Optimisation in the Context of Geological Disposal of Radioactive Waste

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Outline – Key Messages

- Defining terms - need for clarity
- Approaches to design development exist
- Experience with optimisation of repository design components
- Areas for further work and possible collaboration

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Optimisation

- Optimisation is an internationally recognised concept, promulgated and defined by the International Commission on Radiological Protection (ICRP) in ICRP Publication 101:
  - *The source-related process to keep the magnitude of individual doses, the number of people exposed, and the likelihood of potential exposure as low as reasonably achievable below the appropriate dose constraints, with economic and social factors being taken into account*
- The process is forward-looking and iterative, and aims to reduce radiological exposures in the given circumstances
- Takes into account technical and socio-economic issues, and requires qualitative and quantitative judgements
- Considers individual equity, safety culture, and stakeholder involvement
- Still, a narrower definition compared to its more general sense of a process of finding the best decision, result or way forward

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Translation of ICRP Recommendations into a national programme: UK example

- In balancing relevant considerations, the reduction of exposures "…*should not be given a weight out of proportion to other considerations….the best way forward is not necessarily the one that offers the lowest radiological risk*."
- Relevant considerations include:
  - The number of people exposed and other environmental targets that may be exposed to radiological risk
  - The likelihood they could be exposed to radiation
  - The magnitude and distribution in time and space of radiation doses
  - Nuclear security and safeguards requirements
  - Issues similar to those above, but relating to non-radiological hazards
  - Economic, societal and environmental factors
  - Uncertainties in any of the above
- Acknowledges the breadth of considerations

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Design process and “BAT”

- The principle of Best Available Techniques (BAT) provides for consideration of sub-system performance
- Standard part of the design process (whether called BAT or something else)
  - multi-attribute assessments to identify preferred design solutions
- Many design decisions not based on consideration of radiological exposure
- Ability to “optimise” will advance as move through implementation process
  - generic studies, site-specific studies, construction approval, operation approval

Differences with optimisation

- Similar evaluation criteria, but greater scope to tailor to issue under consideration, e.g. engineering feasibility… and criteria weighting may differ
- Swedish example: “General Advice” from regulators (SSM)
  - **where considerable uncertainty is attached to calculated risks** - for instance in analyses of the repository a long time after closure, or analyses made at an early stage of the development work - **greater weight should be placed on BAT**
  - in the event of conflict between application of optimisation and BAT, **priority should be given to BAT**

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Optimisation / BAT – needs of advanced programmes

- Select most appropriate design for repository components
- Design: Focus on effective and efficient engineering
  - …not ever more complex and expensive design solutions
  - relationship to concept of “robustness”?
- Safety: Parallel optimisation during operations and following closure

Endpoints to optimisation / BAT - how much is “enough”?

- Even when a decision has (apparently) been made, it continues to represent an uncertainty until implemented
  - new information could come to light
  - technologies could develop
- Once implemented, forms part of the framework within which future decisions must be made = a constraint
- Example: some wastes are already packaged for disposal

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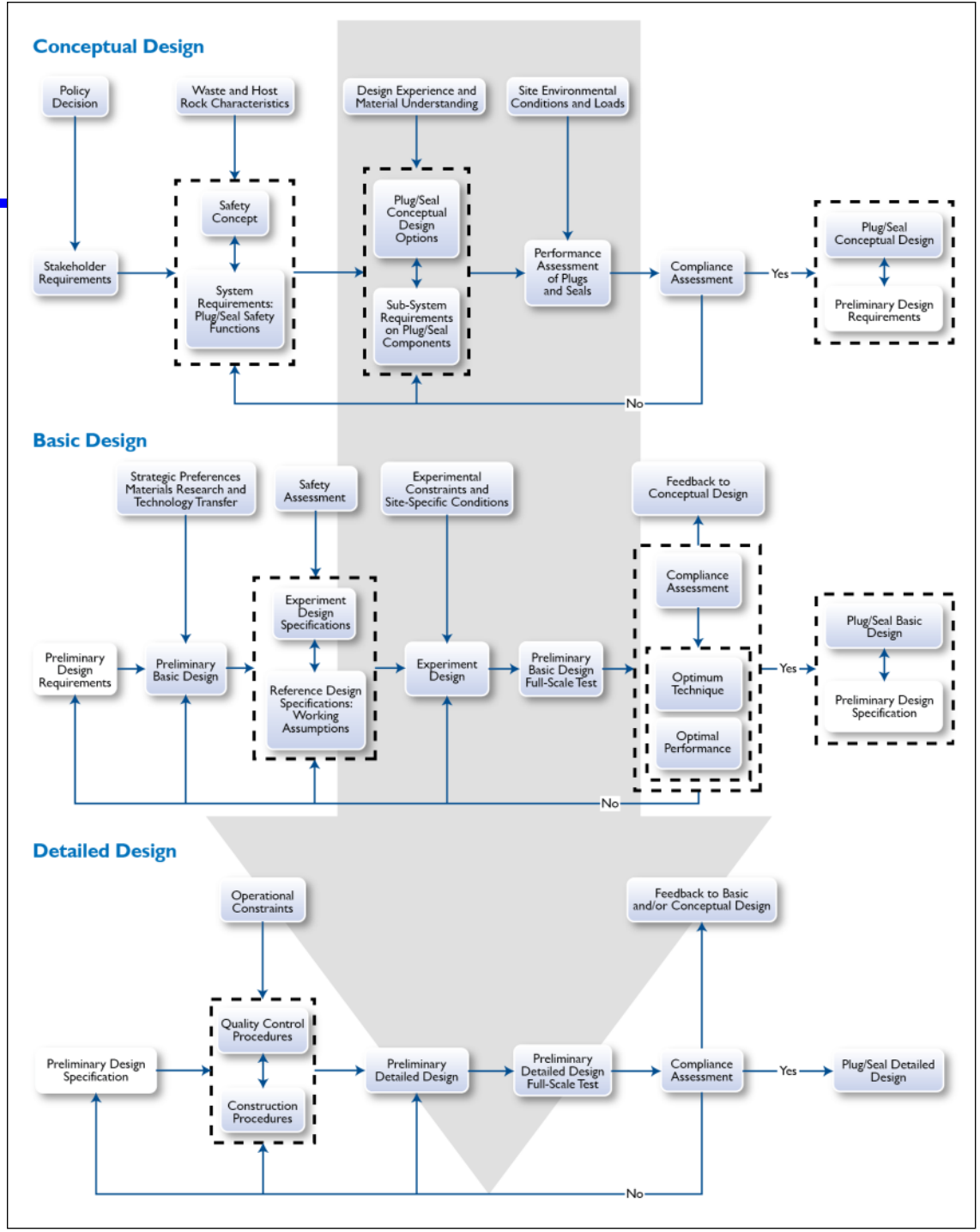
Example 1:

EC DOPAS Design Basis Workflow



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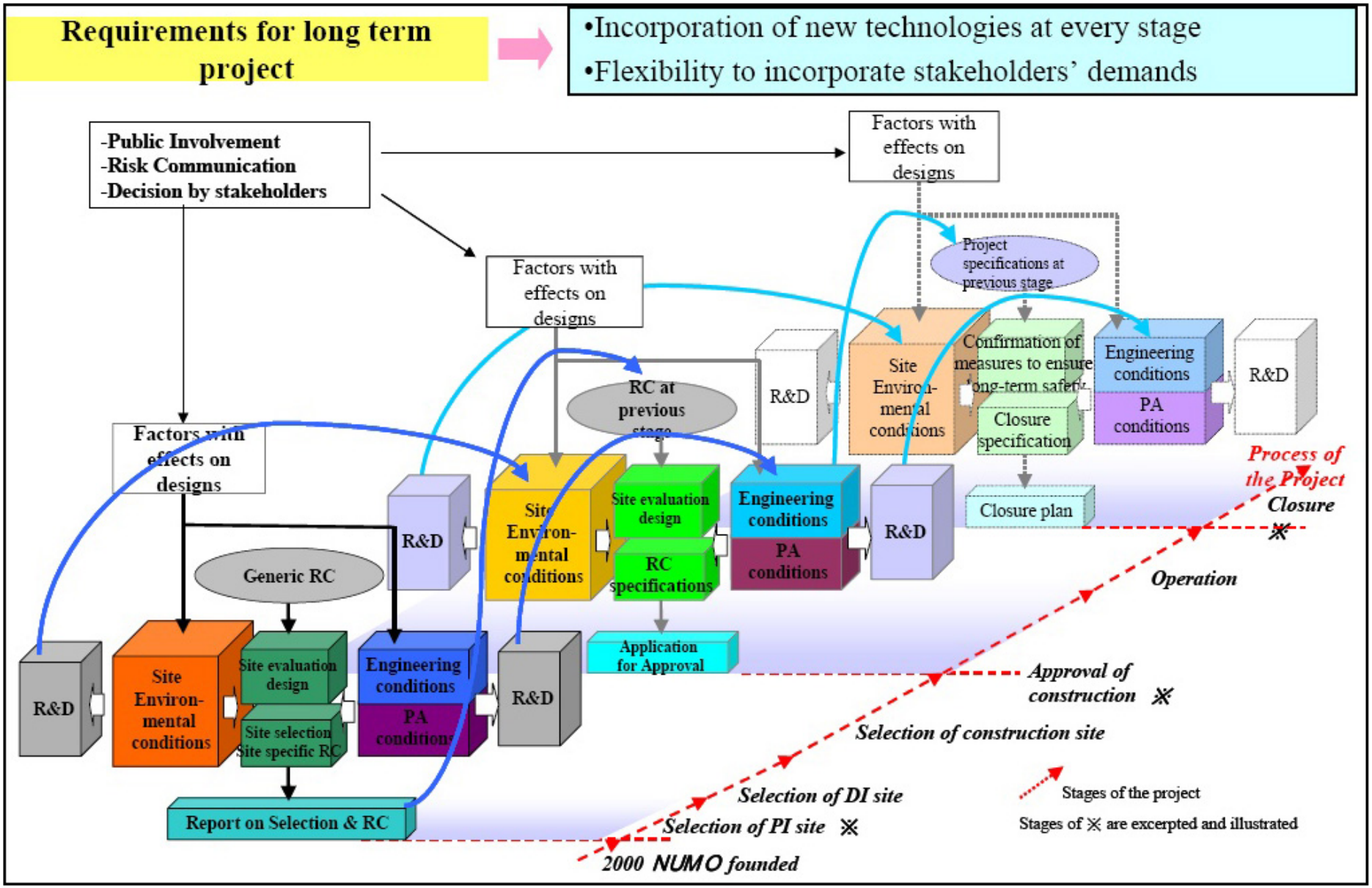
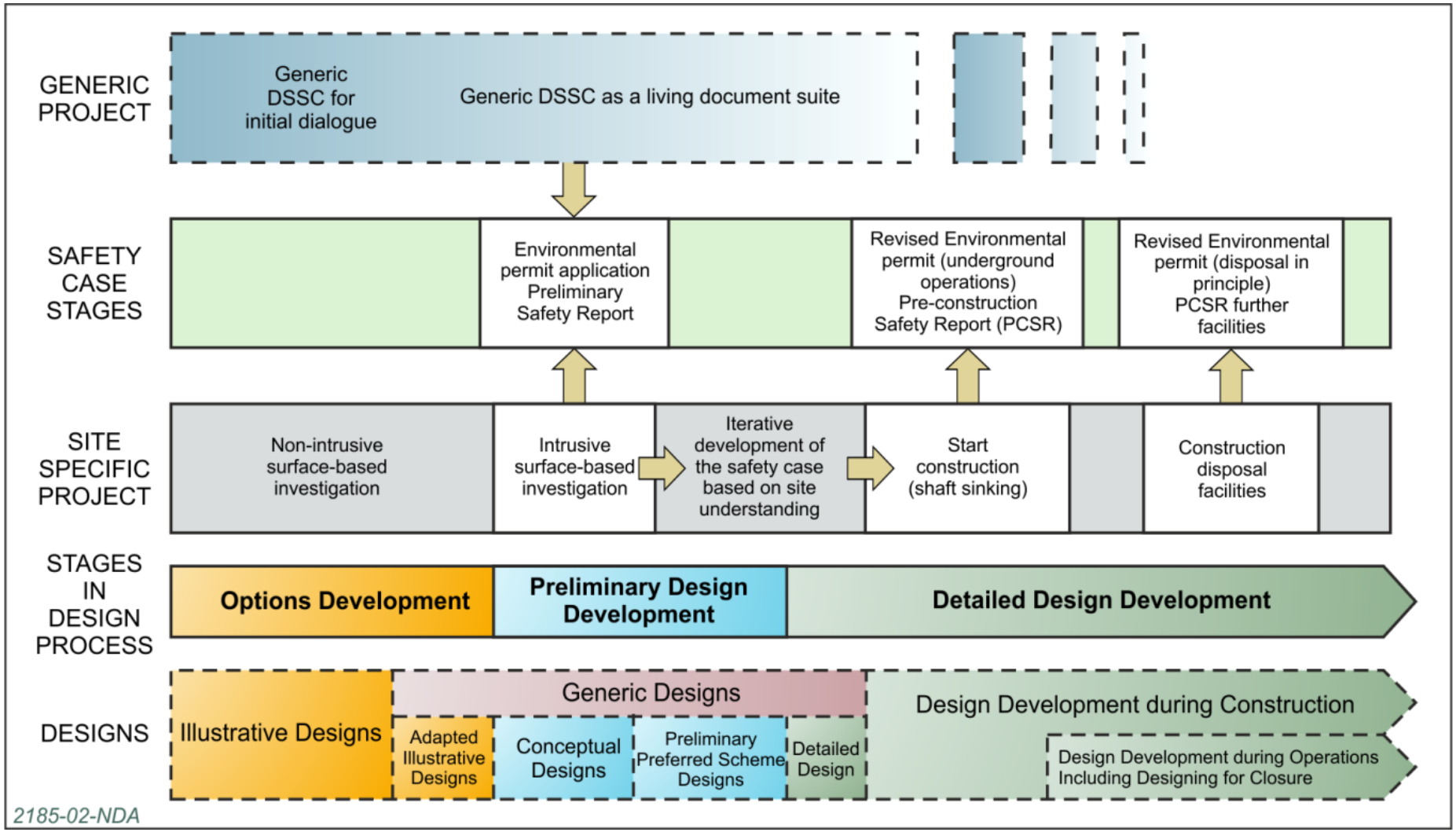
Example 2: NUMO structured approach



Example 3: RWM design process



Optimisation / BAT existing examples

- Examples from WIPP (e.g. selection of MgO backfill)
- Examples from existing near-surface disposal facilities
- Examples relevant to planned geological repositories
  - Cementitious and bentonite backfills
  - Thickness of disposal canister
  - Excavation techniques for deposition tunnels
  - Excavation techniques for plugs/seals & plug design
    - Stripa (1980s-1990s) – Äspö (1990s-2000s) – Domplu (2010s)
  - Granular bentonite material development & emplacement method
  - Shotcrete versus self-compacting concrete for low-pH solutions
  - Drip shields (Yucca Mountain)

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LLW disposal facility at Dounreay, UK

Areas of assessment during the project

Design Area	2004	2006	2007	2008	2010	2011	2014	Planned
Stage	Generic	Planning application	Initial design	Internal reviews	Authorisation application	Detailed design	Construction	Operation
Strategy	All management options	N/A						
Facility Type	A wide range of disposal and storage options	Disposal options – deep cavern, below-surface vaults, above-surface vaults						
Facility Location	A range of options, screened to exclude non-UK locations	Restricted to NDA-owned land at Dounreay		Site selection review taking account of site characterisation and geophysical survey	Borehole monitoring and local-scale hydrogeological modelling	Vault layout review		
Construction and Design		Waste type, waste form, waste container, backfill, wall/base material, cap type	Waste container (Demolition LLW)	Design review taking account of site selection review and site investigation results	Vault walls and base materials	Design review, vault loading strategy, vault aspect ratios	Vault roofs, BPM to repair cracks in Demolition LLW vault walls	
Operational Approach		Temporary roof cover, waste package grouting system, Demolition LLW emplacement, drainage	Vault ventilation, Demolition LLW emplacement, drainage	Drainage and flood management, waste emplacement	Waste classification	Waste Acceptance Criteria, waste conditioning grout, drainage, flood management, ventilation	Concrete HHISO container, lower drainage system, vault flood management, ventilation, load management in the LLW vault	WAC, waste classification, waste packaging - concrete HHISO
Closure approach			Infilling, grouting sequence, backfilling requirements, vault lid, roof removal, final cap, drainage closure, reinstatement		Backfilling between vault walls and rock	Capping system, enhanced geosphere, drainage closure, institutional control	Capping system	Institutional control

So we know a lot…
Purposes of collaborative work?

- Are we following best practice in design optimisation for a disposal facility?
- Have we done enough?
- Is the design unnecessarily complex or costly?
- Are we re-inventing the wheel?
- How can we best learn from others?

For design development, these are increasingly important as move closer to licensing / operation…

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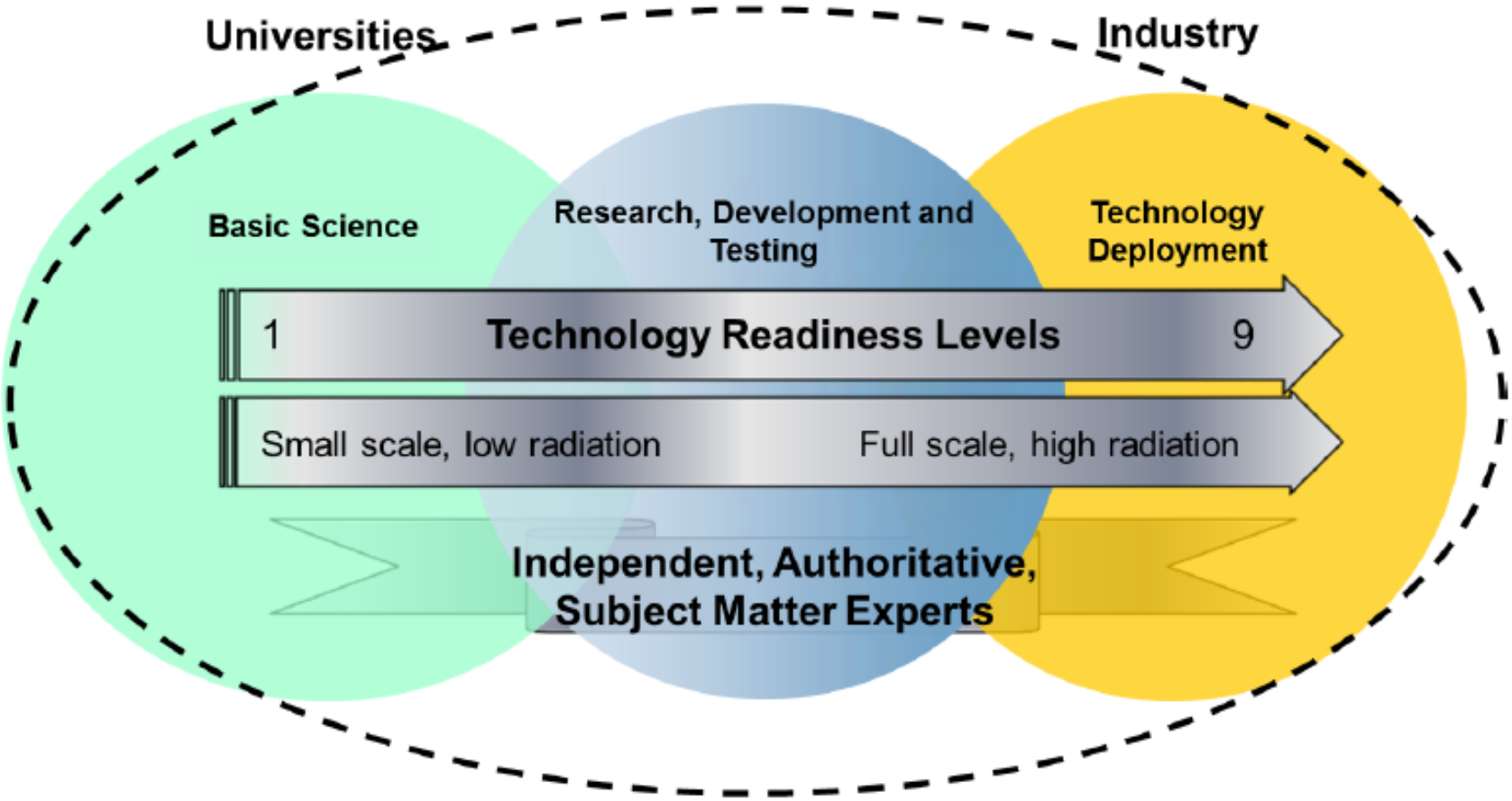
Technology Readiness Levels – can be used to measure design progress



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Safety functions and optimisation / BAT

- Part of optimisation / BAT involves review of safety functions to see whether / how they can be adjusted = close link
- Operational period – waste package example safety functions
  - provide containment
  - limit radiation dose
  - preclude criticality
  - provide the means of safe handling
  - withstand internal and external loads
- Post-closure period – waste package example safety functions
  - Container: protect the wasteform from physical disruption
  - Container: prevent groundwater from reaching the wasteform
  - Wasteform: provide a stable, low-solubility matrix that limits the release rate of radionuclides into groundwater

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Possible aims of collaborative work

- Development of international understanding of optimisation and BAT in the context of geological disposal
  - Provision of an international reference/touchstone
  - Link to TRLs?
  - Link to safety functions?
  - Link to concept of robustness?
- Case studies…. an international databank?
- Development of tools/guidance to demonstrate in a safety case that sufficient optimisation has been undertaken
- Priority optimisation / BAT topics (or repository components) - for representative set of disposal concepts

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