The University of Manchester
Dalton Nuclear Institute

A radical reset: actionable opportunities from the UK nuclear regulatory review 2025

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Contents

List of Acronyms page 3

Foreword 4

Executive Summary 5

1 Development of This Position Paper 6

1.1 **Scope** 6

2 Risk and Governance Across the Sector 7

2.1 **Risk Management** 7

2.2 **A Hierarchy of Governance** 8

3 Opportunities for Duty Holders 10

3.1 **The Role of Boards** 10

3.2 **Outcome-Focused Processes** 11

3.3 **The Role of Innovation** 13

4 Opportunities for Government and Regulators 14

4.1 **Setting the Risk Environment** 14

4.2 **Removing Ambiguity** 14

4.3 **Proportionate Security Arrangements** 15

5 Conclusions 16

References 17

Contact 18

List of Acronyms

AGR	Advanced Gas-cooled Reactor
AI	Artificial Intelligence
ALARP	As Low As Reasonably Practicable
AWE	Atomic Weapons Establishment
BAE Systems	Formerly British Aerospace; BAe
BNFL	British Nuclear Fuels Limited
D8	Stakeholder group for the Magnox sites, operated by NRS
DBT	Design Basis Threat
EDF	Électricité de France
G6	Stakeholder group for Sellafield site
GDF	Geological Disposal Facility
HAW	Higher Activity Waste (ILW plus HLW)
HLW	High Level Waste
IAEA	International Atomic Energy Agency
ILW	Intermediate Level Waste
LLW	Low Level Waste
LLWR	Low Level Waste Repository
MOD	Ministry of Defence
NDA	Nuclear Decommissioning Authority
NRS	Nuclear Restoration Services
NRTF	Nuclear Regulatory Taskforce
ONR	Office for Nuclear Regulation
SMART	Specific, Measurable, Achievable, Realistic and Time-bound
SME	Subject Matter Expert
TLD	Thermoluminescent Dosimeter
UKAEA	United Kingdom Atomic Energy Authority
VLLW	Very Low Level Waste

Foreword

The UK has ambitions to expand the share of nuclear generation in its energy mix, alongside a shift to decarbonisation. The current Government and its predecessors have published ambitious plans for a rapid and substantial growth of civil nuclear energy, including a comprehensive energy strategy and a roadmap for civil nuclear power.



More recently, Government has taken steps to address challenges to practical deployment of new nuclear, for example revisiting the siting process and, as part of this, Government commissioned a review of nuclear regulation, carried out in 2025 by the Nuclear Regulatory Task Force (NRTF), seeking to drive faster, better value for money delivery in both civil and defence nuclear, whilst not compromising safety outcomes. The Task Force was asked to provide clear, actionable recommendations for the whole of government, across planning, environmental, nuclear and conventional safety, the relevant regulators, other delivery partners and industry.

Although it is a 'Regulatory Task Force', the issues it was asked to address do not lie solely within the statutory regulators' vires. The legislative framework governing the sector, and the sector's internal structures, processes and culture, all contribute to making the UK "the most expensive place in the world to build nuclear projects" in which "both civil and defence programmes suffer from large cost overruns and schedule delays".

The NRTF reported at the end of 2025 and made 47 recommendations, the vast majority requiring action by Government. Of those recommendations aimed at duty holders, some were quite light in detail and it could be quite hard to develop them into Specific, Measurable, Achievable, Realistic, and Time-bound (SMART) actions. To aid development of these, the Dalton Nuclear Institute has analysed the Task Force report to identify a series of SMART opportunities which, if taken, would maximise the benefits flowing from it. We hope that this Paper is useful to those seeking to drive change in the sector.

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Executive Summary

The 2025 Regulatory Review offers a 'once in a generation opportunity' to transform the way the UK nuclear sector works. The Dalton Nuclear Policy Group has built on the Review's recommendations, with a focus on opportunities created for duty holders, together with other opportunities for Government and regulators which would enable further improvement.

The first opportunity is to **establish a clear hierarchy of controls, at sector, portfolio and duty holder levels**, with defined roles, responsibilities and accountabilities. Putting this in place will lead to a **balanced view of risk**, its **management at the correct level within organisations**, and **empowerment of the workforce**, together with the **cultural change** needed to embed these.

In this setting, it will be much more straightforward to:

- **adjust safety arrangements during a site's lifecycle as risks change;**
- **develop proportionate approaches to safety cases;**
- **put in place a lifecycle approach to waste management;**
- **innovate at the pace and scale needed to transform the sector;**
- **define and understand different classes of risk, hence aiding proportionate management of risks; and**
- **enable further improvements by developing a more proportionate approach to security.**

1

Development of This Position Paper

The Dalton Nuclear Institute brings together the skills and expertise of the broad nuclear community at The University of Manchester and develops strategic partnerships with academia, industry, regulators, and government.

Many members of the Institute's academic team have practical experience of policy, operations and regulation across the nuclear sector. By drawing on the expertise of its academics and canvassing views from duty holders and other stakeholders in its extensive network, the Institute has developed the thinking of the *Nuclear Regulatory Review 2025* [1] to offer opportunities for real change. These, together with the supporting rationale, are presented here as a contribution to debate. Some are based on contextual discussion and some draw on specific recommendations from the Regulatory Review.

1.1 Scope

The Regulatory Review has made 47 recommendations spanning all parts of the sector. Here, we focus on the potential for operational change by identifying a group of transformational opportunities, some of which can be directly pursued by duty holders, while others, if taken by Government and/or regulators, would maximise gains. For example, security was outside the scope of the Regulatory Review, yet there may well be instances where a changed approach to security would yield additional benefits (see Section 4.3). Where appropriate, the discussion below of specific opportunities is related directly to the recommendations made in the Regulatory Review. The opportunities we offer would enable the UK to:

- **establish coherent, proportionate risk management both across portfolios of activity and across the sector;**
- **drive and track cultural change;**
- **provide clarity on proportionality in safety arrangements;**
- **realise the benefits of a whole lifecycle approach;**
- **innovate at pace and scale; and**
- **develop a proportionate and transformative approach to security.**

This Paper seeks to promote debate, exploring how the principles of the Regulatory Review and the accompanying Strategic Steer create pathways to influence operational practice, recognising that:

- **before any changes to operations can be contemplated, there has to be confidence that there will be no practical detriment to safety, security or the environment; and**
- **innovation, led by Subject Matter Experts (SMEs) and within clearly defined boundaries, should be encouraged.**

2

Risk and Governance Across the Sector

2.1 Risk Management

Guidance on risk management for public undertakings is provided in *The Orange Book: Management of Risk – Principles and Concepts* [2], in which the very first sentence states "Public sector organisations cannot be risk averse and be successful." However, the Orange Book encourages a reductionist approach, leading to consideration in turn of distinct classes of risk (e.g. legal, regulatory, environment, security, safety, financial, delivery, reputation) and sometimes multiple sub-classes within these.

The Orange Book approach to risk can also lead to treatment of the different classes of risk as if they are independent, whereas they are in fact often strongly interdependent, leading to an inability to see the 'wood for the trees' and to poor, badly prioritised decisions. For example the Magnox Swarf Storage Silo at Sellafield is generally recognised as an intolerable hazard and is rightly treated as one of the NDA's highest priority projects. However, a few years ago, during a spell of cold weather, it proved impossible, within the complex, risk averse procurement arrangements, to buy warm jackets for the workforce- massive aversion to a small financial risk impeded progress in managing one of the UK's biggest radiation risks. Although risk classes may be analysed separately, interdependencies mean that the risk appetite associated with a specific piece of work will often actually be that of the most cautious element- in other words a project 'goes at the pace of the slowest'.

It is this issue that the Regulatory Review addresses by introducing the concept of 'Portfolio Risk', the 'overall risk across the system'. The Review identifies the need for what it describes as a 'Controlling Mind' which can take a balanced view at the portfolio level and suggests this should be the NDA for its decommissioning mission and the Ministry of Defence for the warhead and submarine programmes.

While the idea of Portfolio Risk is very sensible, the Review's use of Controlling Mind is perhaps ambiguous since the term has a specific meaning in the UK nuclear context, and the Controlling Mind would usually be the Licence holder. However, most Site Licence responsibilities within the civil decommissioning and defence portfolios actually rest with multiple Site Licensees (in the NDA's case, in its Operating Company subsidiaries, and in the MOD's case in AWE, Rolls-Royce, the dockyards and elsewhere). It might be better to think of NDA and MOD as the 'Coordinators' of their particular Portfolio Risks, with the responsibility to balance risk optimally across the multiple duty holders within their purview. This would be consistent with wider responsibilities under Section 3 of the *Health & Safety at Work Act* [3].

That balancing process would need to provide a transparent framework which allowed duty holders to justify specific decisions to their Boards and to regulators. For example, the need for pace in a programme might necessitate manual handling of materials in a particular facility, with associated increases in worker doses, rather than taking time to develop a remote handling process. A properly implemented

Portfolio Risk framework would be able to provide duty holders with a justification for manual operations.

Such a framework would allow Portfolio Risk to flow down (and up) within organisations, enabling balanced decisions on risk at the correct level within an organisation, while maintaining control at the highest organisational levels. We return to this point in Section 2.2.

Liabilities and responsibilities may be moved into or out of a portfolio over time, for example the ongoing transfer of responsibility for the AGRs, once defueled, from EDF to the NDA. However, the concept of Portfolio Risk needs to be flowed down to lower levels within the sector. It should not require intervention at the NDA Group level to recognise that it is perverse to hold up one of the UK's highest priority decommissioning projects because of an inability to buy some warm clothing.

Portfolio Risk also requires a comparable, overarching approach to ALARP, since almost all nuclear industry operations involve a sequence of events often separated in space and/or time, potentially involving multiple duty holders. ALARP must be assessed across all stages of a project or process lifecycle to find the optimal balance. For example, it may overall be better to retrieve the large volumes of sludge from the Sellafield legacy ponds and silos, and transfer it into robust containers for intermediate storage, even if subsequent processing steps and the ultimate specification and disposability of the resulting waste package are not fully understood at present.

Such an approach requires a focus on overall mission objectives and working 'end-to-end' across a project or programme lifecycle. This could require regulators and multiple duty holders to adopt a strategic approach, balancing risks and working together across operations and organisations, for example as responsibility for waste materials is transferred between different duty holders.

At a local level, such arrangements already exist (e.g. the Sellafield G6 or the NRS D8) and have been proven to be effective. Equivalent arrangements do not, however, exist at the Portfolio or Sector levels. For example, there is no equivalent to the G6 or D8 which looks across the full scope of the NDA mission, although such a body would have obvious value in managing wastes from end-to-end of their lifecycle.

2.2 **A Hierarchy of Governance**

The Regulatory Review has identified weaknesses in the efficient management of risk across the nuclear sector, but it has not suggested a solution to this problem though resolution clearly requires action at all levels. Here, we offer a possible solution.

The UK nuclear sector requires a hierarchy of controls to manage the associated risks. There is already a very clear structure for the management of risks at the operational or site level, through the Nuclear Installations Act, Site Licensing and other tools, including the explicit identification of legally accountable duty holders.

However, as the Regulatory Review has pointed out, there is no coordinated approach to optimising management of risks at the portfolio level; across a group of duty holders all focused on delivery of a nationally significant mission. Examples of portfolios are:

- **The NDA Estate – 18 Licensed Sites, all seeking to deliver the NDA mission of decommissioning and cleaning up the legacy from the UK's historic nuclear programmes.**
- **The Defence Nuclear Enterprise – 13 Licensed Sites owned and operated by multiple organisations, including AWE, Rolls-Royce, BAE Systems, and concerned with manufacturing and operating the UK's military nuclear capability.**
- **Nuclear Generation – 8 Licensed Sites, all operated commercially by EDF Energy but legally owned by three different entities, either generating power or constructing new power reactors.**

The first two portfolios are ultimately direct Government concerns. The Nuclear Generation portfolio is rather different with a more commercial model and the opportunity for new entrants to the market. However, any new entrants will build up their own portfolios of sites and operations and become part of the sector. Other portfolios may also develop over time, for example, if a major UK nuclear medicine programme was established.

Above these portfolios, we believe there is also a need for a national approach to the management of what we term 'Sector Risk' to ensure that activities within one portfolio do not adversely impact other portfolios. While this may be hard to imagine at first sight (how can plutonium management at Sellafield have any effect on dockyard operations at Devonport?), we would suggest that the current position provides a perfect illustration of how such disparate activities do interact. In this case, the Sector Risk has built up over many years by mistaking extreme risk aversion, over-complication, bureaucracy, inefficiency and poor delivery for good practice. It has required drastic intervention from the highest level of Government, through the Regulatory Review and the accompanying Strategic Steer, to provide the necessary response. It would clearly be sensible to ensure that in future, this risk was not permitted to manifest again, and also that other Sector Risks were not allowed to develop.

We offer a possible governance structure for the sector below. Legal responsibility and Controlling Mind authority rest clearly with the duty holders. The responsibility of portfolio owners is to put in place management frameworks which allow coordinated risk management across their portfolio and, since they do not have Controlling Mind authority (in the sense of a Site Licence), they have to do this by working collectively with the duty holders in their portfolio. Such arrangements could include an operational sub-group, modelled on the Sellafield G6 or NRS D8. There is a tension between duty holders' 'local' ALARP and the wider portfolio ALARP, which will need to be managed through judicious use of flexibility and judgement such that Site Licensees can use the shared understanding of risks across the portfolio to defend their local decisions and actions as 'reasonable'. There is also a need for a consistent sector-wide approach to risk management, reflecting national priorities, which we suggest should be overseen by an independently-chaired Nuclear Sector Risk Forum.

Opportunity 1

To make soundly based, balanced judgments on multifaceted risks at the portfolio and sector levels, there is an opportunity for the sector to establish a clear hierarchy of oversight, culminating in a sector-wide Risk Forum. If oversight included representation from duty holders, regulators and other stakeholders, with precautions against conflict of interest, then consistent, clearly argued judgements on the appropriate balance of risks could be developed which duty holders could use to justify operational decisions.

Hierarchy of Controls for Risks across the UK Nuclear Sector

Sector Risk

What?
Ensure consistent, sector-wide risk management approaches through a policy and guidance framework linked to national priorities and fit-for-purpose legislation

Who?
Independently chaired, inclusive Nuclear Sector Risk Forum comprising Government and senior sector leaders

How?
Delivered through Portfolio owners

Define national priorities and requirements; ensure consistency

Changing circumstance; unintended consequences

Portfolio Risk

What?
Coordinate management of risks across a portfolio of activities on multiple Nuclear Licensed Sites, without interfering with Licensees' Controlling Mind status

Who?
A single group for each portfolio, led by the Portfolio Risk Coordinating organisation (e.g. NDA, MOD) and comprising all relevant duty holders

How?
Through the management construct of the portfolio, possibly including an operational sub-group modelled on Sellafield G6/NRS D8

Guides ALARP decisions and prioritisation

Data on safety, security, compliance, delivery

Operational Risk

What?
Controlling Mind responsibility for managing risks associated with operations on a Nuclear Licensed Site, or other relevant activities such as transport

Who?
Duty holders

How?
Compliance with proportionately-set Site Licence Requirements or equivalent statutory controls

3

Opportunities for Duty Holders

3.1 The Role of Boards

Regulatory Review Recommendation 9:

> *"Establish an enterprise-wide system of portfolio risk management across the defence and decommissioning sectors"*

A Nuclear Site Licensee must be a body corporate with "a suitable Board of directors and leadership team to provide the senior strategic direction and leadership of the organisation" [4, Para. 20]. We have discussed earlier the Regulatory Review proposal that the MOD and the NDA should be the Controlling Minds for the management of Portfolio Risk across the defence and civil decommissioning sectors respectively. In our view, MOD and NDA are better viewed as Portfolio Risk Coordinators in this construct. Delivery is via the relevant duty holders and therefore depends critically on the Licensees' Boards which must retain accountability under the Site License. These will therefore need to interact effectively with the relevant Portfolio Risk Coordinator organisation to communicate risk upwards, take a balanced view of risk across their portfolios of activities and put the necessary assurance arrangements in place.

Opportunity 2

There is an opportunity for the Boards of duty holder and Portfolio Risk coordinating organisations to empower their workforces to take a balanced view of risk and to innovate, including providing 'air cover' to give confidence where necessary, with such delegation being done in a controlled fashion so that limits of authority and oversight are clearly understood.

Regulatory Review Recommendation 38:

> *"Boards should assess their organisation's culture, including safety culture, and take decisive steps to align it with delivering their strategic objectives with radical efficiency and effectiveness"*

ONR describes the Boards of duty holder organisations as having "broad-ranging responsibilities, including establishing and maintaining an effective health, safety and security culture, performance and legal compliance and ensuring adequate necessary financial and human resources" [4, Para. 20]. It is important that they take a realistic approach to their duties but, as discussed earlier, the Orange Book takes a reductionist approach to risk rather than holistically considering Portfolio Risk across a project or programme lifecycle, or even Sector Risk. Both this Position Paper and the Regulatory Review have shown this does not properly capture the risks associated with nuclear operations so, in analysing risk at the organisational level, Boards need to articulate the actual risk environment they face, rather than necessarily following the Orange Book's formulaic approach. Their analysis should include consideration of agency, since circumstances (e.g. asset condition or externally imposed requirements), or dependency on others, may constrain their choices. A 'comply or explain' approach may help Boards to show how they have reached their risk positions.

While this may help an organisation's leadership adapt to the Regulatory Review, overcoming the extreme risk aversion, complexity, and conservatism which has become ingrained in the sector over decades will be a major challenge. As noted in Opportunity 2, the Regulatory Review provides an opportunity to adapt these behaviours but cultural change is always difficult and requires sustained commitment. The points made above about Portfolio Risk, and the role of Boards in defining risk appetite, setting the tone, and giving their workforce confidence to innovate are all relevant here. The Nuclear Industry Safety Culture Inventory is a recently established methodology which provides a useful starting point [5]. So is the role of the Board in communicating risk clearly upwards into sponsors or Portfolio Risk managing organisations.

Opportunity 3

Given that responding to the Regulatory Review requires major cultural change across duty holder organisations, there is an opportunity for Boards to make baseline assessments of relevant cultural aspects including for example safety, innovation and risk, and for tracking culture change.

3.2 Outcome-Focused Processes

Regulatory Review Recommendation 5:

> *"Reset safety case development to eliminate duplication and embed simplicity"*

Internationally agreed limits on radiation exposure are translated into UK legislation through the Ionising Radiations Regulations 2017, which provide very clear, consistent limits. In nuclear operations, other measures, for example dose constraints, Basic Safety Levels and Basic Safety Objectives, have assumed a prominence greater than originally intended, confusing what is, in UK legislation, a very simple position, and driving complexity and conservatism. The Regulatory Review has identified the detrimental effects of using these measures inappropriately. Returning to the original purpose of these measures would find a more appropriate balance between cost, whether in money, time or trouble, and programme delivery.

As the Regulatory Review pointed out, current practice is defective in two ways. First, the sector has lost sight of **reasonableness** and **practicability** in defining ALARP; second, conventional health and safety is frequently and unnecessarily managed to nuclear standards, imposing a nuclear premium on every operation on every Nuclear Licensed site.

There is a tendency to over-emphasise continual reduction of workforce dose by minute amounts, while allowing intolerable risks such as those at Sellafield to remain, and also bringing risk to the defence nuclear programme which is a high priority for national security. Rebalancing these risks is not about sacrificing safety to make money; rather, it is reminding ourselves that duty holders have a responsibility to hold their ground and justify maintaining or even increasing doses to accelerate the mission and thus reduce overall risk, particularly in decommissioning where the idea is to reduce and ultimately remove the risk.

Such a shift in emphasis can be accommodated within the definition of a safety case which, at its most fundamental, is defined as "documentation to justify safety during the design, construction, manufacture, commissioning, operation and decommissioning phases of the installation" [6, p. 12]. As the balance of risks changes during a facility's lifecycle, so the safety case will also vary- the nuclear risk associated with an operating power reactor is much greater than that associated with a defueled reactor at end of life, where the fissile inventory may be limited to a quantity of spent fuel in interim storage and, over time, the spent fuel may be removed from the site altogether.

Over the course of the facility's lifecycle, the arrangements which are needed to demonstrate compliance with the Nuclear Site Licence's 36 Conditions will also change and we are aware of examples where the Regulators are taking a pragmatic approach and emphasising particular aspects of the Site Licence as risk on the site changes, but transparency and consistency are unclear.

Opportunity 4

There is an opportunity to devise a clear and transparent process for adjusting safety arrangements in proportion to the nature and balance of nuclear, radiological and conventional risks during a site's or a facility's lifecycle, allowing duty holders to ensure that arrangements are always proportionate. A Sector Risk Forum (see Opportunity 1) would be well suited to oversight of development and implementation of this activity.

Regulatory Review Recommendation 10:

> *"Review arrangements to prevent conflation of nuclear and conventional risks"*

While the position is clear for a relatively simple single purpose site, such as a power station, more complex sites such as Aldermaston, Burghfield, Sellafield or Dounreay comprise multiple facilities carrying out different operations and hence a mosaic of very different risks. Currently, however, it is almost impossible to differentiate individual facilities, or even zones of a site, on the basis of risk. For example, the Calder Hall reactors, which are small Magnox reactors shut down in 2003 and now defueled, still fall under the arrangements associated with the Sellafield Site Licence. At times in the past, site licensing has been

more nuanced with, for example, the Sellafield site being divided between BNFL and UKAEA, with each zone having a separate Site Licence. More recently, site boundaries have been altered to isolate islands of land (e.g. construction activity).

It would be sensible to focus effort and maintain the strongest controls on those parts of a site which present the highest risk but there has to be a trade-off between creation of a complex patchwork of different regimes and the benefits of imposing sufficient but not excessive controls. Increasing the granularity of arrangements would create multiple physical and organisational interfaces so it would be important to assess costs, risks and benefits before embarking on these changes.

Opportunity 5

There is an opportunity for duty holders to build on their already good understanding of the balance between nuclear, radiation and conventional risks for any site, zone, facility or operation where they have responsibility and develop graded, reasonable and proportionate approaches to safety cases under the Nuclear Site Licence.

Regulatory Review Recommendation 23:

> *"Create proportionality in permitting for decommissioning activities"*

We have already discussed the opportunities for all duty holders which are associated with establishing proportionate arrangements under the Site Licence, so we focus here on waste as the product of decommissioning activities. For many years, only a limited range of end points for wastes for radioactive wastes was available, with the principal ones being Licensed Landfill for Very Low Level Wastes (VLLW) and suitable Low Level Waste (LLW), the Low Level Waste Repository (LLWR) for other LLW and, once constructed, a Geological Disposal Facility for Higher Activity Wastes (HAW). This, coupled with the view that extreme conservatism was acceptable, often led to wastes being managed as if they were more hazardous than they actually were and hence to costly mis-consignment.

More recently, characterisation of wastes has started to improve and there has been greater emphasis on routing wastes to the correct end point. For example, improvements in characterisation and sentencing have reduced the volumes of waste disposed to LLWR by around 90% [7]. This preserves LLWR capacity for those wastes which really need to go there, and both drives value for money and greatly extends the facility's life.

In addition, near-surface and in situ disposal have also been proposed as new, alternative end points for suitable Intermediate Level Waste (ILW) [8], offering new options for wastes where volumes are high, and contaminants are relatively short-lived, low radiotoxicity or present in only small concentrations. This greater range of end points should enable fit-for-purpose waste disposals across the whole spectrum of waste categories.

Particularly for HAW, disposability is not simply a function of the radioactivity content of the waste. The disposability of a waste package reflects the nature and form of the radioactive components, as well as the impact on behaviour of treatment and/or immobilisation processes, and the performance of the package itself in the disposal environment. Historically, a waste producer has generally sought comfort that a waste package manufactured in a particular way would meet the Waste Acceptance Criteria. This was provided by the implementer of disposal providing a 'Letter of Comfort' which was intended to signify that a proposed waste route "is expected to produce packages that are compliant with the safety and environmental assessment that support the [disposal] concept" [9]. Over time, expectation seems to have become requirement, and the Letter of Comfort has become a 'Letter of Compliance', which effectively now functions as a 'permit to produce' waste packages, not its originally intended purpose. As a result, it is very hard to make progress in managing so-called 'orphan' wastes where the complete lifecycle is not yet defined and there is no Letter of Compliance for the final wasteform even though, logically, it would be better for example to remove mobile sludges from legacy facilities, which present an intolerable risk, to interim storage rather than leave them in situ.

In addition, because the Waste Acceptance Criteria against which a HAW waste package is assessed are based on a conservative, generic safety case for a currently hypothetical GDF in an unknown geological setting, they are very demanding, as are the requirements placed on the waste producer. These then risk driving over-specification and over-engineering for the waste producer. In the past, the NDA has attempted to balance these factors through 'upstream optioneering' but that work has ceased in the last few years. Nevertheless, there are major opportunities to optimise across the waste lifecycle.

Opportunity 6

There is an opportunity for the NDA Group to take a proportionate, lifecycle approach to waste management, ensuring that there are adequate, not excessive margins through retrieval/creation, treatment, storage, transport and disposal, such that the right waste goes to the right end point in the right form at the right time.

3.3 **The Role of Innovation**

Regulatory Review Recommendation 41:

> ***"Government and industry should establish a nuclear digital programme to accelerate the take up of digital technologies, including AI, as tools for experts to modernise approaches to whole-life safety and regulation"***

While the Regulatory Review has highlighted the potential of digital technology and AI, there is a more general question of innovation in the nuclear sector, particularly public sector nuclear. It is interesting to contrast the nuclear sector with aerospace, another high hazard, highly regulated industry. Over the last half century, aerospace has developed and deployed completely new materials such as composites, established fly-by-wire digital control systems and developed sophisticated real time condition monitoring for safety-critical components such as engines. The overall reliability and efficiency of aircraft has improved substantially. While there has been innovation in public sector nuclear, it has been more incremental, though again with substantial improvements in safety and reliability. Personal dosimetry provides an example, with previous film- or TLD-based dosimeters being replaced by electronic devices, allowing real time rather than retrospective measurement of exposure. The commercial nuclear sector is more innovative with, for example, modern reactor designs being highly digitized.

Public sector nuclear's previous, more cautious approach now offers a major opportunity for the sector if we can create a sustained commitment to digital, with a well-defined pathway to deployment including active demonstrators and a clear approvals process. Obvious areas for development are large scale adoption of autonomy and remote handling; use of smart containers and smart stores to improve condition monitoring; and the exclusion of people from hazardous areas.

The adoption of new technologies in the nuclear sector needs to be thought through. In developing technical solutions, it may be preferable to use existing technologies, proven elsewhere, rather than seek bespoke solutions, though this may bring additional risk associated with adaptation. With time being a strong imperative, the cost and time of developing a specific solution may be unfavourable so it may be justifiable to persist with simpler approaches such as manual operations. The rationale for any technology choices, based on ALARP arguments around time and trouble, needs to be clearly stated. Information could be shared and a group of case studies made publicly available.

In the specific case of digital technologies, qualification and/or certification of digital processes and digital design are a major challenge. AI is more than just Large Language Models and technology like machine learning offers much to the sector. Whatever the technology used, accountability must rest with a suitable Subject Matter Expert (SME) and it is essential to ensure continued development of highly competent personnel who are capable of evaluating AI-generated information. There are perhaps parallels with the armed forces and their requirement to keep a 'human in the loop'. There is a risk that widespread adoption of AI will cut off the traditional development pathway for a future supply of SMEs who will still be needed.

Opportunity 7

By creating a safe space and suitable incentives, there is an opportunity for the sector to innovate at sufficient pace and scale to transform technologies, processes, cultures and behaviours.

4

Opportunities for Government and Regulators

4.1 Setting the Risk Environment

Government rightly sits above the day-to-day realities of nuclear industrial operations – technical complexity, safety and security considerations, asset condition, uncertainty of information – all of which bring risks, and can and do impact performance. However, risk appetite in the nuclear sector has to be nuanced. Currently, there appears to be near-zero appetite for any category of risk, although greater appetite for risk in less critical areas would allow progress while still maintaining strong performance in key areas like safety and security. As described above, senior leaders need to give air cover to their staff who are trying to do the right thing, and in the same way, leaders in duty holder organisations, who frequently have legal duties themselves, need clarity from their sponsoring and overseeing entities.

Current arrangements do not do this effectively so that, for example, the high profile setting of a Select Committee hearing provides a very powerful disincentive to innovate or take risk. From the top of Government down all the way through duty holders, there is a need for leaders to have a realistic understanding of risks and uncertainties, properly reflected in risk appetite statements, to respect the challenges these risks and uncertainties present to those responsible for managing them, and reflect that respect in their behaviours. While the PM's Strategic Steer is a step in the right direction, additional formal direction from senior levels of Government may be required to provide the necessary confidence.

4.2 Removing Ambiguity

Different people and organisations can have quite different understandings of terms commonly used in discussions of safety in the nuclear sector. While what follows is neither a formal definition of terms, nor exhaustive, it is intended to provide precision and clarity since looseness of terminology creates ambiguity and hence the possibility that safety activities are not properly focused on the principal risks.

The UK Health & Safety Executive explains a **hazard** as being something which could cause injury or illness, and a **risk** as the likelihood that someone could be harmed by the hazard, and how seriously [10]. On an industrial nuclear site, there are numerous hazards and risks of different types, all of which need to be assessed, and controlled 'So Far As Is Reasonably Practicable' – a phrase which has significance in UK law.

In the nuclear arena, the International Atomic Energy Agency (IAEA) provides a definition of **safety** – 'the achievement of proper operating conditions, prevention of accidents and mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation risks' [11, p. 139]. It also identifies, without defining them, the terms '**nuclear safety**' and '**radiation safety**', implying these are subsets of safety as defined earlier. The IAEA also defines '**nuclear**' as 'relating to or using energy released in nuclear fission or fusion' so, drawing on the IAEA definitions given above, 'nuclear safety' could reasonably be restricted to 'the safety of activities or facilities where there is a risk of energy release from fission'. In other words, where there is a realistic possibility of criticality.

The position is different in the relevant UK legislation. The word 'safety' is not defined in the Nuclear Installations Act, 1965 (and the term 'nuclear safety' is not used at all), although there is a requirement in the Act not to cause:

- injury to any person,
- damage to any property of any person other than the licensee, or
- significant impairment of the environment,

but explicitly limited to occurrences involving 'nuclear matter', where nuclear matter is defined as fissile material and anything made radioactive through association with the use of fissile material. In most circumstances, the vast majority of radioactive material on the UK's Nuclear Licensed Sites is nuclear matter by this definition.

The Nuclear Site Licence conditions use the word 'safety' in many places but, beyond a statement in Licence Condition 1 that 'safety' refers to the safety of persons (i.e. not of the environment or the plant), 'safety' is not defined. The term 'nuclear safety' is only used in Licence Condition 13, which requires the establishment of a Nuclear Safety Committee to consider 'all matters required by or under the Licence Conditions', implying a very wide-ranging but unclear definition of 'nuclear safety'.

Thus, 'nuclear safety' based on the IAEA definition has a very restrictive definition while, based on the Site Licence conditions, it has a very broad definition. There are examples where the term is used in both senses within a single organization (even in a single conversation!) and clarity would be useful.

Opportunity 8

There is an opportunity for the sector to consistently and unambiguously distinguish (however defined) nuclear, radiation and conventional risks and ease the proportionate management of safety associated with operation of nuclear installations.

4.3 Proportionate Security Arrangements

Security is obviously and rightly a major consideration in the nuclear sector. Although security was not considered in the Nuclear Regulatory Review, that Review is very clear that many of its observations and findings are relevant outside its specific remit. Security is an obvious area for read-across from the Review and many of Government's and the sector's ambitions will not be achievable without change to the security regime which is comparable to that envisaged in safety practices.

Security in the civil nuclear sector is governed by the Nuclear Industries Security Regulations and regulated by the ONR who have developed a set of Security Assessment Principles. However, the basis of security regulation is totally different from that of safety regulation. Key differences include the development of a Design Basis Threat (DBT; a scenario used as the basis for designing security arrangements) and the absence of any equivalent to ALARP. Security risk is an absolute- if there is any possibility of something happening, mitigation must be put in place.

Changes to the security regime are essential if it is not to become a barrier to change. Areas for exploration include the general applicability (or otherwise) of the DBT across the sector and the potential value in developing more relevant and specific examples, for example for decommissioning; and taking account of the probability and consequences of occurrence, which are currently excluded from consideration.

The current state of some of the Magnox sites provides an example. The reactors have been long since defueled but small quantities of 'Fuel Element Debris' (principally metallic ILW) remain on the sites. Although it is securely stored behind multiple layers of physical security, it is possible to envisage a scenario where sabotage leads to off-site consequences. The scenario is quite improbable but, because the probability of occurrence is non-zero (i.e. the negative cannot be proved), and even though the potential consequences are far lower than for an operating reactor, this still leads to periodic pressures to reinstate costly and potentially disproportionate armed security at these sites.

Opportunity 9

There is an opportunity for Government to conduct a rapid review of security across the nuclear sector to allow a less prescriptive, more flexible and proportionate approach, and hence ensure security arrangements do not become a barrier to change.

5 Conclusions

The Regulatory Review has set out an ambitious agenda for change across the entire sector. The sector has been challenged to respond via a letter from the Chancellor of the Exchequer, seeking substantial change at pace, with no compromise on safety and security [12]. The letter requires a response by September 2026, giving information on:

- proposed improvements in delivery while maintaining safe outcomes;
- changes to processes and systems to improve pace, proportionality and coordination;
- response to the cultural issues identified;
- changes to contractual arrangements to align incentives better to prompt delivery; and
- the cost and time savings expected;

and it is in this context that we offer the opportunities below.

Opportunity 1

To make soundly based, balanced judgments on multifaceted risks at the portfolio and sector levels, there is an opportunity for the sector to establish a clear hierarchy of oversight, culminating in a sector-wide Risk Forum. If oversight included representation from duty holders, regulators and other stakeholders, with precautions against conflict of interest, then consistent, clearly argued judgements on the appropriate balance of risks could be developed which duty holders could use to justify operational decisions.

Opportunity 2

There is an opportunity for the Boards of duty holder and Portfolio Risk coordinating organisations to empower their workforces to take a balanced view of risk and to innovate, including providing 'air cover' to give confidence where necessary, with such delegation being done in a controlled fashion so that limits of authority and oversight are clearly understood.

Opportunity 3

Given that responding to the Regulatory Review requires major cultural change across duty holder organisations, there is an opportunity for Boards to make baseline assessments of relevant cultural aspects including for example safety, innovation and risk, and for tracking culture change.

Opportunity 4

There is an opportunity to devise a clear and transparent process for adjusting safety arrangements in proportion to the nature and balance of nuclear, radiological and conventional risks during a site's or a facility's lifecycle, allowing duty holders to ensure that arrangements are always proportionate. A Sector Risk Forum (see Opportunity 1) would be well suited to oversight of development and implementation of this activity.

Opportunity 5

There is an opportunity for duty holders to build on their already good understanding of the balance between nuclear, radiation and conventional risks for any site, zone, facility or operation where they have responsibility and develop graded, reasonable and proportionate approaches to safety cases under the Nuclear Site Licence.

Opportunity 6

There is an opportunity for the NDA Group to take a proportionate, lifecycle approach to waste management, ensuring that there are adequate, not excessive margins through retrieval/creation, treatment, storage, transport and disposal, such that the right waste goes to the right end point in the right form at the right time.

Opportunity 7

By creating a safe space and suitable incentives, there is an opportunity for the sector to innovate at sufficient pace and scale to transform technologies, processes, cultures and behaviours.

Opportunity 8

There is an opportunity for the sector to consistently and unambiguously distinguish (however defined) nuclear, radiation and conventional risks and ease the proportionate management of safety associated with operation of nuclear installations.

Opportunity 9

There is an opportunity for Government to conduct a rapid review of security across the nuclear sector to allow a less prescriptive, more flexible and proportionate approach, and hence ensure security arrangements do not become a barrier to change.

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