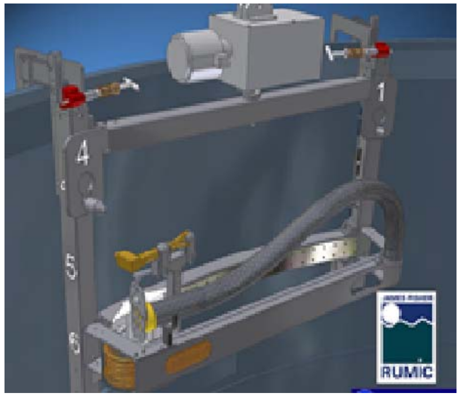
Current status (2018):
All internals deconstructed to concrete bioshield

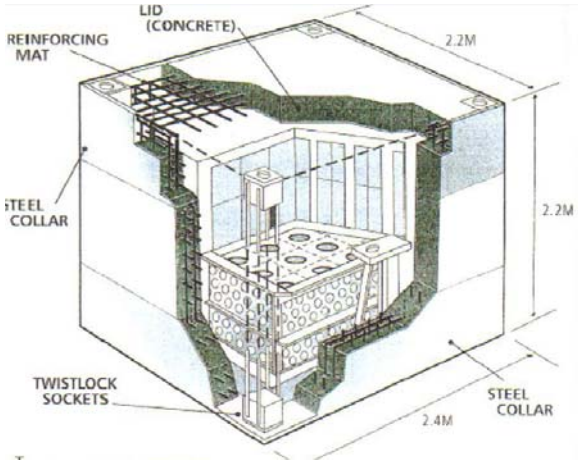
To date, the only UK deconstructed power reactor

WAGR RECTOR DECONSTRUCTION







MOTT MACDONALD TÜV NORD

GENERAL PROJECT - OVERVIEW

- WAGR - UK demonstration project for the ‘immediate dismantling’ for the UK fleet of GENII and GENII graphite moderated reactors
- The project showed that ‘immediate dismantling’ and safe storage of wastes for disposal can be completed:
  - as a commercial venture
  - using the available technologies at that time (using the ‘D’ of R&D and not being dependent on the ‘R’)
- The Project has been used to underpin the safety case for the ‘SAFESTOR’ strategy for GENI Magnox reactors
  - If you can take it apart at any time, why not wait for Co60 to decay….?
- Wastes were assayed and conditioned for storage – LSAII IP2 self-shielded package (‘the WAGR box’)
- Storage of waste is ‘temporary’ until such a point as a final disposal route is in place
  - currently ~ 2045 by UK strategy

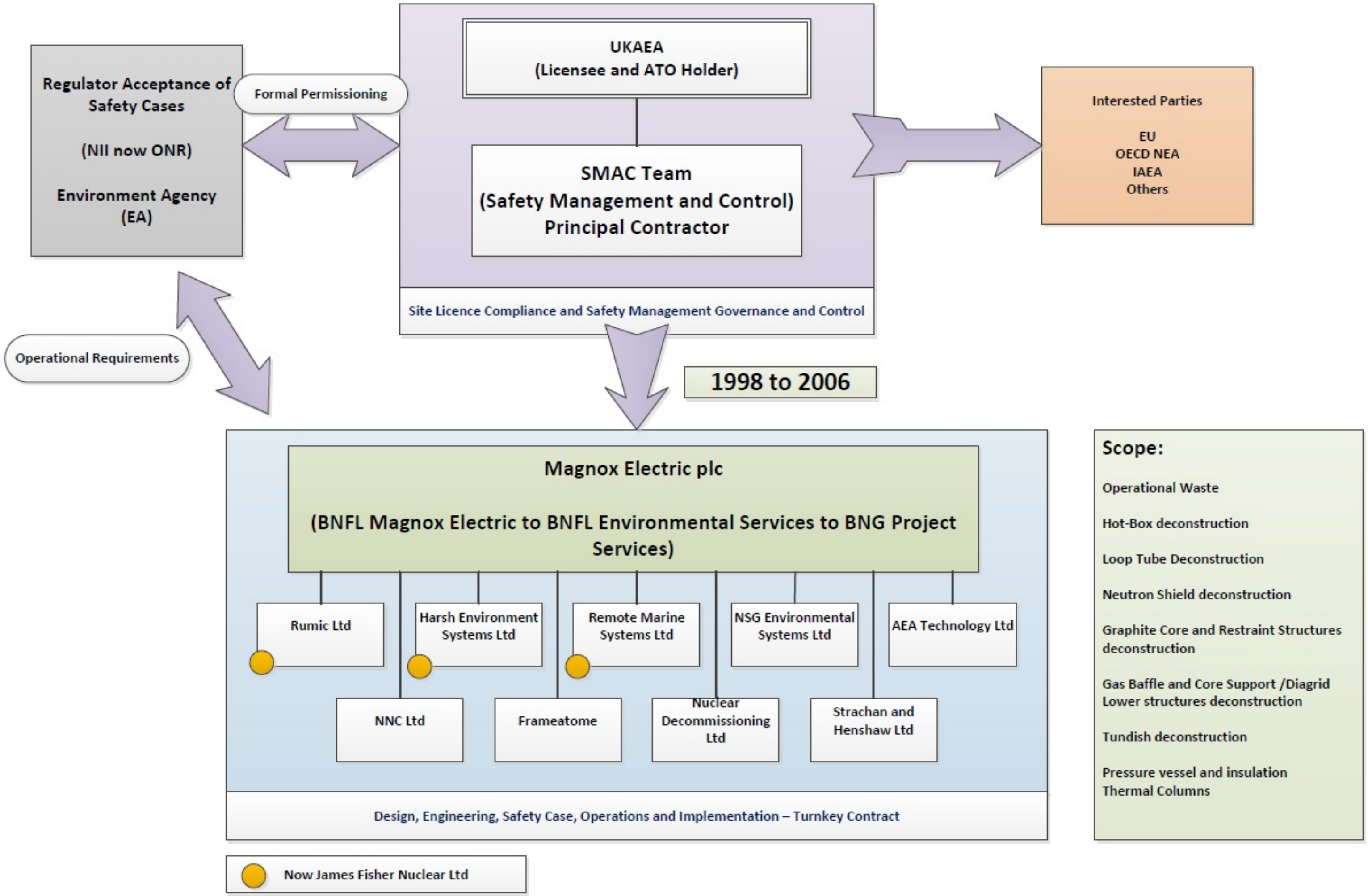
PROJECT WAGR: DEVELOPMENT HISTORY

- OECD NEA pilot demonstration project – EU funding provided
  - Test bed for tools and techniques
- Late 1970s: Decommissioning planning started
- 1981: WAGR Shut Down – then defueled / deplanted
- 1990’s: change of focus:
  - less research (!) and more actual deconstruction (!)
  - 1990 to 1996: development of RDM,
  - removal of WAGR Pile Cap, Heat exchangers and construction of the Remote Dismantling Machine (RDM)
- 1996: Appointment of Magnox Electric Ltd
  - for Operations and Maintenance
  - 1998: Appointment of Magnox Electric Ltd for design, engineering, safety case and substantiation, testing, implementation, operations, waste processing and clean up
- 2006 – Contract closed

WAGR DECONSTRUCTION DELIVERY ARRANGEMENTS

- WAGR is – to date – a ~40 year project
- Multiple companies have been involved over this time
- Project has changed formal Licensee 2 (3!) times
  - UKAEA, Sellafield, NDA
- Most of the supplier companies involved 10 to 20 years ago have
  - Broken up / closed down / ceased trading
  - Been bought / changed hands / changed business
  - Consolidated into other ventures
- No company holds exclusive WAGR 'Intellectual property rights' – IPR
  - It's a EU funded demonstration project - Information is in the public domain
- The people and the experience gained are still involved in the industry
  - Lessons learned and techniques can still be applied

WAGR DECONSTRUCTION DELIVERY ARRANGEMENTS

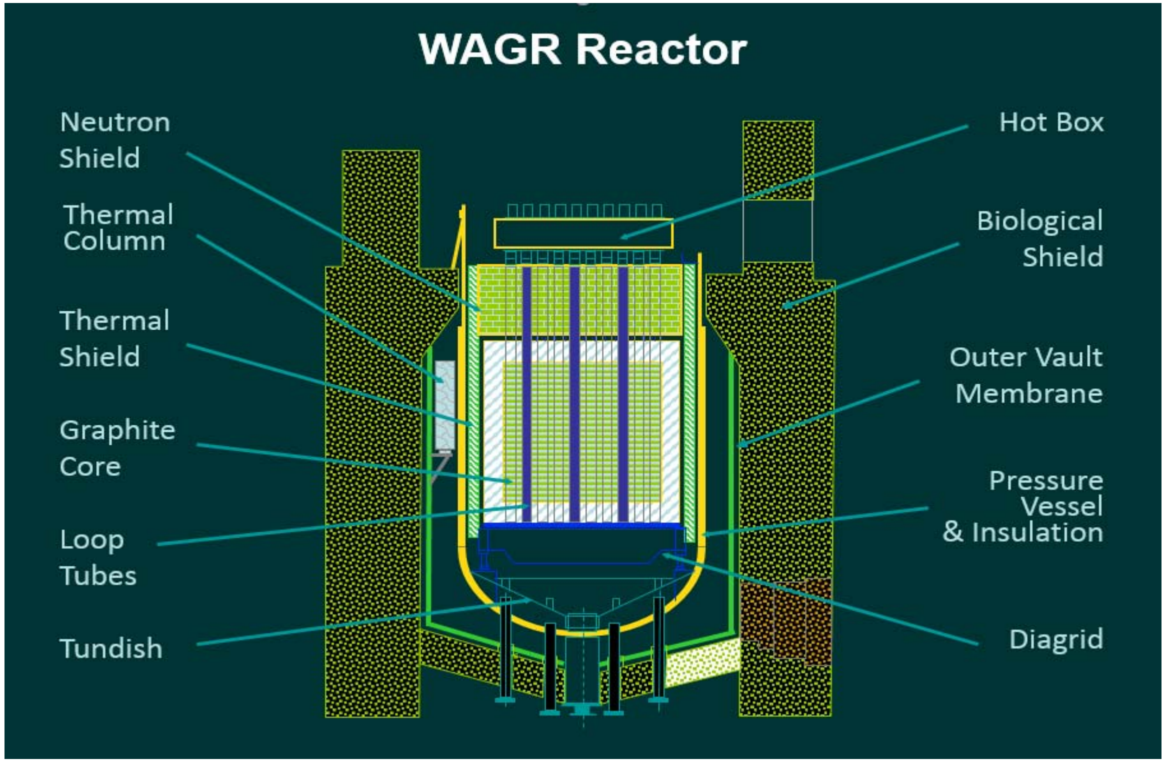


MOTT MACDONALD TÜV NORD

WAGR DECONSTRUCTION DELIVERY ARRANGEMENTS

- Magnox Electric plc was accountable for ~ 10 years for the deconstruction of the reactor itself
- High level strategy had been set by UKAEA and formed the Decommissioning Safety Case (DSC)
  - Use of a remote dismantling machine (RMD) on the Pile Cap and engineered waste route via heat exchangers
  - Manual methods so far as is reasonably practicable and remote methods where not
  - Fingerprinting and activation modelling – 'West Codes' and development of the LSAII IP2 package
- Magnox Electric plc had accountability for
  - The development of tools and methods for the deconstruction of the bioshield internals
  - Development, justification and submission of ALARP safety cases for the works
  - All operations including waste processing

WAGR DECONSTRUCTION CAMPAIGNS



Project was structured into 10 campaigns

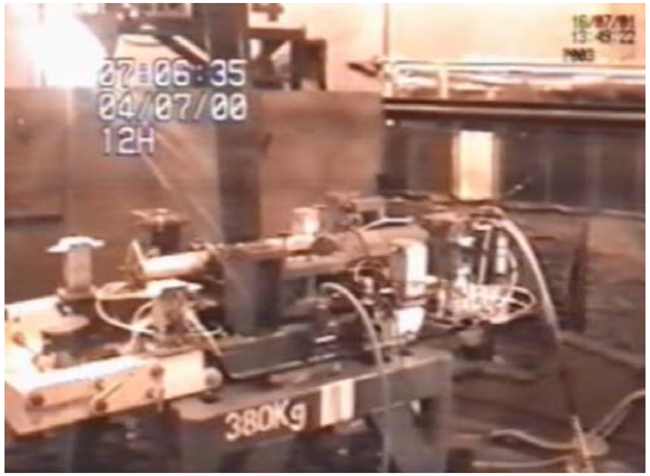
Each campaign:

- Had similar construction and materials
- Had broadly similar levels of neutron activation

SOME KEY WAGR CAMPAIGNS –SIMILAR TO INPP

- LOOP TUBES: experimental channels sued to develop fuel configurations (3 months)
  - Fully remote / high dose - 30% of the total reactor radiological inventory – high Co60 with wastes up to 250 Sv/hr at contact
- NEUTRON SHIELD: designed to limit gamma and neutron radiation to the pile cap whilst allowing fuel passage from in / out of the core (8 months)
  - Complex feature – [73 tonnes of graphite, 35 tonnes of steelwork]
  - Bespoke graphite bricks, borated steel plates, instrumentation
  - Marked the change from part semi-remote (man access) means to fully remote
- GRAPHITE CORE AND RESTRAINT STRUCTURES (8 months)
  - Fully remote - 253 channels [210 tonnes of graphite, 25 tonnes of steelwork]
  - 1976 PGA moderator bricks, 1104 reflector bricks and 1764 graphite spigots, 48 graphite loop bricks in 8 layers, held all together with tensioned steel restraints
  - Thermocouples, flux scanning tubes, steel spigots, 96 restraints band sections, 337 cores support bearings
- LOWER STRCUTURES, DIAGRID AND PRESSURE VESSEL
  - Fully remote, steel structure

WAGR CAMPAIGN IMAGES



WAGR TOOLING TECHNIQUES – KEY OBSERVATIONS 1

- Remote Dismantling Machine (RDM) could not do the job (!) – great on paper but a poor tool for deconstruction
  - low load capacity, manipulator inadequate, poor access, mast height required changing too frequently, mast sections not aligned to features
- The auxiliary 3 tonne maintenance and basket transfer hoist became the primary tool for deconstruction
  - Low technology (didn't break down much)
  - Little capability for complex control in the deployed tooling – 'KISS'
- RDM manipulator use changed –
  - Used for low load movements and awkward access cuts (such as thermocouples)
  - Changing of 'tooling umbilical's' – where process gases needed to be connected to a tool

WAGR TECHNIQUES – KEY OBSERVATIONS 2

- Waste route did not allow ‘sorting’ of waste
  - Every item had be deconstructed to a formal and fixed plan
  - Wastes had to be carefully positioned within ‘box furniture’ to ensure that the IP2 package complied with transport regs (2mSv@contact, 0.1mSv at 2m, 10mSv@contact on loss of shielding)
- Regulatory
  - Safety is paramount !!!
  - Keeping radiological doses down to meet regulatory requirements DOES NOT mean ‘zero dose’
  - Make strong ‘practicable arguments’
  - Time is also money (‘delays due to hotel costs’) - resources have to be paid
- Critical Path
  - Known your critical path : design the tools that will be needed before they are actually needed!

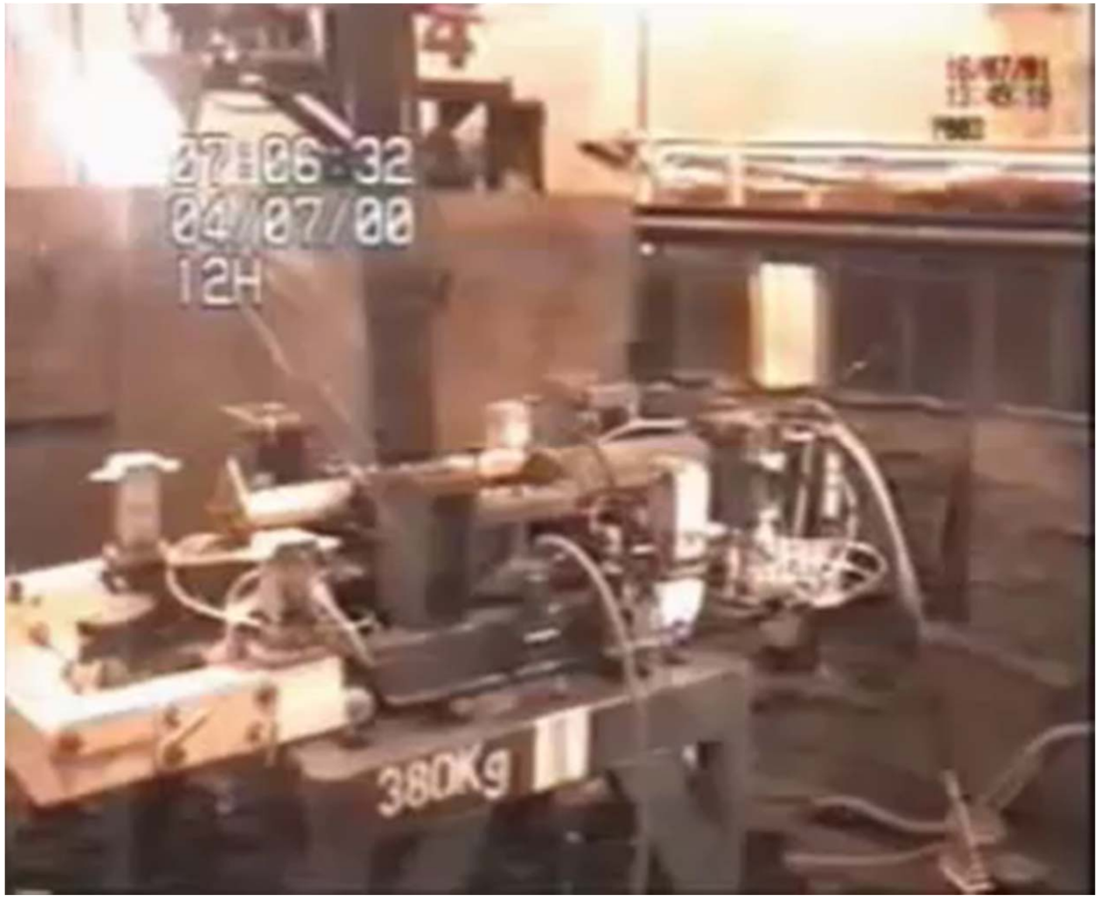
MOTT MACDONALD TÜV NORD

TOOLING AND METHODS – SOME LESSONS

- Every campaign was ‘driven’ by a detailed work instruction
  - Every cut, every action, every waste form and every basket. Plan, plan and plan. - GET IT RIGHT FIRST TIME
- Simple tooling (‘KISS’)
  - Didn’t break down – no maintenance and cheap to replace
  - Designed to do <u>one job well</u> – <u>not several jobs badly</u> [Mantra: one tool, one job]
  - Self locating where possible – <u>do not rely</u> on ‘things being as the drawing’
- Waste consigned
  - Close to source – minimise handling operations (time) and packaged in sequence in accordance with the assay and transport requirements
- Methods
  - Don’t plan in detail too far ahead though – as the reality will be different
  - <u>Always</u> have two different ways of doing the same job

WAGR Tooling Examples

PRE-CORE DISMANTLING – LOOP TUBES (2000)



Highly activated components – 6 off co-axial fuel test channels.

Filled with grout to give compression strength / rigidity.

Loop tube shear installed around loop in sub-assemblies. Hydraulic jacking of the loop tube upwards and then shearing (750te).

One loop per package.

GRAPHITE CORE DECONSTRUCTION (1) – REF 2003

Core Brick removal using mechanical ball grab

Box furniture

Spigot ring puller (in box furniture)

Removal of steel centre brick spigot using manipulator

Arranging bricks in the basket

Tripping of high activated spigots in the centre basket export

MOTT MACDONALD

TÜV NORD

CORE RESTRAINTS BAND CUTTING (2) – REF 2003

Fitment of restraint features and cutting guide

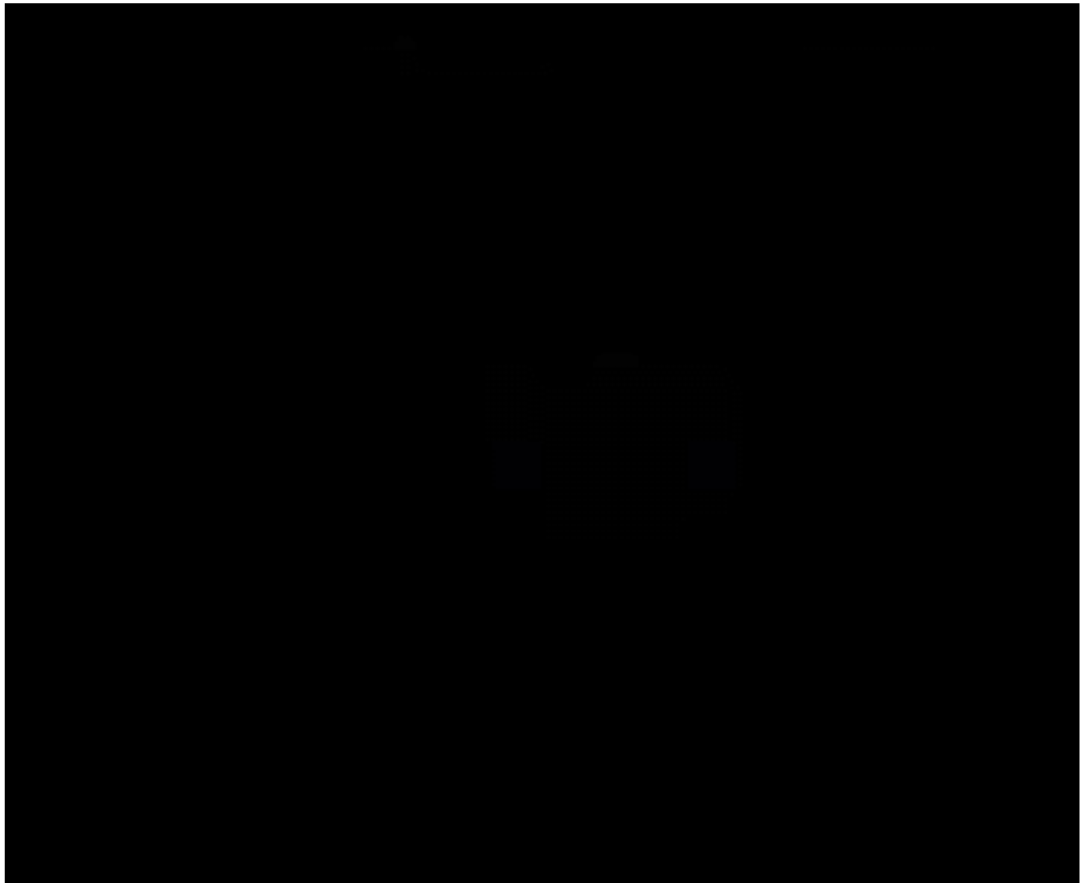
Fitment of restraint band retainer (for section removal)

Deployment of restraints band cutter

Cutting of restraint band (through the reflector graphite)

Overview of core operations

OUTER NEUTRON SHIELD BRICKS (3) - 2002



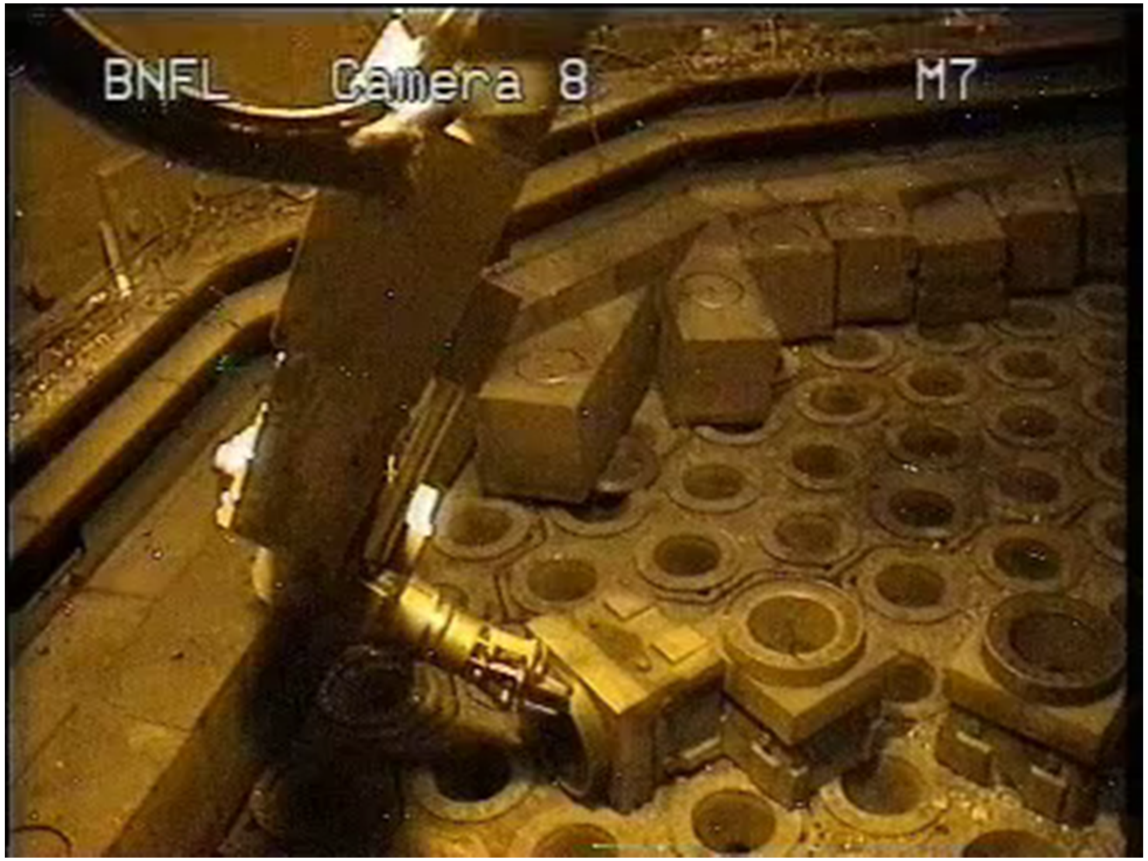
Neutron Shield bricks

Difficult to pick up with a vacuum grab – due to shape, set down area and debris

Use of bespoke tooling – the ‘drilly tappy’ tool – a lost drill and tap machine (multi-point) that allowed the block to be lifted free once seated

Placement in furniture

GRAPHITE CORE LAYER 1A – REMOVAL (4) - 2003



Lowest layer of core interfaces with the core support bearing top races – high dose!

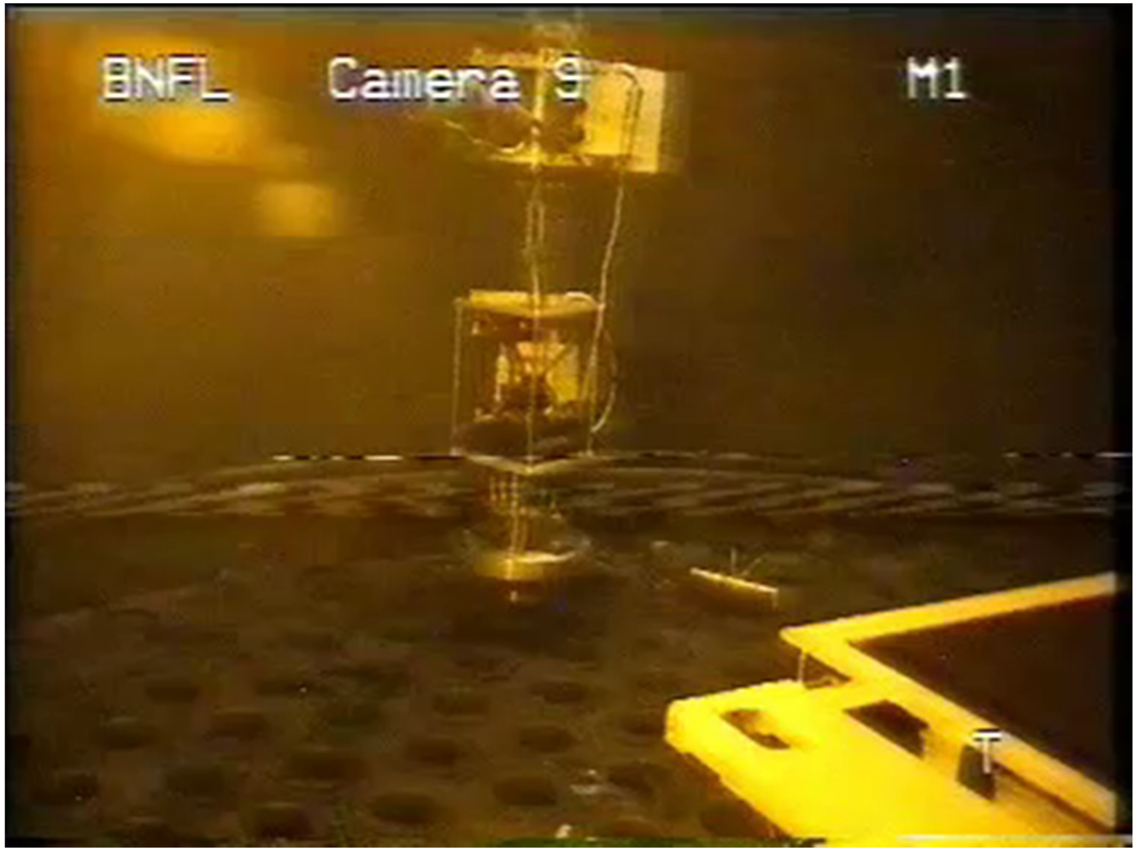
Use of manipulator to ‘turn over’ bricks

Use of ball grab to pick and place bricks into the furniture

Note the debris of the gas seal and core support plate – cleared with a ‘brush’

MOTT MACDONALD TÜV NORD

CORE BEARING RACE REMOVAL (5) - 2003



Core supported by thrust bearing to allow movement due to thermal transients

Bearings are exotic material and highly activated.

Had to be placed in the centre of a WAGR box to mange dose rates and to allow access to arrestor mechanism housings.

Removed from the core support plates by jacking against the arrestor mechanism housings.

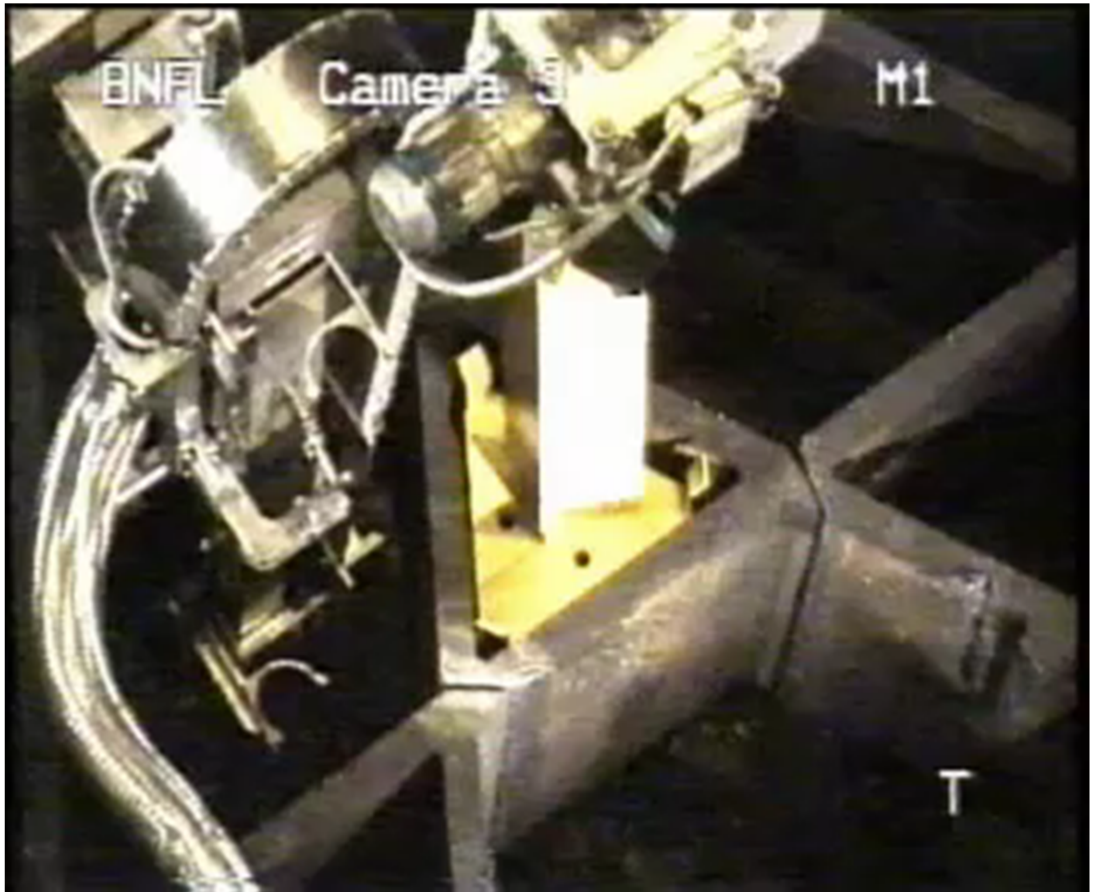
CORE SUPPORT PLATE REMOVAL (6) - 2003

Steel core support plates – highly activated. Removed after all bearings, arrestor mechanisms and residual op waste in the housings dealt with

Use of a simple magnetic grab (4 point) to lift free and place in furniture

Video shows the export route through the sentencing cell and the 3tonnes hoist– via old heat exchanger bioshield

SUPPORT STRUCTURES –OXY PROPANE (7) - 2004



Lower steel structures supporting the core. Deep section of 75mm plate.

Size reduced using oxy-propane torch with a motorised tool running a fixed, pre-set path. Low complexity of control – pre-set parameters proved by trials.

Deployed early Wi-fi cameras (2003)

Manipulator used to connect the process gas umbilical – gases fed through a separate wall penetration.

MOTT MACDONALD TÜV NORD

WAGR – 'KISS'

Layer 1 Gas seal debris – needed to be cleared prior to deploying a plasma cutting head to section

Can't get simpler than a 'brush on a stick'

Gas seal had to be 'cleaned' to enable accurate plasma cutting (sensitive to debris presence)

All debris eventually vacuumed.

Takeaway Thoughts

KEY TAKEAWAYS – COST / SCHEDULE / QUALITY

- Reactors decommissioning projects are often unique (one-off design)
  - High uncertainty leads to low confidence interval on cost and schedule out-turn
  - Schedule management is well served by ensuring redundancy in methods (two tools)
- Triangle of Cost / Schedule / Safety [the Quality or Performance]
  - Safety is effectivity fixed [radiological and environmental limits]
  - Then the two variables are cost and schedule
    - Short schedule means high cost --- low cost means long schedule
    - An optimum must be reached
  - Letting "turnkey" T&M Contracts does not always achieve workable solutions.
- Stakeholders are most important [political / regulatory]
  - If stakeholders are not 'on board' – then you don't have a project

KEY TAKEAWAYS – TOOLING

- Keep it simple (KISS)
  - High tech solutions involving complex control have very low availability
  - Spend most time not working or broken
- If reactor was built bottom up
  - Then the most efficient and safe way of deconstruction is top down!
  - Reverse the construction and don't argue with gravity
- Waste segregation and buffer storage
  - Can be time consuming and expensive due to multiple handing
  - Model, then plan it right in the deconstruction sequence – 'right first time'
- Test tools in representative environments
  - No tool ever works 'out of the box' – use mock ups to develop
  - Reactor features are often <u>not</u> as depicted in drawings
    - So engineer 'flexibility' into the tool

KEY TAKEAWAYS – STRATEGY AND OPTIONS

- ‘Big solutions’ fail at the detail level
  - The RDM was a good idea – but could not deploy the tooling required in the right place at the right time
  - Design machine to align to the reactor features
  - Design machine to fully integrate with waste export routes
  - A single waste route enforces a bottleneck on the critical path
- Don’t plan too far ahead at a high level of detail
  - One very large safety case covering all details will waste time – the details will just be wrong
  - Develop detailed safety cases, methods and tooling at the campaign level from an overarching DSC – step by step approach
- Test (use a TRL methodology if necessary)
  - High reliability reduces schedule duration AND operator dose uptake
  - Use manual methods where most dose efficient

KEY TAKEAWAYS – OPTIONEERING PROCESS

- Wastes must be retrieved and packaged
  - To meet all safety and environmental requirements

- If the waste from the reactor can’t be retrieved and packaged,
  - Then there isn’t a project to do
  - Start planning again

- The development of all methods to deconstruction the reactor must work backwards from the waste product spec
  - Wastes must be removed in a manner that enables the waste product spec to be met

THANK YOU FOR YOUR ATTENTION