Assessment of the benefits of the past and current NDA Corporate Centre innovation portfolio

A report for

FINAL REPORT

know.consulting

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Contents

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www.know.consulting hi@know.consulting

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[1] **know.**consulting ltd. (CRN: 12152408; VAT: 333424820)

Executive Summary

The NDA Corporate Centre's innovation programme covers a range of supply chain focused calls and competitions that have been run since 2006. It is targeted at the NDA's growing ambition to deliver its decommissioning mission **safer, faster and at lower cost**. The programme is part of the NDA's wider R&D programme, run as part of its statutory requirements under the Energy Act 2004 to carry out research into matters relating to the decommissioning of nuclear installations and the cleaning-up of nuclear sites.

The programme has evolved over time, with the design of recent calls taking on board learnings from the experience of previous competitions. While benefits from projects were captured through project-level reporting, such as the monitoring officer reporting system for calls with Innovate UK, the programme-wide benefits have historically not been reported on in a consistent way. With this in mind, the NDA commissioned **know.**consulting to deliver a **baseline benefits assessment** of the past and current NDA Corporate Centre innovation portfolio.

We developed a theory of change for the programme, then conducted extensive research fieldwork (comprising **26 detailed interviews, a survey, and desk-based research**) to draw conclusions on the impact of the programme to date. Our research shows that the programme has delivered or is expected to deliver:

- **Innovation outcomes** with NDA funding seen as key to normalising the use of lasers, robotics, and UAVs in the sector;
- **Enhanced business outcomes** with businesses reporting significant growth in employment and revenue, including exports, as a result of the programme; and
- **Broader outcomes for the sector and beyond** with enhanced operational capabilities, a more accepting attitude to innovation, and increased engagement with Small and Medium Enterprises (SMEs) from other sectors.

We found evidence of significant benefits that have already been realised, with the potential for exponentially larger ones to come as technologies and solutions are applied in the sector. We group these benefits into 4 main themes:

1. **Safer, faster, cheaper decommissioning** – while most of the benefits are still to come, reflecting the long-term nature of innovation and nuclear decommissioning and the aims of the Corporate Centre innovation programme to date in developing capabilities, there are already examples of where NDA-funded innovation projects have helped lead to new, better ways of working that are delivering cost savings and safety improvements. The report highlights several examples of where benefits are already being realised through the use of robotics, laser cutting, and other new/improved products and processes. Interviewees noted potential savings in the hundreds of millions or billions, with one supplier estimating a £4bn potential saving from one funded technology alone (though we could not independently analyse this claim). The programme has also helped to change attitudes, with for example over 70% of respondents to our survey viewing that the programme has had a material positive impact on the level of understanding and acceptance of innovation in the nuclear decommissioning sector.

2. **Technological progress** – NDA Corporate Centre-funded innovation projects have led to the development and deployment of novel technologies and solutions in nuclear decommissioning. They have also led to wider benefits realised through technology transfers within and outside the sector, and to 'spillover' benefits to the wider economy. 8 of 9 companies (that we had access to Innovate UK project completion forms for) reported that they expect to introduce new products within 3 years as a result of their project, with these 9 companies alone (representing c. 5% of all projects) reporting expected follow-on R&D spend of £7m over 5 years. From a separate sample of 12 projects, we found 38 examples of publications related to project funding, and 4 patents (including expected applications).

3. **Business growth** – the NDA Corporate Centre innovation programme has helped many businesses grow their revenues, expand internationally, increase high-skilled employment, and develop internal technical skills. For some, NDA funding through the programme was seen as critical to their growth and sometimes their existence in the sector. In case studies, we profile companies who have expanded both domestically and internationally, with funded projects playing a strong role in their development and resulting in millions of pounds of new revenue each year. We found examples of where project success has led to revenue generated worth 20-40 times the original grant investment and annual exports worth millions, and found £47m of increased and expected revenue directly linked to programme participation. This could be interpreted as the programme helping to increase their revenue by well over twice the level of the total NDA funding for the Corporate Centre's innovation programme (£18m), for these projects alone. 38% of respondents to our survey reported new international business as a result of involvement in their project. Companies also pointed to new annual export revenues worth millions, with expectations to grow further. From a sample of 9 companies, we also found evidence of 116 jobs created / expected to be created, and 67 jobs retained, as a result of project participation.

4. **Stronger sector** – the programme has helped bring in new entrants to the nuclear decommissioning supply chain, while improving attitudes and openness to innovation, and enhancing operational capabilities. The programme is seen by stakeholders as having both strengthened the nuclear supply chain and provided opportunities for the existing supply chain to participate in other sectors. It has attracted many SMEs, bringing new ideas into the sector with significant cost saving potential. 20 of the 21 organisations for which we had access to project completion forms (9 for Innovate UK projects and 12 for TSB-run projects) reported that they expected to continue collaboration with project partners after completion. The programme has also boosted skills in the sector, with over three quarters of respondents to our survey reporting that they had improved their technical knowledge as a result of their involvement in their project, with well over half reporting improved skills and business networks.

Many companies were keen to stress that the NDA Corporate Centre innovation programme has enabled them to undertake activities that they would not otherwise have carried out. None of the companies we spoke to or whose project documentation we analysed said that their projects would otherwise have gone ahead. We judge that the programme's **benefits and impacts are highly additional**. In our view it is unlikely that the benefits discussed in this report would have been realised through other activity by Operating Companies (OpCos) or their supply chain, in the absence of the programme.

The NDA Corporate Centre's innovation programme operates in addition to the core research, development and innovation work carried out by OpCos, and alongside wider NDA R&D activity. The programme has received c. £18m NDA funding and £35-40m total funding (i.e. including contributions from other BEIS-funded public agencies such as Innovate UK, and the MOD-funded DSTL) since 2006, making it relatively small when compared to anticipated decommissioning costs, currently estimated as £132bn over the next century. While there should be realism about benefits realised to date and those that are expected in future, we found a clear consensus that the programme is welcomed by industry and wider stakeholders, and that individuals and organisations across the sector agree with its aims and ambitions.

The size of the prize is undoubtedly significant, and the programme would only need to have a relatively small dent in decommissioning costs to pay for itself many times over. Under some illustrative analysis, which is intended to showcase the size of the prize and not to be an estimate of cost savings that will be attributable to the programme, we show that for each 1% reduction in decommissioning costs, over £400m could be saved over the longer term (present value, 2020 prices). In other words, **if it was seen as credible that without the 2006-present NDA Corporate Centre innovation programme, decommissioning costs would be at least 1% higher, then the programme could be seen as likely to pay for itself more than 20 times over** based on the NDA contribution, or more than 10 times over based on contributions from all delivery partners.

We also consider what the return would be if returns were similar to other comparator evaluations, which we discuss in the report. Grouping NDA calls together according to the mechanisms used to deliver them, and multiplying spend by the impact-per-pound findings of the evaluations, we could see **a return on investment to date of between £56m-£77m on the £18m invested by the NDA** through the NDA Corporate Centre innovation programme. This would represent a **Benefit:Cost Ratio of between 3.1 and 4.3**. While caution is needed when comparing this with other studies, given differences in evaluation scopes and methodologies, this would be broadly in line with estimated returns for other public R&D investments in science and innovation – such as an approximate average ratio of 3-4 for UK public investments in the space sector (excluding spillovers, which are similarly not included in the comparator evaluations).[2]

Considering the evolution of the programme over time and the evidence collected in this study, we discuss some **key lessons learned** regarding how the NDA Corporate Centre innovation programme's design affects its impact:

- Direct grants are an effective way to encourage innovation activity in the sector
- Having the stage-gating of SBRI was noted as a valuable aspect of the programme
- Feasibility study calls get lots of ideas moving, so can be an effective means to catalyse activity
- Working with the customer can be instrumental to accelerating development – but is sometimes hampered by SBRI terms
- Calls should be kept broad enough to enable wider commercial opportunities to increase the overall value
- Where collaborative projects are led by tier 1 companies in the sector, there is a risk that the smaller companies are overlooked or marginalised
- Programme design needs to consider the gap between an innovation project and deployment on site

[2] London Economics, October 2015, *Return from Public Space Investments*, study for the UK Space Agency. See also: Frontier Economics, July 2014, *Rates of return to investment in science and innovation*, study for BIS (now BEIS).

We conclude by setting out suggested **indicators and metrics** that could be used to track impact of the programme in future, intended as a starting point for future work. Based on the project team's extensive experience of research and innovation evaluations and our discussions with the supply chain in this project, we also provide some **recommendations** for the programme's evolution. These are intended to enable better evaluation in future, ensure future decisions are underpinned by the best available evidence, and maximise return on investment:

- Reflecting the value observed in combining different approaches within the NDA Corporate Centre innovation programme, maintain a **portfolio approach** with appropriate risk appetite, i.e. looking across the suite of projects to decide the right mix to maximise expected value for money, and accepting that failure is part of the story and not necessarily a 'bad' outcome.
- Build a **culture of evaluation**, identifying and agreeing KPIs & metrics and building in data collection, building off the theory of change and indicators listed in this report.
- Focus on **end-user involvement and the route to market** of new technologies, in particular being mindful of SMEs' short time horizons and the challenges posed by procurement rules.
- Encourage **culture change** and put the **right incentives** in place for adoption, including considering how (why) those on the front line will use new technologies and recognising the need to work with commercial teams and the supply chain to suitably incentivise innovation in contracts with the NDA Group.
- Be **substantive** in ambition, recognising the potential for innovation to drive down huge expected decommissioning costs over coming decades, while noting that a small programme is only likely to be able to have a small impact even if offers high 'bang for buck' returns. While analysing lessons from other sectors falls outside the scope of this study, we note that examples such as the role of public R&D in driving decreases in the levelized cost of energy for offshore wind and other low carbon energy generation technologies may offer useful comparators and case studies.

1 Introduction

1.1 Background

The Nuclear Decommissioning Authority (NDA) is cleaning up the UK's earliest nuclear sites, and as part of this process, it seeks to explore new technologies and wider innovation opportunities. As well as supporting delivery, maintaining key skills and reducing risks, NDA-funded projects are increasingly targeted at the NDA's growing ambition to deliver its mission **safer, faster and at lower cost**.

Focused on this ambition, the NDA Corporate Centre's innovation programme (referred to subsequently as the NDA CC innovation programme or simply 'the programme') – seeks to develop projects that have the potential to transform how the organisation works and that could benefit the NDA group in future years. It is part of the NDA's wider R&D programme, run as part of its statutory requirements under the Energy Act 2004 to carry out research into matters relating to the decommissioning of nuclear installations and the cleaning-up of nuclear sites. Accordingly, the remit of this study is on the NDA CC's innovation programme specifically (outlined in Chapter 3) rather than the entirety of the NDA's R&D activity or R&D undertaken by the wider NDA Group OpCos.

The programme has been running in some form for over 15 years, and is designed to fit into the overarching NDA strategy as a strategic portfolio of investments aiming to address NDA Group-wide needs and opportunities to complement Operating Company (OpCo) delivery activities. It has focused on developing strategy, delivering innovation, and maintaining technical skills.

The programme has evolved over time, with the design of recent calls taking on board learnings from the experience of previous competitions. In its early years, it followed an exploratory approach, recognising the increasing role of innovation as the NDA mission shifts from maintaining operations to decommissioning at scale. It has taken a correspondingly long-term view with regards to benefits, focusing on achieving a secure programmatic footing for future NDA activities rather than the realisation of short-term benefits.

While benefits from projects were captured through project-level reporting, such as the monitoring officer reporting system for calls with Innovate UK, the programme-wide benefits have historically not been reported on in a consistent way. With this in mind, the NDA commissioned **know.**consulting to deliver a **baseline benefits assessment** of the past and current NDA Corporate Centre innovation portfolio. This independent, evidence-based assessment aims to ensure that the impacts of NDA-funded innovation are properly captured, analysed and communicated.

The study examines whether and how value was created, notably looking at interim benefits and wider and unexpected impacts.

1.2 Methodology

We followed a three-stage process to generate the findings presented in this report:

Stage 1: Theory of Change development → **Stage 2:** Primary & secondary research → **Stage 3:** Evidence synthesis & analysis

Stage 1: Theory of Change development

A **Theory of Change** seeks to map out the different routes to impact of an activity, setting out the causal links between the inputs (e.g. funding, people), the intermediate outputs and outcomes (e.g. new products, processes, know-how) and the ultimate impacts (e.g. cost savings, safety improvements).

To build the theory of change, we conducted extensive **desk-based research**, reviewing all existing programme and project documentation provided to us by the NDA team. This enabled us to gain a full understanding of the different routes to impact of the NDA's innovation funding (including direct, supply chain, spillover and end-user benefits), the causal links and bigger picture, the external factors that can influence outcomes, and the data gaps.

Developing a robust theory of change was a critical part of ensuring that the data collection tools were correctly designed. It is also intended to be useful for future **monitoring and evaluation activity**, for example through identification and development of a consistent set of impact metrics.

The theory of change is presented in Chapter 2.

Stage 2: Primary and secondary research

We then gathered extensive information on the impact of NDA funding from various stakeholder groups, including suppliers, end-users, delivery partners, and those in the wider community with an interest in the NDA CC innovation programme.

The core of our evidence was collected through **26 detailed interviews** with stakeholders across the NDA innovation landscape, from those running programmes to those delivering them and potential users of new solutions developed. For some organisations – the NDA in particular – multiple interviews were held with different teams within the organisation. The organisations consulted are listed below, with a more detailed list with individuals and roles contained in Annex A. As some companies have been involved in several calls and competitions, some interviews covered multiple projects. Interviews were designed to cover the breadth of the NDA CC innovation programme, and to not over-focus on any single call, competition or 'type' of activity. Carefully targeting our data collection was essential for ensuring that the findings of this study are robust and representative. For example, we sought to strike a balance between:

- Businesses and academic organisations
- Companies who had been successful and unsuccessful in securing follow-on funding
- Participants in older and newer calls
- Different funding mechanisms

We also ran an email-based **light touch survey** to complement the inputs gathered during interviews, notably targeting participants of legacy technology feeder programmes, ensuring wider engagement and coverage. Overall, we contacted over 120 organisations and had a response rate of 11%. This relatively low response rate was expected, as the survey mainly targeted stakeholders involved in legacy technology feeder programmes. Indeed, the stakeholders contacted received funding several years, sometime over a decade ago, meaning individuals involved may have moved to different companies or retired, companies had been taken over, and/or paperwork may be inaccessible. Additionally, the light touch survey was not intended to collect detailed, statistically-robust data on impact, but to provide some coverage for these legacy programmes, to complement the data gathered during the extensive semi-structured interviews.

Figure 1: Interviewee organisations (see Annex A for more detail)

Suppliers / funding recipients:	
• AB5 Consulting	• Nuvia
• Barrnon	• Shadow Robot Company
• Cavendish	• TWI
• Createc	• University of Bristol
• Holoxica	• Viridian Consultants
• Jacobs	
Delivery Partners:	
• NDA	• DASA / DSTL
• Innovate UK (inc. project monitoring officers)	
End users:	
• Sellafield	• Dounreay
• Magnox	
Wider Stakeholders:	
• Knowledge Transfer Network	• National Nuclear Laboratory

Additionally, we developed five **case studies** of examples that highlight the range of impacts generated from NDA funding. When relevant, follow-up information was gathered by email from the stakeholders to ensure comprehensiveness and accuracy of reporting. These case studies are presented throughout this report.

Finally, to complement the primary research, we also used desk-based analysis of **project completion forms** for projects run in partnership with Innovate UK (including previously as the Technology Strategy Board). While not available for all projects or calls, we analysed a total of 21 project completion forms, consisting of 9 forms for Innovate UK and 12 for TSB-run projects. These were complemented by **final reports** for the Integrated Innovation for Nuclear Decommissioning (IIND) programme, which provided some further evidence (NB there was overlap between these reports and the Innovate UK completion forms, so care was taken to avoid double counting of benefits). While these did not cover all 170+ projects funded across the programme (see Annex B for a full list), they nevertheless formed a useful source of evidence on realised and expected benefits.

Stage 3: Evidence synthesis and analysis

The evidence gathered in the two previous stages was then synthesised and analysed to draw conclusions on the impact of the NDA CC's innovation funding to date and expected future impact. We also considered how the programme's design and mechanisms used to deliver innovation projects affected its impact, and developed recommendations for the future. We conducted:

- An assessment of the **qualitative and quantitative impact** of NDA CC-funded innovation projects, informed by a range of indicators and 'softer' evidence, including consideration of the unexpected and spillover benefits.
- An assessment of the **potential return on investment**, where (expected) benefits could be monetised under some illustrative assumptions.
- A **comparison** of the NDA CC's innovation funding with other innovation programmes, including broader evaluations of funding mechanisms used to deliver NDA CC calls and competitions (e.g. Innovate UK's Feasibility Studies Programme, SBRI, and Knowledge Transfer Partnerships). While we were unable to identify many good international comparators, there are some potential lessons and commonalities with other UK programmes, which we discuss.
- A discussion of the **lessons learned**, drawing off the research to identify gaps, risks, opportunities and recommendations for the future.

Throughout, our analysis adopted **HM Treasury Green Book and Magenta Book compliant** approaches to produce the most robust findings and recommendations possible.

1.3 Structure of this report

- **Chapter 2** presents the logic model and discusses the theory of change for the programme
- **Chapter 3** provides a brief summary of the different calls, competitions and demonstrators which constitute the NDA CC innovation programme
- **Chapter 4** presents a thematic grouping of the different 'types' of benefits generated by the programme, based on our analysis
- **Chapter 5** examines how the use of different mechanisms within the NDA CC innovation programme has affected benefits over the years
- **Chapter 6** considers some next steps and potential indicators to enable better monitoring and evaluation of benefits in future
- **Chapter 7** draws together the findings from previous chapters into conclusions and recommendations for next steps

1.4 Caveats

As with any analytical study, there are several caveats that affect how results should be interpreted:

- **Data paucity** – In general, beyond the project completion forms available for a subset of projects (see above), there was limited data or documentary 'hard evidence' on outcomes available from projects, beyond funding values and timings. Reflecting the exploratory nature of the early years of the programme in particular, the risk of not having full NDA access to other commercially sensitive

information (which the supply chain often – and understandably – did not want to share) was understood at the time, though hampers the ability to analyse outcomes at this stage. This was compounded by data confidentiality restrictions and changes to IT systems affecting the ability to access some legacy documents. While our analysis of reported and expected outcomes from project completion forms provide some useful evidence which we summarise at appropriate points, findings beyond these were often heavily informed by the interviews and discussions we held with suppliers and others. This meant that we could not, for example, conduct any econometric analysis or other more advanced analytical techniques (though some simple aggregation of reported / expected outcomes from project completion forms was possible).

- **Long timescales** – innovation is long term process and – particularly in the risk averse environment of nuclear decommissioning – it can take many years for new technologies to be fully deployed. Many of the benefits are therefore *potential future* rather than already-realised benefits, and as such carry some inherent uncertainty. We try to make this clear in this report, where relevant.
- **Coverage** – those that accepted requests for interviews are arguably more likely to be positively engaged with the NDA CC innovation programme than those who did not, which could lead to some selection bias. However, as this is a benefits assessment rather than a rigorous programme evaluation (e.g. we do not seek to answer questions such as 'was it worth it?'), we do not believe this will meaningfully affect our conclusions here.
- **Attribution** – the NDA CC innovation programme is part of wider organisational activity, and many of the impacts that could be realised if new technologies are deployed will depend on factors such as other NDA OpCo R&D funding, deployment / diffusion support, and organisational culture. The NDA Corporate Centre does not have responsibility for implementation on site and it is the Site Licence Holders who ultimately realise the benefits. Isolating the impact of the programme amongst this wider activity is therefore complex and arguably not possible. We discuss this where appropriate, though recognise that benefits are rarely the result of any single input or programme.

2 Theory of Change

The NDA Corporate Centre's (CC) innovation programme focuses on delivering one key objective: **safer, faster, and more cost-effective delivery of the NDA's mission.**

Whilst always an aim, in 2019 this objective was focused through the NDA's Grand Challenges for technical innovation[3], which provide overarching strategic direction for the NDA CC innovation programme. The Grand Challenges identified four areas through which efficiency gains could be achieved, as well as wider societal/environmental impacts: moving humans away from harm; adopting digital approaches for capturing and using data to improve planning and decision making; using autonomous technology to manage assets proactively and efficiently; and reducing waste sent for disposal.

In particular through the collaborations with Innovate UK (see Chapter 3), the programme has also sought to develop **a resilient and growing nuclear sector in the UK**. Aims here are and have been to deliver economic and productivity growth through innovation, supporting businesses in the nuclear sector and beyond to deliver product and process innovation to support decommissioning, supporting high-skilled jobs, global market share, increasing revenues, and encouraging more efficient ways of working. To deliver these broad impacts, the programme has used approaches to deliver:

- **Innovation outcomes**, including bringing new products or services to market and seeing technology transfer into nuclear decommissioning from other sectors.
- **Enhanced business outcomes**, including growing employment, revenue, and exports.
- **Broader outcomes for the sector and beyond**, through strengthened supply chains, enhanced operational capabilities, an improved innovation culture, and spillover benefits within the sector and beyond.

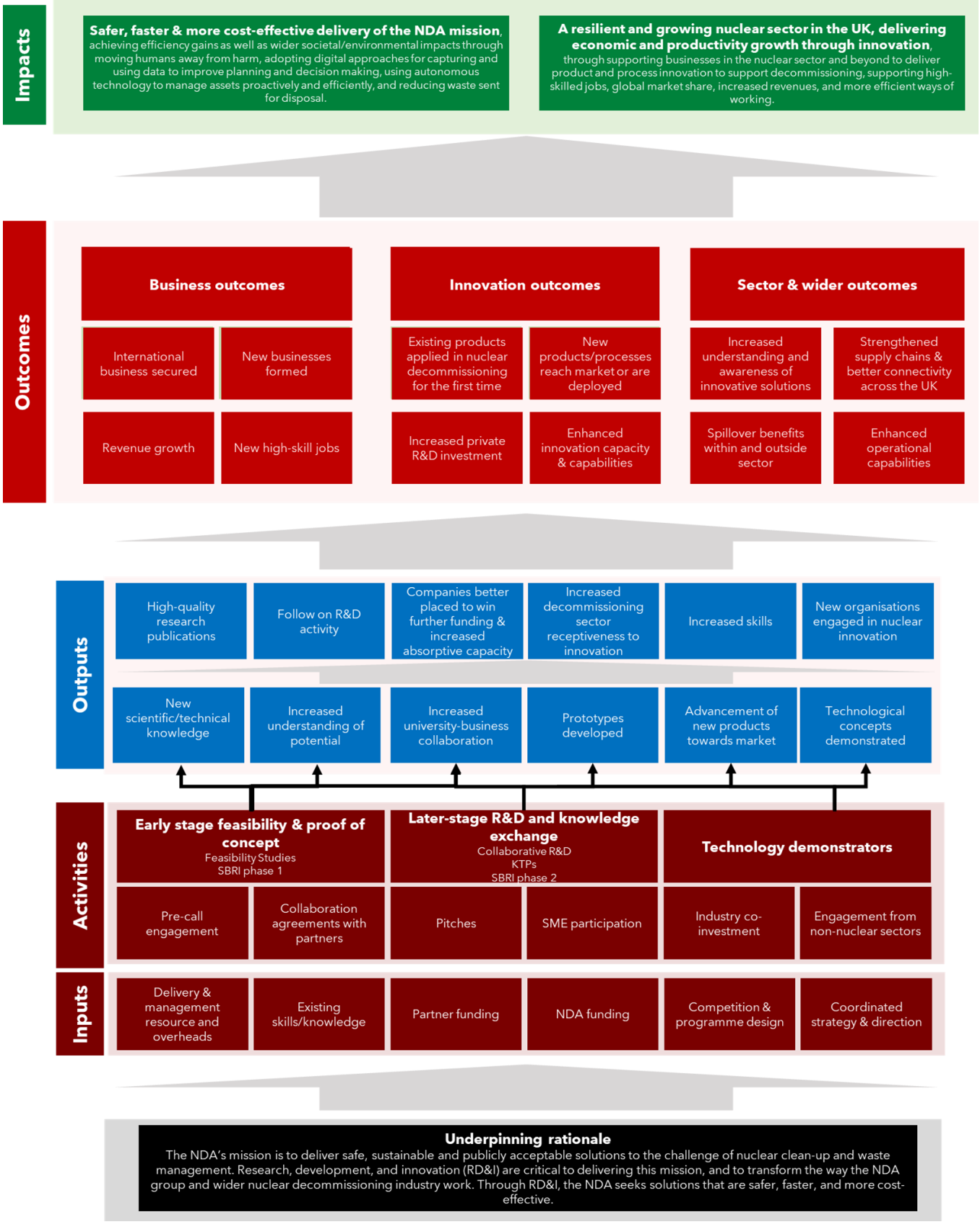
2.1 Logic Model

Figure 2 below sets out a high-level logic for the programme, charting the causal links between the inputs to the programme to the anticipated outcomes and impacts. This model was developed iteratively in discussion with NDA officials.

Inputs and activities across the TRL (Technology Readiness Level) chain, from early-stage feasibility studies through to technology demonstrator projects, help drive new knowledge, spur on further R&D activity, increase companies' competitiveness, improve skills, and help create a receptive environment for new innovations to be applied and build cross-sector links. This, in turn, drives the business, innovation and wider outcomes discussed above. Companies secure new business and grow employment, new products and services are deployed in a nuclear decommissioning environment while innovation capacity and capabilities are improved, and the industry supply chain is strengthened while new 'spillover' benefits are realised both within and outside the decommissioning sector. These outcomes ultimately then feed into the impacts in terms of safer/faster/cheaper decommissioning, and a resilient and growing UK nuclear sector.

[3] https://www.gov.uk/government/news/nda-sets-out-its-grand-challenges

Figure 2: NDA Corporate Centre Innovation Programme logic model



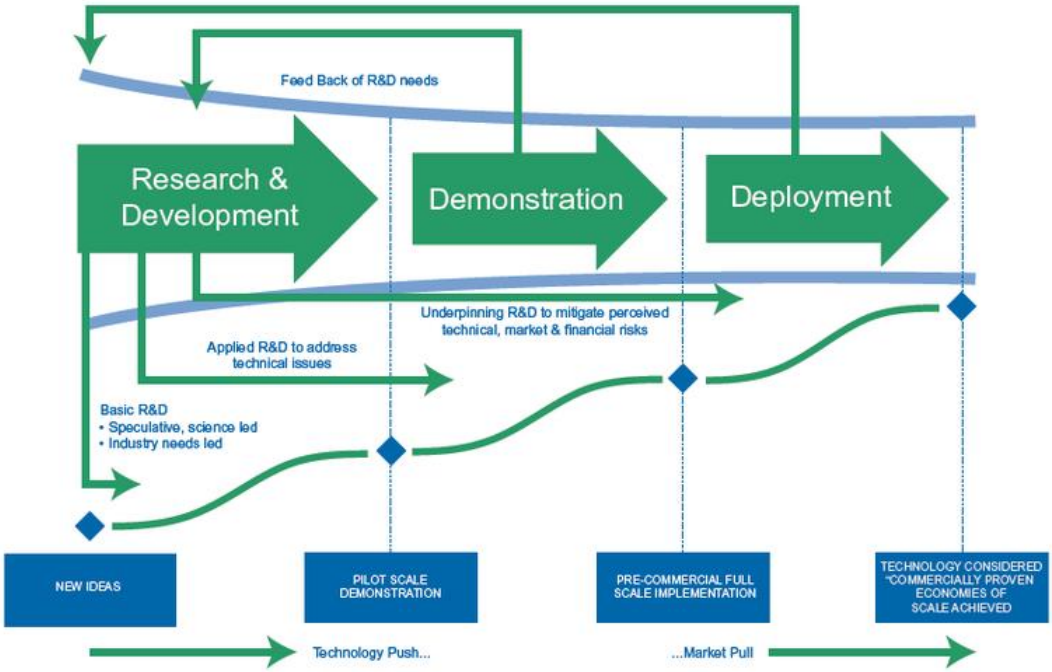
2.2 Routes to impact

For clarity, in the visual model there is a clear distinction between the different mechanisms, and the outputs they lead to. In practice, **innovation is not a linear process** from early-stage to later-stage, and demonstrations or concept proving can occur multiple times, at different stages. Furthermore, whilst the outputs are broadly grouped above the mechanisms most likely to lead to them – with earlier stage R&D more associated with new knowledge than with the demonstration of technology – in practice any mechanism could lead to any of the outputs.

Figure 3 provides a stylistic representation of these feedback loops and gradual, inconsistent progress towards the deployment of new innovations. Any stage can feedback to any previous stage, with research and development serving as a problem solving process throughout the innovation process[4]. As such, a call for later-stage collaborative R&D might result in some projects which do move towards demonstration and deployment in a more linear fashion, along with some that go back to revisit proofs of concept or technical issues within the same TRL level, whilst others will come to a halt.

The actual realisation of outputs will depend on many factors, including the specific design of the call, the types of projects and organisations involved, and the success of those projects.

Figure 3: visual representation of the non-linear innovation process



Source: Energy Research Partnership, 2007

The design of the NDA CC innovation programme, including the selection and definition of mechanisms and the route through the logic model these lead to, is set out in more detail in chapter 5.

[4] BIS (2011) Economics Paper #15 *Innovation and Research Strategy for Growth*

The pathway to impact is also often more complicated than the logic model can imply. In some cases, an R&D project will lead to a solution being proven, developed further, taken to market, and commercialised by the company or companies involved in the initial project. Sometimes, ideas developed in a project by a company might be used elsewhere, by other companies, and for unforeseen applications, potentially in different sectors altogether.

These **spillover effects** (which research suggests can often account for a substantial proportion of the overarching impacts of R&D funding, with one study estimating that approximately two-thirds of all returns to R&D are realised through spillovers[5]) can occur within the sector – e.g. for alternate nuclear decommissioning or maintenance purposes – or across sectors, creating value in alternative sectors outside of nuclear, yet still achieving impacts in terms of enhanced business outcomes and a return on the investment from the perspective of the UK taxpayer.

Of course, spillovers can also travel into the nuclear sector from R&D undertaken in other domains, such as laser cutting techniques being transferred from the automotive sector, and some of the programmes implemented by NDA CC are specifically designed to enable and encourage such impacts.

[5] See e.g. Frontier Economics, 2014, *Rates of return to investment in science and innovation*

3 The NDA Corporate Centre Innovation Programme

The NDA Corporate Centre's (CC) innovation programme covers a range of calls and competitions that have been run since 2006, summarised in Figure 4 below.
The programme has evolved over time, originating in direct grants through the Concept Development Programme, before the organisation began working in partnership with other government funders Innovate UK, the UK's national innovation agency, and the Defence and Security Accelerator (DASA), a Ministry of Defence (MOD) and Home Office initiative run by DSTL, a MOD agency, that works to find and fund exploitable innovation to support defence and security[6]. In particular, the early partnerships with Innovate UK reflected strategic decisions at the time to ensure the programme had the ability to make progress through common procurement rules. Annex B has a list of all 170+ projects run under these calls and competitions, together with their contractual value where available.

Initially, the NDA ran its own open calls for innovation under the Concept Development Programme (CDP), which offered grants of up to £50k to companies with innovative ideas to improve the efficiency or effectiveness of nuclear decommissioning. Two calls were launched, in 2006 and 2007, funding 26 projects. As open calls, these invited any idea to support innovation for nuclear decommissioning, and the projects funded covered a broad scope across the NDA's remit. As would be expected, many projects did not ultimately progress further, though we identified at least one example of a project (N-Visage) that progressed all the way from this early CDP funding through to much more recent calls such as IIND (discussed in more detail below).

For later stage projects, the NDA ran the Technology Demonstration Programme (TDP) in 2008, resulting in one large (£915k) demonstration project being funded, for TWI Limited for concrete scabbling and pipework size-reduction using fibre lasers.

The NDA began collaborating with Innovate UK in 2010, initially through providing information to inform Innovate UK's nuclear R&D programme and assisting with the development and promotion of calls, before launching a joint £15m call (of which the NDA contributed around £3m) – 'Developing the civil nuclear power supply chain' – alongside the Engineering and Physical Sciences Research Council (EPSRC) and Department for Energy and Climate Change (DECC, now part of the Department for Business, Energy & Industrial Strategy) in 2012.[7]

This call enabled a continuation of funding for feasibility studies similar to the CDP calls, through Innovate UK's Feasibility Studies Programme (FSP), alongside larger-scale Collaborative R&D (CRD) projects and Knowledge Transfer Partnerships (KTP). CRD grants offered up to £2m for consortia to collaborate on R&D projects typically at a later stage, and sometimes as a follow-on, to feasibility studies. KTPs support knowledge exchange from academia into industry by placing a recent graduate in a business to work on a specific innovation challenge. LabLogic Systems Ltd, discussed in more detail in Chapter 5 and in a 2016 NDA R&D brochure[8], are an example of a company who participated in an NDA-funded KTP and who then progressed to on-site testing.

[6] https://www.gov.uk/government/organisations/defence-and-security-accelerator/about
[7] Note: as decommissioning was part of this wider nuclear supply chain-focused call, some of the projects listed in Annex B have broader applications that go beyond decommissioning. For the £15m call, the basis of the call was up to £1m for Knowledge Transfer Partnerships, £2m for feasibility studies, and £14m for CR&D.
[8] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/564451/Research-and-Development-Driving-solutions-delivering-progress-brochure2016.pdf

Figure 4: NDA Corporate Centre Innovation programme calls

Competition Call	Funding Bodies[9]	Route to Market	NDA CC funding[10]	Other partner funding [11]	No of projects	Max. Contract Value [10]	Year
CDP (Concept Development Programme) – 1	NDA	Open Competition	**£550k**	-	11	£50k	2006
CDP – 2	NDA	Open Competition	**£650k**	-	15	£50k	2007
Technology Demonstrator Programme	NDA	Grant Agreement	**£915k**	-	1	£915k	2008
Developing the Civil Nuclear Power Supply Chain – 1	NDA, IUK, EPSRC, DECC	Open Competition, including Feasibility Studies (FS), Collaborative R&D (CR&D), Knowledge Transfer Partnership (KTP), and Special Project (SP)	**Total: £2.9m** FS: £346k CR&D: £1.1m KTP: £470k SP: £1m	£6.4m (actual; available data – see footnote)	35	FS: £54k CR&D: £729k KTP: £134k	2012
Developing the Civil Nuclear Power Supply Chain – 2	NDA, IUK, EPSRC, DECC	Open Competition, including FS and CR&D	**Total: £3.0m** FS: £1.3m CR&D: £1.7m	£9.0m	41	FS: £137k CR&D: £727k	2014
Energy Game Changer – Feasibility Study	NDA, IUK	Targeted Call	**£450k**	£720k	19	£70k	2016
Integrated Innovation for Nuclear Decommissioning (IIND) – Phase 1	NDA and IUK	SBRI – Open competition via IUK	**£3.5m**	£3.6m	15	£60k	2017
IIND – Phase 2	NDA, IUK, BEIS	SBRI – Limited competition via IUK			5	£1.5m	2018
IIND – Phase 3	SL, NDA	Grant Agreement via SL	**£1.0m**		2	£2m	2019
Telexistence (Phase 1)	DSTL, NDA	DASA – Themed open competition	**£250k**	£700k	10	£100k	2020
Sort and Segregate Nuclear Waste (S&S) – Phase 1 & 2	NDA	SBRI Open competition	**£4.7m**	-	19 (P1: 14) (P2: 5)	£60k (P1) £900k (P2)	2020 /21
Total			**£17.9m**	**£20.4m** (see footnote)			

[9] IUK: Innovate UK; EPSRC: Engineering and Physical Sciences Research Council (now part of UKRI); DECC: Department of Energy & Climate Change (now part of BEIS); SL: Sellafield Limited; DSTL: Defence Science & Technology Laboratory.

[10] NB: figures in 'NDA CC funding' and 'max contract value' columns are NDA Corporate Centre *advertised* spend levels, and *actual* spend may differ in some cases. For this reason, figures for NDA CC funding and maximum contract value do not necessary match exactly with those presented in Annex B, which is based on actual spend data. Furthermore, some of the maximum contract values may be inclusive of VAT, and others exclusive, depending on the competition mechanism used.

[11] We estimated partner contributions based on data provided to us by the NDA, together with desk based research to fill in gaps, e.g. using Innovate UK transparency data. These are approximations based on available information and – while we have made our best efforts – they cannot be guaranteed as accurate. For example, some figures may include VAT, whereas others do not. For this reason we present total funding as '£35-40m' elsewhere in the report. Sums in this column are also based on actual spend rather than funding announced at the launch of a call, so there may be discrepancies in totals.

The 2012 call was followed by a second 'Developing the civil nuclear power supply chain' call in 2014. This did not include any KTPs but offered £3m through the FSP and £10m through CRD across project partners (NDA contributed around £3m). Many projects funded at this stage have since gone on to being deployed at site (e.g. Viridian and DEEP concrete depth profiling; combining N-Visage with drones), and were seen by the NDA technology and innovation team as being particularly effective in opening up funding for the supply chain that was not previously available.

A further collaboration with Innovate UK in 2016, the 'Energy Game Changer', demonstrated further ways to encourage different routes to impact through similar mechanisms, with a focus on cross-sector applications within the energy sector. Here, there was a requirement for each project to be led by an SME whose main business lay outside the sector their project was addressing, which helped bring new organisations into the field of nuclear innovation, as well as seeing existing products applied in nuclear decommissioning for the first time. This was a result of learning from previous calls and competitions, and reflected the evolving strategy discussed above, where in this call the aim was to encourage new market entrants and incentivise SME participation.

In 2017, a new Innovate UK-NDA partnership saw the launch of the 'Integrated Innovation for Nuclear Decommissioning' (IIND) call, which aimed to integrate the solutions for different parts of decommissioning from the previous calls to an integrated offering. This was the first SBRI (Small Business Research Initiative[12]) competition the NDA was involved in, a route followed in the 2020 'Sort and Segregate Nuclear Waste' call. SBRI is a programme of pre-commercial procurement contracts designed to increase the use of innovation solution to public sector programmes where an off-the-shelf solution does not exist. Designed to bring in a public sector body as the lead customer, it provides 100% funding through a contract for a company to develop a proposed solution. Typically run over two or three phases, it allows for a similar funnelling of projects as seen in the combination of feasibility studies with later-stage collaborative R&D. Phase 1 offers smaller contracts for early-stage ideas, before a second phase offers a larger contract to those with the most potential to meet the requirements. A third phase then typically focuses on real-world deployment of the solution. We understand that IIND represented the first time that Innovate UK collaborated to take an SBRI to a third phase, which could be seen as evidence of pushing boundaries and developing new good practice.

Recognising the similarity of some of the defence and security challenges faced and to leverage wider government R&D investment, the NDA then entered into a 5-year SLA (Service Level Agreement) with DSTL to access DASA Innovation Services. As the first project co-funded under this arrangement, in 2020 the NDA partnered with DASA on a Telexistence call, focused on three areas: Telepresence, enabling a human operator to experience the sensation of self-presence in a remote environment; haptic feedback, providing an immersive solution with transmits sensory information from the remote environment to a human operative, and; robotics, providing manoeuvrable solutions to enable human operators to interact with a remote environment.

In running these calls and competitions, there was an explicit recognition by the NDA Corporate Centre Technology & Innovation Team that early innovation calls with new partners tend to be higher risk, where the benefits may be more around business outcomes for the supply chain rather than directly implementable solutions. In Chapter 4 we discuss the benefits in more detail, though we stress these calls are often part of a longer-term process towards strengthening the supply chain and positioning the sector for the future rather than securing immediate reductions in decommissioning costs.

[12] https://www.gov.uk/government/collections/sbri-the-small-business-research-initiative

4 Benefits

We used our primary and secondary research to collect views and evidence on the benefits that the NDA Corporate Centre (CC) innovation programme has had to date, and that it is expected to have in coming years. In the discussion in this chapter, we frame the benefits around the themes in the outcomes and impacts elements of the logic model discussed above.

As the programme is in practice a portfolio of many different calls and competitions, most of which funded a range of different projects, the benefits picture is naturally varied, with successes, failures, and sometimes contrasting views on benefits. In the following sections we seek to present the balance of evidence together with notable examples of benefits. Chapter 5 then provides a deeper dive into how the design of the different calls and competitions have influenced these benefits.

4.1 Theme 1: Safer, faster, cheaper decommissioning

"The funding is absolutely worth it. It's developed some real solutions to real problems"

"There's so much scope [for cost savings] in nuclear decommissioning we don't know where to start"

"We think there's a potential saving of £4bn from this technology"

"There could be a 20% [speed/cost] improvement compared to the current way of doing things"

"We could see savings in the hundreds of millions of pounds if this is seen through"

"The bigger picture potential is in the billions of pounds worth of cost savings"

"This project has helped to change the prevailing internal "not developed here" mind set"

Ultimately, the aim of the NDA CC innovation programme is to help in the NDA's growing ambition to deliver its mission **safer, faster and at lower cost**.

The story we found here was that **the potential for cost savings is exponentially larger than the cost savings that have been realised to date**. To a large degree this reflects the long-term nature of innovation and the fact that many of the competitions and calls described in chapter 3 are relatively recent or indeed still ongoing. However, it does also reflect that the route to full deployment can be a difficult, with many consultees discussing the challenges of the slow route to market, particular difficulties for SMEs, and the challenges posed by process and the need for culture change.

Nevertheless, we did find examples of cost savings already being delivered due to the programme, such as through laser cutting technologies being used to significantly reduce the cost of skip cutting, by an estimated £500k per skip . Indeed, TWI have estimated that decommissioning of all the contaminated Magnox skips using the laser technology would

provide a cost reduction of approximately £30m.[13] We were also informed that Sellafield have put up a complete system based around this new process at their facility, which is helping to deliver real cost savings.

Over a third of respondents to the survey thought that positive material impacts on safety, cost and speed (36%, 36%, 43% respectively) have already been delivered, as shown in Figure 15 below.

While these survey results could equally be interpreted as saying that a majority of respondents thought that material impacts have not yet been delivered, it is nevertheless clear that there is a **huge prize on offer** if new techniques are able to be successfully developed and deployed across the NDA estate. As can be shown by several of the quotes above, many industry consultees thought that the scope for cost savings is in the hundreds of millions if not billions. As discussed in the following section, when set against the bigger picture cost of decommissioning over the next 100 years, the relatively modest NDA CC innovation programme could pay for itself many times over with only a small impact on these costs.

Our review of Innovate UK and TSB project completion forms found various other specific examples of actual and potential savings, such as:

- an expectation of a £1m cost saving from the use of the funded laser technology on-site
- Identified potential for 50% reduced concrete waste on future projects due to optimised surveys
- Potential savings of £10m to the NDA from use of combined acoustic and modelling technology for each waste stream
- A 60-day speeding up of the time to decommission a single cell, offering a potential saving of £10m per cell

The longer term savings realised will naturally depend on the extent to which solutions are further developed and then deployed widely across the NDA estate and beyond, though the general picture from our desk-based research and interviewees was one of huge potential.

4.1.1 Illustrative return on investment analysis

In this benefits study we do not attempt to make any formal judgement on whether the NDA CC innovation programme has proven itself to be value for money, and likewise we do not seek to carry out a detailed cost benefit analysis or other similar assessment. We also note that even if this were an aim of this study, data availability for legacy programmes (see above in section 1.4) would hamper the ability to do this robustly.

However, building on the point discussed in section 4.1 above around the potential scope for cost savings being in the hundreds of millions or billions, in this section we present a simple analysis based on this 'size of the prize' point. In Chapter 5 (section 5.8), we then present potential ROI based on previous Innovate UK evaluations, which are discussed in the chapter. Neither the analysis set out below or the subsequent Chapter 5 analysis are

[13] https://www.twi-global.com/media-and-events/insights/laser-cutting-an-innovative-approach-to-size-reduction-of-magnox-skips

intended to be firm estimates of actual return, whether already-realised or expected, and are presented purely for illustrative purposes.

As a starting point for our initial analysis, we take publicly-available estimates on future UK decommissioning costs, and assume that NDA CC innovation programme has some effect on these. We use the 2020 House of Commons Publics Accounts Committee report on the NDA's management of the Magnox contract, in which it is stated that "the cost of the long-term liability to decommission the UK's civil nuclear sites now stands at **£132 billion**".[14]

As a cost profile for this £132bn figure is not publicly available, we use the profile that was set out in the 2018 National Audit Office publication on NDA progress with reducing risk at Sellafield, reproduced below, and scale the £132bn accordingly.[15]

These costs (as noted in point 3 in Figure 5) are real and not nominal, so no inflation-adjusting is required. We then use standard HM Treasury discount rates (i.e. 3.5% for the first 30 years, 3.0% for years 31-75, 2.5% thereafter) to discount future costs.

We then assume that the NDA CC innovation programme plays some role in cost reduction. Following discussion with the NDA Finance team, we understand that some innovation-driven cost reduction is already 'baked in' to the cost assumptions set out above. We assume, therefore, that without the programme, costs would be higher than in the above projection.

The question of 'how much higher is realistic' is one that we do not seek to answer here, as it is beyond the scope of this simplistic analysis and would need a more detailed study to consider. We leave this open to the reader for the time being. Instead, intended purely as an illustrative analysis, we calculate the difference in (present value) costs between the following two scenarios:

- **With NDA CC innovation programme**: £132bn cost to 2120, in line with cost profile set out below
- **Without NDA CC innovation programme**: costs increase over time to be 1% higher by 2030, then 1% higher per year for the remainder of the 2030-2120 period

In this illustrative analysis, the cost saving due to the programme (present value, 2020 prices) per 1% impact on longer-term decommissioning costs is estimated to be **over £400m**.

We estimate the total cost to the public purse of the programmes that constitute the NDA CC innovation programme (see chapter 3) at between £35m and £40m over 15 years (2006-21). This includes contributions from all delivery partners, e.g. Innovate UK, EPRSC, DASA, and not just the NDA – the NDA Corporate Centre contribution is estimated at £18m (see Chapter 3).

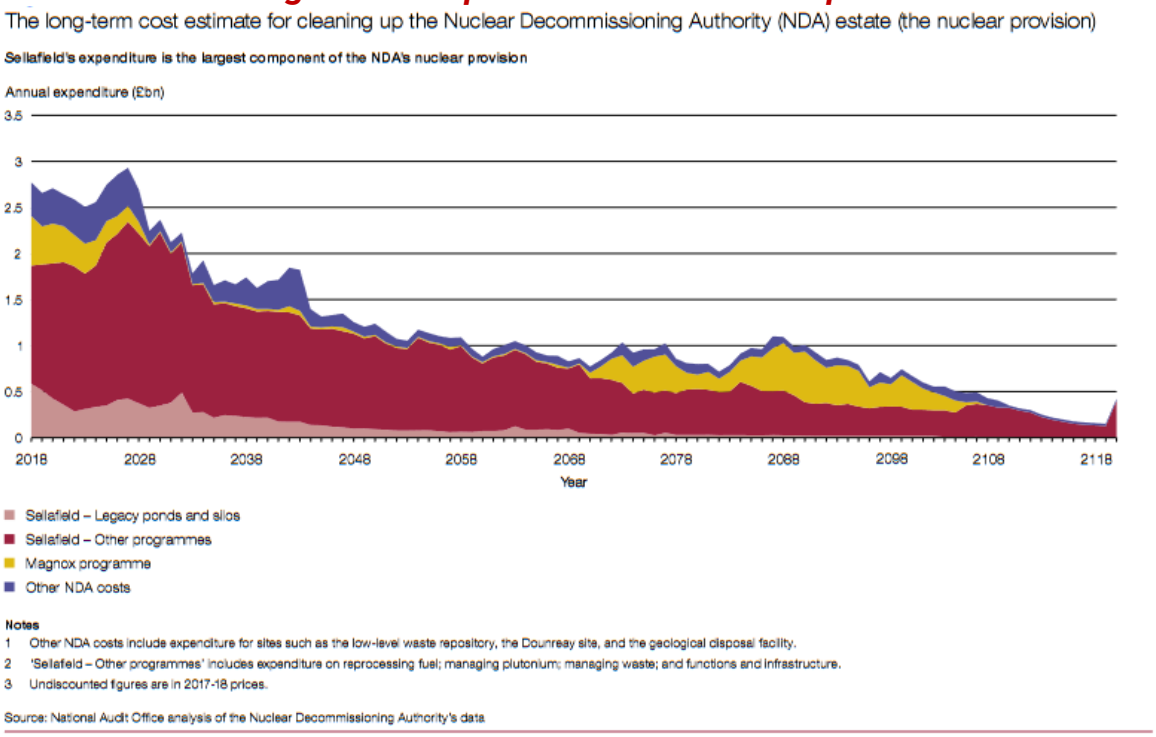
As such, **if it was seen as credible that without the 2006-present NDA CC innovation programme, decommissioning costs would be at least 1% higher, then the programme could be seen as likely to pay for itself more than 20 times over** based on the NDA contribution, or more than 10 times over based on contributions from all delivery partners. Similarly, if a 10% difference in costs was seen as credible, then a

[14] https://publications.parliament.uk/pa/cm5801/cmselect/cmpubacc/653/653.pdf

[15] https://www.nao.org.uk/wp-content/uploads/2018/06/The-Nuclear-Decommissioning-Authority-progress-with-reducing-risk-at-Sellafield.pdf

benefits of over £4bn could be realistic, with a 100x return (though this would ignore any future funding inputs). Again, we make no judgement on this point but only seek to present this as a 'what if' style analysis.

Figure 5: Cost profile from 2018 NAO report



As suggested by the NDA Finance team, an interesting extension to this analysis would be to carry out a comparison to other sectors such as pharmaceuticals, aerospace, steel, or automotive to see what quantum of cost saving has historically been realistically attributable to public innovation funding. We are unaware of any analysis of this sort available in public literature, so leave this as an illustrative analysis for the time being while noting the potential value in such a comparison being made.

4.2 Theme 2: Technological progress

New products and services

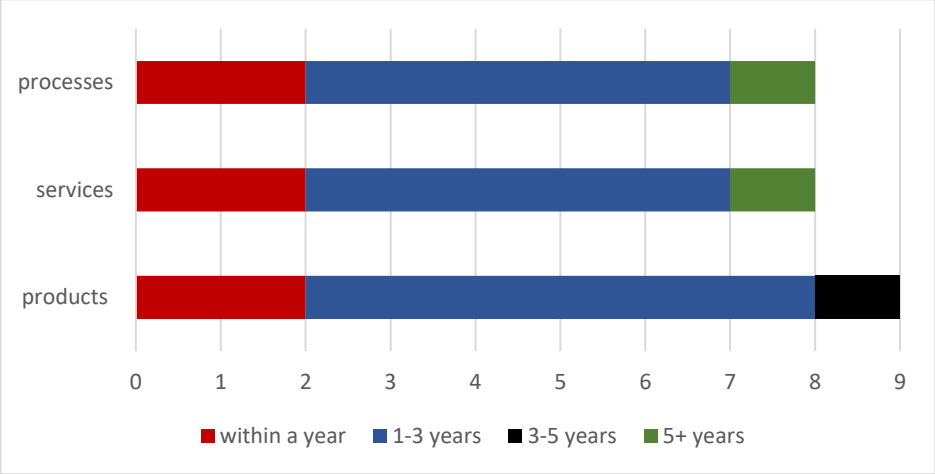
> *"Laser cutting and robotics systems have become the norm – if it wasn't for the NDA [CC innovation programme] and Innovate UK funding, this would not have happened"*
>
> *"It has introduced robotics and imaging technology into a part of the nuclear industry that has traditionally relied on low tech solutions."*
>
> *"[The project has] accelerated our time to market and we're now ahead of our US competitors. We believe we have a world leading capability."*

A clear theme from our evidence-collection was that NDA-funded projects were typically successful in their aims to raise the technology readiness levels (TRLs) of new products, processes and services.

Around a third of respondents to our small-scale survey (31%) reported that the projects had already led to new products or services[16], while many interviewees pointed in particular to the impact that the NDA CC innovation programme has had in terms of **developing and spurring on the use of robotics** in Sellafield and other sites. One industry consultee noting there was "no doubt" that uptake of robotics, laser cutting, and AI technologies has been accelerated. We present an in-depth case study of the LaserSnake technology below, which many interviewees pointed to as a strong example of technical success.

A high proportion of companies who completed project completion forms for projects run in collaboration with Innovate UK[17] expected that (at the time of completing the report) they would launch new products, services or processes as a result of the project. For example, 100% (9 out of 9) of organisations expected to introduce new products within 5 years, with 8 out of these 9 expecting this to be within 3 years.

Figure 6: Do you expect to introduce any new products, services or processes as a result of this project (n=9)?



Source: Innovate UK project completion forms

[16] Question: 'Did your involvement directly or indirectly lead to any new products/services being commercialised?', n=13
[17] With the caveat that forms were not available for all projects, or for all calls and competitions.

While not directly comparable to the 9 Innovate UK project completion forms due to differences in questions asked, our analysis of the 12 TSB (precursor to Innovate UK) project completion forms found that in total, funded companies reported that 7 new products and services had already been launched due to involvement in the projects.[18] This represents a small subset of the 170+ projects funded through the NDA CC innovation programme and, while scaling up to the total would be methodologically unsound (in particular as the forms are likely to be for some of the more successful projects), it is likely that the 'true' number of new products and services launched is higher, potentially significantly so. Indeed, for the 21 projects for which we were able to obtain Innovate UK (9 forms) or TSB (12 forms) project completion forms, **17 of the 21 (81%) reported that the project results had been successfully met**, with the number rising to 21 out of 21 when partial success is included.

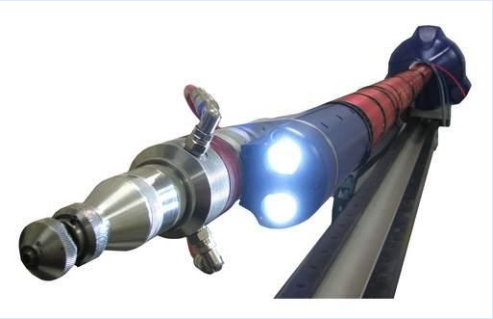
While the question of route to market / wide deployment is a more difficult one, which we discuss in more detail below, interviewees were typically positive about the technical success of their projects. Naturally, not all projects were successful, though, with numerous interviewees stressing that failure is an inevitable part of innovation activity and that it should be embraced. Some respondents pointed to the IIND programme as a good example, where technologies have been developed to high TRLs, with at least two now on site at Sellafield and another solution undergoing testing abroad.

The RISER[19] project, funded through the Energy Game Changers competition, was seen as having had an influence on the use of Unmanned Aerial Vehicles (UAVs) in decommissioning activity, which offers the potential to reduce risk and offer cost savings relative to the status quo, e.g. where the need for in-person inspection could be reduced. Consultees at Sellafield Limited (SL) noted that they conducted over 200 UAV flights in 2021, with around 60% being asset inspection tasks. A paper written in October 2021 ('Sellafield UAV Case Study') noted that Remote Visual Inspection (RVI) and UAV technologies used in the case study had removed 3840 working-at-height hours, accelerated the collection of the requested data by 11.5 working weeks, and saved £100k in costs. The paper recommended that the use of RVI and or UAV's are considered as first choice for all asset inspections at height at Sellafield, suggesting much larger scope for cost, speed and safety improvements in the site.

[18]Question: number of new or improved products or services launched?
[19] https://bbsr.co.uk/products/riser

Figure 7: LaserSnake Case Study – technology development

A series of NDA investments from 2008 have supported the development and deployment of an innovative remote-controlled laser-cutting technology; LaserSnake. It has already led to cost savings, new business opportunities and exports, with significant future growth potential that could see the technology pay for the original NDA innovation investments many times over.



Technology development

In 2008, the NDA awarded its first Technology Demonstrator Project to TWI for a project looking at the use of fibre lasers for concrete surface removal and remote pipe cutting. The project took the established use of lasers for accurate cutting in other industries, such as aerospace and automotive, and focused on opening up their broader application for remote laser cutting in nuclear environments.

The project was a success, advancing laser cutting systems to TRL 5, enabling the NDA estate to make informed decisions on usefulness and application and the technology was demonstrated to a range of SLCs, regulators, and supply chain businesses[21].

Two further NDA-funded projects, in 2010 and 2012, saw TWI partner with OC Robotics to combine the laser-cutting technology with a 'snake-arm' robot that could be controlled remotely to navigate contaminated areas. The technology was dubbed LaserSnake, and would go on to become the first ever fibre laser cutting in contaminated environments with all operations conducted from outside the process area.

Deployment

Following the 2012 LaserSnake2 project, the technology was successful demonstrated at Sellafield in 2016, completing the size reduction of an active dissolver cell[22]. In the same year the laser cutting technology, decoupled from the robotic snake arm, was also successfully deployed at the Magnox reactor site to cut up fuel skips safer, quicker, and cheaper than using previous techniques.

More recently, in 2018, it completed a complex procedure on the Dragon reactor at Winfrith, marking the first time laser-cutting technology had been deployed directly on the core of a nuclear reactor. The first-of-a-kind procedure saved at least £200k as well as four weeks on the programme's wider critical path to decommissioning and a large potential radiation dose had additional infrastructure been required[23]. Costs and time savings can be expected to grow as the procedure is refined and scaled up. It is now a core technology for the Dragon dismantling project, and is also being used internationally to support the clean-up operation at the Fukishima Daiichi nuclear power plant, creating exports and international business opportunities for UK companies.

Costs and benefits

The development and successful demonstration of the LaserSnake technology transformed the use of laser cutting in the industry and had a significant impact for TWI, developing skills and understanding, increasing employment, and leading to significant

[20] Source: https://www.ocrobotics.com/lasersnake--nuclear-decommissioning/
[21] TWI End of project benefits report (unpublished)
[22] https://www.twi-global.com/media-and-events/insights/laser-cutting-for-nuclear-decommissioning-at-sellafield
[23] https://www.gov.uk/government/news/snake-slithers-through-to-tackle-dragon

contracts both domestically and globally. The technology has gained interest from countries including Japan, US, China, France, and Eastern Bloc legacy plants.

"Because of the work coming out of the 2010 Technology Demonstrator Project, the laser has become the default technology for the sector."

TWI consultee

For the sector itself, the technology offers not just a cheaper means for decommissioning sites, but also a quicker and safer one, as dismantling times are reduced and the need to put people in contaminated areas is reduced or removed. One industry consultee estimated potential cost savings to SLCs in the UK in the hundreds of millions of pounds.

With total public investment reaching £6.7m[24] over the three central projects, it also demonstrates the significant upfront cost required to innovate in a complex environment, which can necessitate public intervention in the form of funded innovation programmes which provide the resource and direction to enable companies to focus on finding solutions to decommissioning challenges.

"LaserSnake is a fantastic example of a project from NDA funding, it captured people's imagination and opened people's minds – it was a big effort to bring stakeholders around that to show what could be done, and to show what a small team could do."

SLC (Site Licence Company) representative

Further development and applications

Following the success of the initial LaserSnake projects, the NDA and Innovate UK, as well as suppliers themselves, have funded a number of follow-on projects exploring alternative applications or further developments. Whilst not all of these have progressed to market, and many will require further development, they demonstrate the range of potential applications – and benefits – that could yet arise from the initial NDA investment in the LaserSnake technologies.

<u>Examples of further and alternative developments of snake-arm technology</u>

SeeSnake sought to augment OC Robotics' snake-arm capabilities with the radiation mapping capability of Createc's N-Visage technology (funded via another NDA grant).

Robotic inspection of offshore oil and gas pressure vessels saw OC Robotics partner with Chevron North Sea Ltd. To use the LaserSnake technology on offshore oil rigs.

<u>Further development of laser-cutting technology mounted on robotic arms</u>

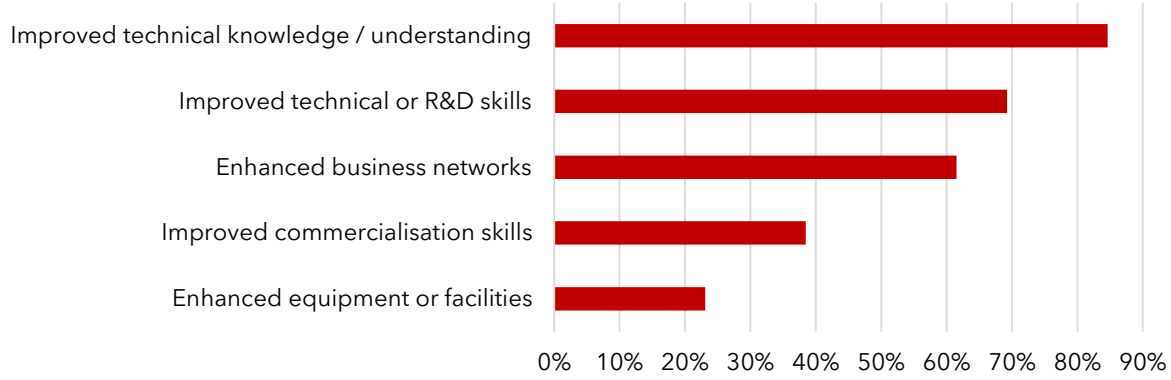
The *Sellafield Skip Size Reduction Facility* uses automated robotic laser-cutting systems to cut and pack two skips to fit inside a third. Inactive trials have been successfully completed and active trials are planned to run from 2021 to 2023[25].

The *Alpha Active Demonstrator* uses a laser-cutting system on a robotic arm to reduce the size of decommissioned glove boxes, minimizing human interaction. Inactive trials have been completed at Sellafield, with active tests planned for 2022. This approach is expected to have safety, cost, and schedule benefits when proven and optimized[26].

[24] From the NDA, DECC, and Innovate UK. The £6.7m consisted of £1m through the original NDA Technology Demonstrator Programme, £112k from the LaserSnake feasibility study, and £5.6m for LaserSnake2
[25] Sellafield annual R&D review 2021-22
[26] Sellafield annual R&D review 2021-22

While the sample was relatively small (n=14), respondents to the survey also overwhelmingly reported that their involvement in the project had improved their technical knowledge and/or understanding.

Figure 8: As a result of your involvement in the project(s), have you (n=14)...



Technology transfer and spillovers

"These programmes play a critical role in connecting actors across different sectors"

"NDA projects give us a base point to develop capabilities and markets so we will be ready to leverage it – in nuclear or elsewhere"

Most companies we spoke to are active in multiple sectors, and there is a clear cross-sectoral story of technology transfer at play – both 'spin-in' of technologies from outside the sector into nuclear decommissioning, and 'spin-out' into other sectors.

Fundamentally, several interviewees including in well-established nuclear industry companies spoke of the benefits of the NDA CC innovation programme in terms of **bringing in new knowledge from outside the sector.** One Tier 2 company noted that every supplier they worked with through the NDA programme was from outside the sector.

Examples of spin-in include Barrnon, who started in the fishing industry, Holoxica and potential applications of holographic technology for nuclear decommissioning through telexistence, i.e. technology that enables a human being to have a real-time sensation of being at a place other than where they actually exist, and being able to interact with the remote environment. These companies are discussed in the *Engaging SMEs* case study in the sector benefits section below.

There are numerous examples of spin-outs and applications of technology developed through NDA programmes to **other areas of the economy**. A frequently mentioned one was the OC Robotics snake arm and its applications in aerospace, with interviewees noting the big scope for cost savings in engine inspection, where robots snaking through the engines could negate the need to dismantle them. With engine maintenance responsible for a significant share of aircraft running costs (noted as 40% by one university-based consultee), this offers a potentially significant source of efficiencies.

Others also discussed new applications of their technologies in areas as wide-ranging as defence (submarine dismantling), medical diagnostics, agriculture (parasite detection), energy (offshore wind), space, and oil and gas offshore decommissioning.

Indeed, the technology transfer process was often noted as being a **two-way rather than one-way flow**, with (for example) programmes such as those currently being run in partnership with DASA/DSTL seen by many as opening up new avenues and collaborations that benefit both the defence and nuclear sectors.

As a small but illustrative example of knowledge impact and benefits, our analysis of the 12 TSB project completion forms found **38 examples of publications (papers and articles) related to the project funding, and 4 patents** (including expected patent applications).

As discussed above (and further below), failure of a given project should not necessarily be seen as a bad outcome. Consultees talked of examples where no commercially viable product was developed, but where aspects of the development enabled by the NDA project have found their way into other commercial propositions for Sellafield, other products on the market, and other customers.

Figure 9: Ice-pigging™ case study – technology transfer to other industries

Whilst the NDA Corporate Centre innovation programme is focused on delivering the mission for faster, safer, and cheaper decommissioning, the nature of innovation means technologies developed through the programme can also go on to drive improvements in other sectors. One of the earliest projects funded by the NDA, through a Concept Development Project competition shows how this type of technology transfer leads to benefits in the wider economy.

source: https://ice-pigging.com/

The ***Ice-Pigging: Effective & Low Risk Pipeline Cleaning using Ice Slurry*** project examined the potential for a pipe cleaning technology that uses ice slurry to remove waste quickly and safely in the decommissioning process. Whilst the initial decommissioning trial was not successful, the technology has proved highly effective for other sectors including manufacturing, wastewater, district heating, and cleaning pipes for drinking water, where Ice Pigging™ can be up to 200 times faster than previous methods.

NDA funding supported the project and also a PhD student, who developed the technology and went on to spin-out a company from the University of Bristol. The technology was licensed to Suez, who went on to acquire the spin-out and now exclusively provide Ice-Pigging™ equipment and services around the world, exporting the technology to countries including Japan and the US. Over 10,000km of pipes around the world have been cleaned with Ice Pigging™ technology, resulting in a return on the NDA investment to the wider UK economy, if not to the nuclear sector itself.

4.3 Theme 3: Business growth

New business

"There's no doubt that the NDA's [Corporate Centre] innovation funding has led to new domestic and international contracts….laser-based work has led to huge amounts of work within the sector, and not just for us"

"It's like a Christmas tree: you can see the snowballing from the original NDA project"

"[The NDA CC innovation programme] give a stamp of approval effect that puts us on the map and gives us credibility"

"NDA projects are a means to step up our capabilities to then use parts of it for our services and to develop more complete solutions"

"The outward-looking, connection-making, success-celebrating attitude the NDA has consistently applied has enabled us to succeed"

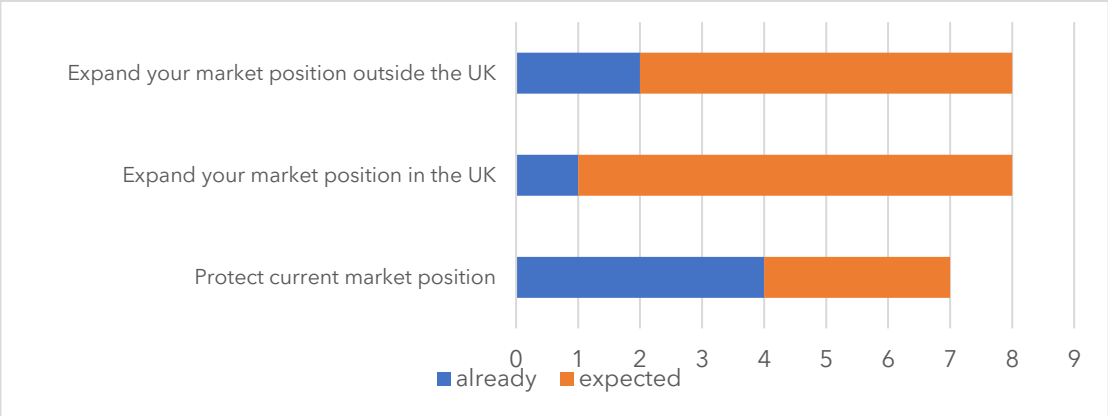
"We have developed a significant number of contacts in the nuclear industry which will help our business grow as a whole"

The second major theme of benefits is around company growth, and the role that the NDA CC innovation programme has played in driving new **revenue, exports, funding, investment, skills, jobs, reputational benefits, credibility, and new partnerships**.

For companies such as Barrnon, Createc, Nuvia and TWI, there is a clear story around NDA innovation funding helping them to grow their revenue and develop new, commercially successful products and services both domestically and internationally.

For example, our analysis of Innovate UK project completion forms is presented in Figure 10 below, showing a positive market impact is expected for almost all participating companies. 7 of the 9 organisations for whom we were able to analyse Innovate UK project completion forms also reported that their commercial opportunity had "greatly increased" (question: "how do you think your commercial opportunity has changed as a result of this project"?) with 1 of the remaining 2 reporting it has "moderately increased".

Figure 10: Thinking about market impacts, do you expect this project to… [n=9][27]



[27] Based on a sample of 9 companies for whom we were able to obtain access to Innovate UK project completion forms for the IIND and *Developing the Civil Nuclear Supply Chain* programmes, i.e. this should not be interpreted as statistically sound across the whole NDA Corporate Centre innovation portfolio.

While benefits cannot be wholly attributed to the NDA CC innovation projects alone, these companies point towards millions of pounds worth of revenues a year that their NDA-funded projects are now realising. As an illustrative analysis, we can show that this could be interpreted as the programme having more than paid for itself in terms of revenue increases for these companies alone:

- Total NDA Corporate Centre funding for the calls and competitions listed in Chapter 3: **£18m**
- As discussed further in the *Growing International Business* case study below, companies we spoke to reported that the NDA CC innovation programme has already contributed toward revenue increases, notably:
    - Barrnon's estimate of revenue from projects: **£5-7m** over 2010-20 period
    - Createc's estimate of revenue from projects: **£1-2m annually** in exports
- If we assume that these revenues will continue to 2030, with £0.6m and £1.5m annual revenues respectively, then we can create an estimate for total revenue (at least partly) attributable to NDA funding over the 2010-30 period.
- For other companies, while evidence is not available on the extent to which expectations have turned into reality, our analysis of 9 Innovate UK project completion forms for the *IIND* and *Developing the Civil Nuclear Supply Chain* programmes identifies a total of £19.3m expected sales revenue as a result of the project, or **£16.6m** without Barrnon and Createc (to avoid double counting)[28]
- We plot this over time, as the project completion forms also noted the time period over which revenues were expected to be realised, and then use standard HM Treasury Green Book approaches to discount future revenues and adjust for inflation.
- We find a total of **£47m** of total increased revenue (present value, 2020 prices) at least partly attributable to the NDA CC innovation programme.

This is not a detailed economic assessment, and we do not factor in considerations such as attribution or additionality, nor do we seek to convert revenue increases to net output (GVA) impact. Instead, we leave it as a simple finding: that **the NDA CC innovation programme is expected to help companies increase their revenue by well over two times the level of the initial NDA funding**. This simplistic analysis also only focuses on a small subset of companies who received funding, and so would likely underestimate true, sector-wide impacts.

While the NDA CC innovation programme is only part of the activity feeding into commercial success, one company funded through the Integrated Innovation for Nuclear Decommissioning programme noted that they have "a clear route to market for any technology that originates from this competition", highlighting:

- A $10-20bn accessible market size in nuclear industry (dismantling)
- $125-175bn market in spin-out nuclear markets (operational support)
- $25-40bn accessible market in non-nuclear dismantling
- Plus $20-40bn accessible market in non-nuclear spin-out (design, licensing)

Companies noted objectives to achieve 50% market share in overseas markets for specific technologies, to more than treble their turnover over five years to £10m+, and to access numerous new international markets that were not previously available. In the quantitative

[28] Project form question: "Thinking of the likely impact of these new products, services and processes [that have been introduced as a result of this project], what do you expect the future average annual financial impact in pound sterling, to be on your sales and licensing revenue?"

analysis above we do not include these revenue projections, given that they were framed more in terms of general company direction rather than new turnover specifically attributable to the NDA-funded innovation activities, but many interviewees were keen to highlight the important role that these activities play within their wider strategy.

There is a particularly strong story for Barrnon and Createc in terms of exports and international expansion, which we explore in the case study below. This story is far from unique to them, however, with 38% of respondents to the survey reporting **new international business** as a result of NDA funding (Question: 'Did your involvement in the project lead to any commercial relationships with overseas customers/institutions?', n=13).

Some companies stressed that (in their view) many others are missing a trick through *not* pursuing more export opportunities, noting that it is a major opportunity for the UK nuclear sector given the UK's history in nuclear technologies and decommissioning.

Beyond these companies, several others also pointed to the role that NDA funding and activity has played in terms of generating interest from both the UK and overseas. Some interviewees pointed towards the snowballing effect that can happen over time, as experience is gained and products are successfully developed. In the words of one industry consultee, "the value of projects is getting bigger and bigger, and lots of confidence is being built", while another (earlier stage) interviewee noted that "it's a process of building out credibility".

The 9 available Innovate UK project completion forms also supported the positive export story, with **8 of the 9 companies reporting that participation in their project had increased their likelihood of exporting** goods or services.

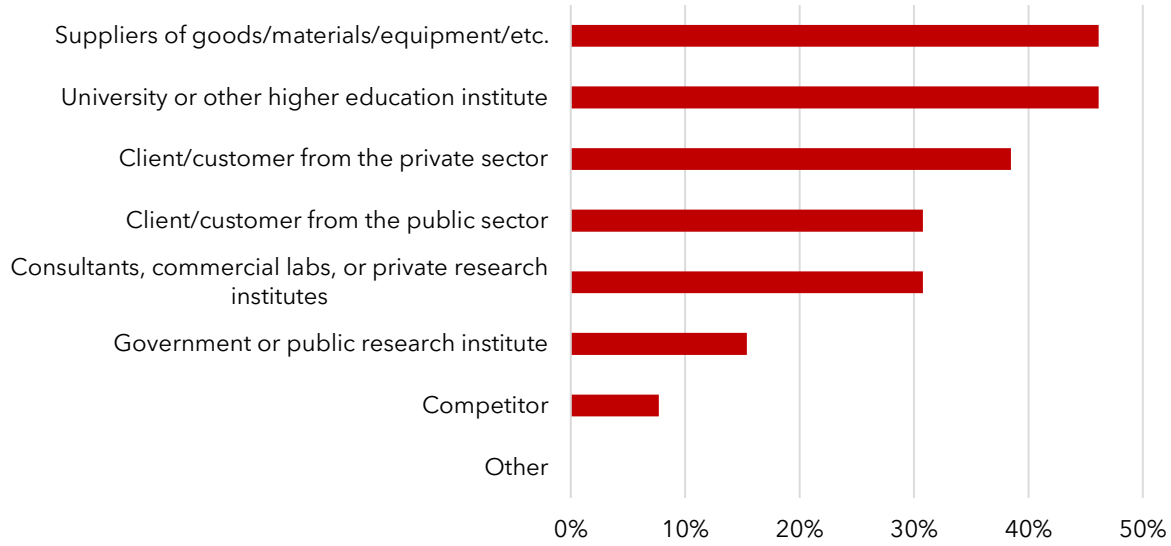
An important way through which the NDA CC innovation programme helps enable these exports and lead to benefits for funded companies is through opening new markets. Domestically, the defence market was frequently noted as particularly important and where new avenues had often been opened, often through indirect routes following NDA projects, such as **new collaborations** that had been secured or even chance conversations that happened along the way. We investigated this in the survey, where between a third and a half of respondents reported new collaborations with suppliers, academics, or customers in the private sector.

Similarly, our analysis of Innovate UK and TSB project completion forms found that of the 21 organisations for whom forms were available, **20 of the 21 organisations reported that they expected to continue collaboration after project completion**.

Often, the NDA funding was seen as playing a particularly important role in boosting companies' **reputation, credibility and visibility**. At least four companies we spoke to talked about the 'stamp of approval' effect that the programme brought, which is seen as being **particularly important for SMEs**. In the simple words of one SME, "more people now want to work with us". While NDA CC innovation programme funding is only one of many ingredients evidence for this effect can also be seen in supply chain awards, where for example:

- Barrnon won the Queen's Award for Enterprise for innovation in 2021, as well as other awards including the Innovate UK SME award for Innovation in 2016 and the Real Innovation Award from the London Business School.
- Createc won the Queen's Award for Enterprise: International Trade 2018 and the Queen's Award for Enterprise: Innovation 2019.

Figure 11: As a result of your involvement in the projects, have you formed any new collaborations with (n=14)...



The business growth benefits were often enabled through the **new and strengthened partnerships** that NDA innovation funding helped deliver. Interviewees noted, for example, that being able to invite prospective companies to see physical demonstrations gave them credibility in being seen as being able to deliver a project on time and successfully. As shown in Figure 8, over half of respondents to our survey (57%) reported that they had enhanced their business networks as a result of their involvement in NDA-funded projects, while over a third (36%) reported improved commercialisation skills.

Companies also noted that the programme directly incentivised them to go to new companies, with one consultee commenting that there was a "large number of companies that we would not have worked with without this project and funding" and another noting that the programme "got us talking to new people, and has led to new opportunities beyond the NDA project". This route to impact through spurring on new collaborations is a particularly important one, and one that helps deliver longer-term benefit to the UK economy even where a given project was ultimately unsuccessful.

Figure 12: Growing International Business Case Study

Through opening doors, building connections, and driving innovative solutions to industry challenges, NDA support for business innovation is helping drive exports and economic growth through international expansion. In successful cases, this has led to **revenue generated worth 20-40 times the original investment** through the NDA Corporate Centre innovation programme.

Several companies highlighted the positive effect that support from the NDA CC innovation programme has had in developing products and services for international clients. In the case of Barrnon, a specialist engineering company based in Cumbria that pivoted to nuclear from the fishing industry, NDA funding provided the resource as well as the direction, enabling a pivot from the fishing industry to now focusing 100% on nuclear. An initial NDA grant of £136k to develop their innovative sludge-dredging technology has since led to work with Japan and the US, and **export revenue estimated at £5-7m over the last decade**. Barrnon has also received further funding to develop the technology further, including from the Department of Energy in the US [ref: Dry Sludge Retrieval System – DOE Chief Technology Office].

Another company, Createc, noted that the NDA has been instrumental in helping grow their international business both directly from the projects supported and through forging broader relationships with overseas clients. A £50k NDA grant to test the feasibility of their N-Visage technology enabled its development and growth, opening the door to collaboration with Japan, and leading to **annual export revenues of between £1-2m**. The non-funding aspects of the NDA's activities were also highlighted as impactful, through introductions, organising trips to the UK for overseas customers as part of wider NDA activities, and promoting the strengths of the UK supply chain.

"The NDA makes a massive difference in terms of UK industry's standing in the global market"

Small, high-growth technology company (Createc)

Other companies who have benefitted in this regard include Nuvia, the international nuclear engineering, project management and service provider, who won new business in Canada after their participation in the IIND programme.

Even where projects have not directly led to commercial success, they have provided a route to new commercial relationships with international clients. A key aspect of some NDA-funded competitions has been not just the development of technology, but the opportunity to demonstrate the outputs to potential customers, including from overseas.

For an established large company specialising in nuclear services (Cavendish Nuclear) this provided an opportunity to demonstrate successful outputs from a technology innovation project to potential clients from Japan and Canada. The successful demonstration boosted their credibility as an innovative company able to deliver, which over time has led to a closer relationship and new contracts coming through.

"Being able to invite overseas clients to a physical demonstration got us a lot of credibility as a company that can deliver a project successfully and on time. It opened doors for us."

Tier 2 supplier

Jobs and skills

"It [the NDA CC innovation project] has been a key part of getting our skills to where they need to be"

"This is vital for our organisation and [the NDA CC innovation programme] has been a critical part of the story – there is a clear message from the NDA that they want robotics and autonomous systems to be used"

"It's helped us strengthen our skills in robotics and the integration of robotics in complex systems"

"The Robotics department in its entirely was created through the project, and it's at least twice the size that it would have been by now without it"

Most companies we spoke to had positive stories to tell on skills and jobs benefits due to NDA funding.

Some spoke about the benefits of the NDA CC innovation programme in terms of **allowing them to try riskier activities and explore different ideas**, in turn helping develop their capabilities and skills in a way which 'status quo' activity would not. The point was also made that even where projects were unsuccessful, new knowledge was gained that could still have future value to a given company or the wider sector.

Firstly, many companies reported having scaled up their teams and recruited in direct response to winning a given contract. This **recruitment often turned permanent** if the project led to follow-on activities and business (though likewise where a project was ultimately unsuccessful, they were often let go). Companies we spoke to spoke of having increased headcount as a result of NDA Corporate Centre innovation funding by 6 people, 7-8 people and 20 people respectively – with the latter being noted as **high-skill employees** being paid wages over £50k p.a. We found examples of companies who had grown from small beginnings (in some cases one person operations) to over ten or twenty staff, with the programme recognised as playing a core role in this growth, while other, larger companies noted its role in developing entirely new areas of their business.

Linked to the company growth story set out above, as companies grow and expand due (at least in part) to NDA innovation funding, this leads to **longer term jobs growth**. Several companies noted that beyond the job numbers referenced above, the programme is playing a key role in the wider growth story of their organisations.

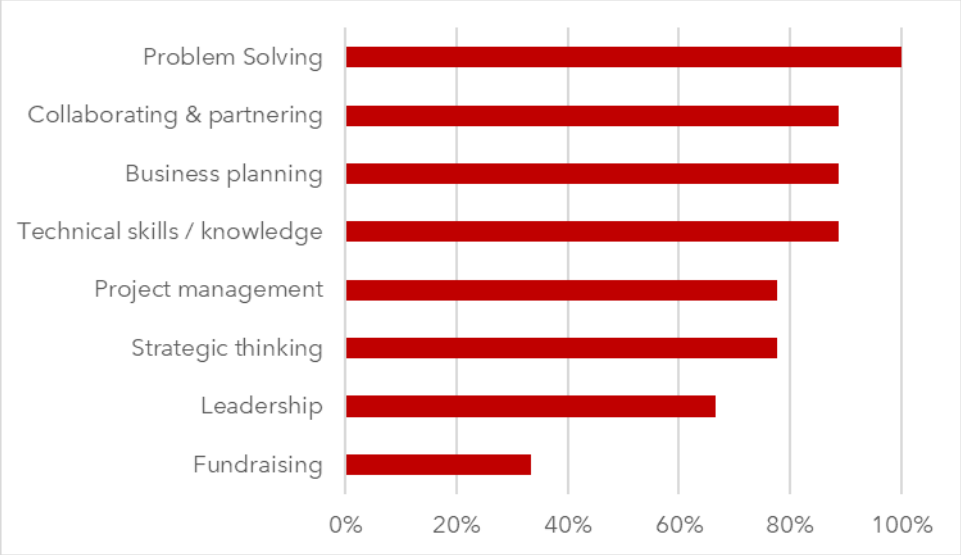
While only covering a small subset of the 170+ projects funded through the various calls and competitions that constitute the NDA CC innovation programme, the 9 Innovate UK project completion forms we assessed for the *IIND* and *Developing the Civil Nuclear Supply Chain* calls provide some quantitative evidence on jobs creation and retention:

- **21 jobs were reported to have been retained** during the projects, and **8 jobs created** as a result of participation in the projects
- Within 3 years of project close, **33 jobs were expected to be retained**, and **37 jobs created** as a result of participation in the projects
- Within 5 years of project close, **67 jobs were expected to be retained**, and **116 jobs created** as a result of participation in the projects

Analysis of TSB project completion forms for 12 funded projects (mostly feasibility studies) also found another **35 jobs** that were reported to have been created or safeguarded as a result of these projects (44 in total, though we remove companies covered by the 9 Innovate UK forms, due to the risk of double counting).[29]

For skills, almost two thirds (64%) of respondents to our survey also reported that they had improved their technical or R&D skills as a result of project involvement, as shown in Figure 8 above. This was supported by our analysis of project completion forms for the Innovate UK-run 'Developing the civil nuclear supply chain' and 'Integrated Innovation in Nuclear Decommissioning (IIND)' programme, which – while the sample size is small (n=9) – found an overwhelming majority of participants reported improved or developed skills, as shown in Figure 13.

Figure 13: Did funding for this project result in the development of new skills or improvement of existing skills for your work force in any of the following areas [based on IUK project completion forms, n=9]:



[29] Question: Number of new UK jobs created or existing jobs safeguarded. TSB forms did not distinguish between created and safeguarded, so cannot be directly combined with the Innovate UK figures presented above.

Figure 14: From Elephants to Ants - Case Study on driving growth through nuclear innovation

NDA, in partnership with BEIS and Innovate UK, launched the £8.5m Integrated Innovation in Nuclear Decommissioning (IIND) SBRI competition in January 2017. It was a competition that maximised the potential for innovation, seeking integrated end-to-end solutions to characterise the environment, dismantle cell contents, and package it away in a safe manner.

For Createc, a UK company specialising in technology and innovation in industrial applications, IIND was an opportunity to develop and demonstrate their vision for nuclear robotics, and their ambition to integrate modular robotic solutions and software tools into the decommissioning process. *Elephants to Ants* enabled them to take on a nuclear project that was bigger in scale and ambition than anything they had done before.

Working with a consortium of partners, including RACE, REACT Engineering, RED Engineering, StructureVision, OC Robotics, and IIT, they focused on an open, modular, and reusable system of smaller robots - 'ants' - rather than a single large 'elephant'. This novel approach provided a versatile and resilient system of robots capable of adapting to conditions and challenges. This meant the project not only provided a solution for the lead customer, Sellafield, but also enabled Createc to adapt it for wider commercial use - something that was critical to the success of the project for Createc.

"Given the broad scope of the competition brief, we combined that request with observations from other stakeholders around the world. Based on this, we were able to provide a solution that not only met Sellafield's challenges, but had generic value in global markets. We immediately knew how we could adapt it to make it available to the wider market rapidly."

The project has had a lasting impact for Createc. It led directly to the development of an in-house robotics capability, with 5 permanent roles in the new robotics team that are still in the company today, along with a further five throughout the wider organisation which has grown to around 30 people in total. Beyond nuclear decommissioning, it opened up robotics as a new business line in multiple sectors, now bringing in a substantial portion of their overall business. This resulted in a lasting step-change in revenue, jumping by around 30% a year and continuing to grow from there to a forecast 100% growth by 2023.

The project has led to commercial opportunities in Japan, where *Elephants to Ants* is being applied at the Fukushima Daiichi nuclear power plant. The first phase of this work alone has led to 60% growth in Createc's nuclear business in Japan, prompting the opening of a branch office in Tokyo to promote future growth opportunities. The potential export revenues from future phases could be in the millions of pounds, just from one application with one customer of the project outputs.

The project has also led to a new spinout company – Createc Robotics – focused on broader applications of the technology and software. Createc Robotics has broadened the customer base for the technology and is already bringing in an annual turnover of hundreds of thousands of pounds.

4.4 Theme 4: A stronger sector

"Without that original NDA investment, support and encouragement, we wouldn't exist"

"Through competitions giving the opportunity to work with established operators such as Cavendish and Jacobs, many robotics companies who were not working in nuclear have been brought in"

"It's a classical insular engineering community with a tight supply chain, and it's unusual for people to talk to you if you don't have relationships with the big guys – the [NDA CC] innovation programme helps on that front"

"[The NDA CC innovation programme] has encouraged us to do development work and to think bigger because we would not have done this without a good level of customer buy-in"

"If we didn't have [the innovation programme] we wouldn't be developing solutions to some of the thorny challenges we have in the sector"

"These programmes allow us to take a step back and explore new solutions in a direct-to-customer project"

"It provided us with the time and discipline to really engage with Sellafield to (a) understand their needs and (b) take on board their ideas for the next phase of trials."

Whilst the c. £18m size of the NDA CC innovation programme (£35-40m including spend by all delivery partners) needs to be contextualised against the much larger nuclear decommissioning sector as a whole (e.g. £132bn estimated decommissioning costs over the next century, as discussed above), we found evidence that the programme has had some success to date in terms of strengthening the nuclear decommissioning supply chain. The main routes to these benefits we identified are through:

- **Bringing in new entrants into the sector**, particularly innovative SMEs
- **Enhancing innovation capacity** and innovation/operational **capabilities**
- **Improving openness to innovation** within the sector

For new entrants or spinouts, companies such as Createc and Barrnon have been discussed in the analysis above. We also spoke to other innovative SMEs who have been brought into the sector, such as the Shadow Robot Company who are working on technology transfer into nuclear, albeit with limited sales to date, and Holoxica, an innovative SME (profiled below). Having these new entrants is seen by almost everyone we spoke to as having a positive effect on the sector, **increasing its depth, resilience and skills base**. Others, though, were keen to point out that while this movement is positive, it is still a sector dominated by a few, large, long-standing companies.

For innovation capacity and capability, many companies were keen to stress that the NDA CC innovation programme helps them carry out activity that they would not otherwise undertake ("we wouldn't be doing any of this stuff"). Based on the evidence we received, we judge that the programme's **benefits and impacts are highly additional**, and view that it is unlikely that they would otherwise have been realised through other activity by Operating Companies (OpCos) or their supply chain. For example, all 9 of the companies for which we were able to analyse Innovate UK project completion reports stated that

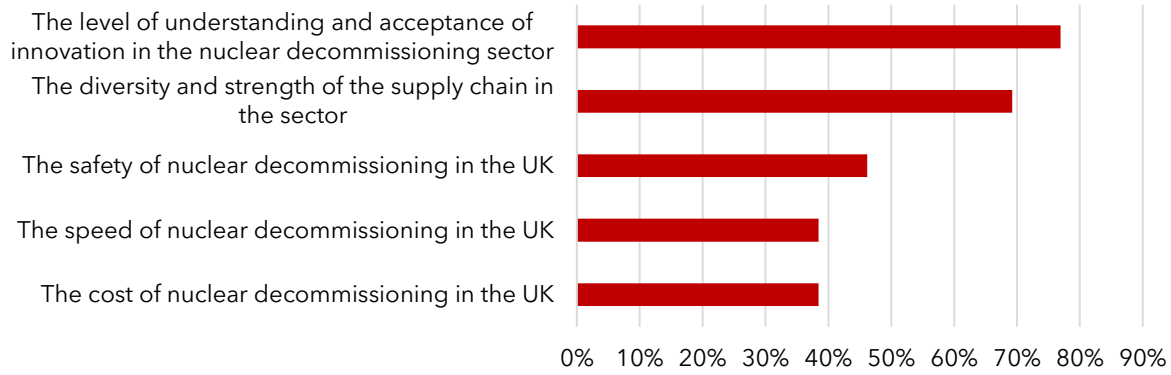
their project would not have gone ahead had they not received Innovate UK (and by extension NDA) funding. A core aim of the initial programme calls and competitions was to test approaches and better understand the art of the possible, with a view towards long term potential, rather than seeking short-term commercial gain for funded companies. This affects how the benefits set out here should be interpreted, i.e. given that the focus has been on setting the groundwork for longer-term activity, many of the benefits are expected to come in the future and will not have been realised to date.

This does however cut both ways. Many companies who were selected in initial phases of competitions but who were then ultimately unsuccessful in securing next-phase funding spoke of their products "sitting on the shelf", requiring further investment if they are to progress further. With a limited innovation budget, the inevitable result is that there are many potential solutions that to date have not yet delivered on their potential: "the story is around the benefits that could have been", in the words of one company.

A similar point that was often raised by interviewees is around the need for a 'pull' from potential customers, and how new products or techniques can only be developed so far without this. In some cases we found examples where projects had been technically successful, but without a clear route to deployment had not progressed any further. One company told us that they have "an all-singing, all-dancing system that's ready to go, but it's not clear when or if it'll ever go ahead – without the route to market and end-user interest, it's gathering dust". We explore barriers to impact further in chapters 5 and 6.

We asked all the interviewees about their perceptions on whether the NDA CC innovation programme and activity has had a meaningful impact on **attitudes and openness to innovation within the decommissioning sector**. Views were mixed, but many were positive in their assessment, for example noting that the programme (and the activities of the NDA technology and innovation team in particular) has helped lead to some change in mentality and attitudes to risk within the wider NDA estate. Overall, around 7 in 10 respondents to our small-scale survey thought the programme has had a positive effect to date on this front, with a little under two thirds (64%) reporting that there had been a **positive impact on the diversity and strength of the sector supply chain**.

Figure 15: From your perspective, do you think the NDA Corporate Centre innovation programme has had a material positive impact on (n=14)...



Such as one exists, the consensus seemed to be that there has been movement in the right direction over the last 10-15 years, with more focus on new technologies, less (unnecessary) risk aversion, and greater openness to new ways of working. Almost all consultees, however, were similarly keen to stress that there is still a long way to go and

that the issue of culture change in particular (discussed in chapter 7) is a critical one ("it is difficult to turn the oil tanker").

For operational capabilities, while many new technologies still have some way to go before they are fully deployed across the NDA estate, some consultees were keen to note that the programme is helping lead to better ways of working – for example through taking humans out of hazardous environments (e.g. Telexistence, UAVs) or enabling on-site processing rather than needing samples to be sent across the country.

We found some quantitative evidence on the impact of the NDA CC innovation programme in terms of spurring on further R&D spend. For the 9 projects for which we had access to project completion forms for Innovate UK-partnered programmes, for the question "are you planning on conducting further R&D to commercially exploit this project?" 8 of the 9 respondents responded affirmatively. **Total expected follow-on R&D spend reported from these projects was £7.1m over 5 years**, with an average of £0.9m per project (range £0.1m-£1.5m).

Figure 16: Bringing innovative SMEs into the sector - case study

A key aim of the NDA CC innovation programme is to bring new innovative companies into the nuclear supply chain from other industries, enabling the application of existing technology to benefit the sector and help achieve its mission of safer, faster, cheaper decommissioning.

Links to R&D intensive sectors, particularly those also grappling with hazardous environments, are clear and we heard many stories of cross-overs between nuclear and aerospace, defence, and oil & gas. But innovation occurs in all sectors and we also saw example of less likely candidates successfully entering nuclear innovation as a result of the programme.

The International Growth Case Study above shows how the NDA's funding for early-stage research into the use of sludge dredging technology supported Barrnon Ltd. to pivot from the fishing industry, to be 100% focused on nuclear engineering.

NDA funding gave me a clear path to follow – one I might not have been involved in otherwise. With that direction, we turned ourselves into 100% focusing on the nuclear industry instead of fishing.

Andy Barr – CEO, Barrnon

More recently, the Telexistence call with DASA attracted Holoxica, an award-winning high-tech company specialised in holographic 3D visualisation technologies, to try new applications of their technology for nuclear decommissioning. *Holographic 3D Telexistence with Light Field Displays for Remote Object Interaction* was supported with a £56k grant and was instrumental in engaging Holoxica in the nuclear sector, broadening out from their existing applications including medical imaging, engineering, and architecture. The technology is still being developed, but has clear potential for saving human lives, as well as export revenue for Holoxica.

NDA innovation activity has definitely improved the understanding and acceptance of innovation in the sector, from our experience, and it has supported new companies to come into the sector with their technologies. If we hadn't received this grant, we would have continued to grow our capabilities… but not involved in nuclear decommissioning.

Wendy Lamin – co-founder, Holoxica Ltd.

Challenges in realising the potential

"Proof of concept is easy, it's integrating solutions into a business that is difficult"

"Nuclear is a hard nut to crack. We've been kicking on the door for 12-14 years, and might finally make sales in next 12 months. Fundamentally, the industry is structured in a way that leads to continuation of the status quo"

"We're [the NDA group] good at developing good ideas, but not finishing them"

Most consultees we spoke to highlighted the **slow route to market** and challenges in reaching full deployment for their technologies and products.

There are arguably particular **difficulties for SMEs**. Given that SME time horizons are typically short term focused, given the need to find sources of revenue quickly, the long timeframes are often not conducive to their participation in the sector, where deployment of technologies on-site can take many years to achieve. Ultimately, few SMEs can develop new ideas and products based on a potential payoff that can be years in the future.

SMEs also noted the difficulty in speaking directly to end-users, in competing with established tier 2 companies, and in the challenges from procurement rules and bureaucracy. For example, some described the level of reporting and meetings required as "onerous for often small amounts of money", while others expressed frustration with not being able to speak directly to end-users. We note, though, that many of the comments we heard on procurement difficulties related to wider issues in working with decommissioning sites rather than commentary on the NDA CC innovation programme specifically. Indeed, most interviewees were positive about the work of the technology and innovation team and very much welcomed the existence of the programme, though were keen to point out these wider issues that affect commercial realities.

Many were of the view that it is too difficult for them to build a business solely around nuclear decommissioning given these challenges, and viewed that it is often necessary to make a success outside nuclear then seek new applications of their technology within the sector ("we need applications in other sectors, or international markets to tap into").

Beyond Sellafield, there is of course a much wider decommissioning sector, and as part of our end-user stakeholder engagement we also held discussions with Magnox and Dounreay. Again, here the story appears to be one of somewhat limited engagement with the NDA CC innovation programme to date, reflecting organisational strategies at the time. However, interviewees saw good longer-term potential and recognition of the importance of the programme in future. Clearly full engagement with and involvement of all potential end-users will be key to unlocking the potential benefits that could be realised.

The wider story around the need for **culture change** came out as a strong theme from our discussions. Sellafield themselves (or at least the teams we spoke to) agreed that it is fair to say it takes too long to get innovative ideas to deployment at the moment, and the delivery partners and end-users were all keen to stress the importance of involving the operators and others who will actively be using new technologies in their day jobs. Arguably this has not been done enough to date – at least according to many of those we spoke to.

A common view we heard was that historically, innovation has not been necessary for the organisation's success for many years, which in turn has led to a "cultural deficit" across the NDA Group in relation to innovation. Many interviewees spoke of risk aversion within the organisation, and an "if it ain't broke, don't fix it" attitude that can be prevalent. As we discuss further in chapter 7, it will be necessary to align incentives if innovation is to be widely deployed. For example, if a new innovative method is a new entry on a risk register, and a given individual or board's role is to manage that risk register, it is unlikely to be embraced as a new and better way of working. These challenges all influence the extent to which future benefits will be able to be realised.

5 Effect of programme design on realised benefits

We have seen in chapter 3 how the NDA Corporate Centre (CC) innovation programme developed over time, utilising different mechanisms and delivery partners to support innovation for nuclear decommissioning, and chapter 4 discusses the benefits that have been realised as a result of the programme. This chapter looks at the different stages of the NDA's activity and considers **how the design of the programme and the combination of support mechanisms has both delivered on a range of different objectives for the programme and affected its overall impact**. It draws out the varied routes through the logic model enabled by the different mechanisms, drawing out examples which demonstrate those pathways to impact, and sets out evidence from the existing literature on the impact of the mechanisms used.

5.1 Direct calls for R&D

Following the NDA's initial CDP and TDP calls, an internal review in 2010 found that whilst the vast majority of projects were successfully completed, it was a time-consuming process for the NDA to award and monitor projects, the route to market for innovations was not always clear, and the potential benefits of funding cohorts of projects was not always realised, which in part contributed to a move towards working with external partners such as Innovate UK to deliver calls.

Pathways to impact for innovation, however, can take many years, and evidence from this review has demonstrated significant benefits from these early programmes which would not have been known about or realised back in 2010. Some of these have already been explored in the previous section, and include the £50k grant in the 2007 CDP call, resulting in a technology which is yielding £1-2m export revenue each year for Createc Ltd., and was instrumental to the company existing at all, according to Createc CEO Matt Mellor.

In another example, the continued development of the technology demonstrated in the TDP led to LaserSnake and a series of laser-cutting and robotic projects which have yielded significant benefits (see case study at Figure 7). Further, a number of consultees highlighted the benefits of competitions which focused specifically on smaller companies, offering funding for a wide range of projects.

As such, whilst the findings of the 2010 review should not be discounted, the benefits of revisiting such an approach should also be borne in mind for future planning purposes.

> *The NDA could have a greater impact if they ran more grant schemes like [CDP]. The focus was on small businesses, place-based economic development, technology-based. Without that initial funding, we wouldn't have companies like Barrnon in the sector.*
>
> Medium nuclear engineering company (not Barrnon)

We are very small, but we're bidding against Tier 2, Tier 1 companies. The competition should just be with other small companies. We should encourage the NDA to engage more directly with SMEs and support brokerage between them.

Small company with experience in SBRI phase 1

5.2 Partnership with Innovate UK

In partnering with Innovate UK, the NDA was able to utilise a range of new mechanisms, from feasibility studies similar in nature to the CDP programme, to later-stage collaborative R&D, KTPs, and pre-commercial procurement through SBRI. Each of these mechanisms offered something distinct to the NDA, providing alternative routes through the logic model. This is shown illustratively in section 5.5.

Early-stage feasibility and proof of concept projects explore the potential of new ideas which are still some way from market. Through funding a larger number of small projects, companies are enabled to try higher-risk projects, many of which can be expected to fail, but some of which have the potential to lead to significant impacts over time through further R&D activity. Projects funded through these calls included the initial RISER project which brought a greater focus on the use of UAVs for decommissioning, Barrnon's horizontal sludge dredging research, and Lucideon's research into treating radioactive waste.

Collaborative R&D projects provide more funding for later-stage R&D, increasing collaboration between academia and industry as well as the large established companies in the sector and innovative SMEs from the wider economy. These projects can lead to outputs higher up the TRL scale, with prototypes developed and potentially moving towards on-site testing and new products/processes reaching the market. The collaborative nature of the projects also supports a key outcome from the logic model: strengthening supply chains and better connectivity.

The ability of Collaborative R&D projects to deliver these outcomes was seen in a 2014 grant to Viridian Consultants Ltd. It followed a successful FSP project in 2012 and provided funding for Viridian to work with Sellafield to develop a novel mobile Non-Destructive Testing (NDT) sensor for nuclear decommissioning. This three-year project enabled them to take the output of their successful FSP and develop it much further along the TRL scales, working in collaboration with the end user and successfully demonstrating their capability on site. They have since gone on to develop a laser sampler from the product and now have a full laser sampling system ready to commercialise which if deployed would increase safety and speed and lower costs.

KTPs offer a different route, focused on university-business knowledge exchange, increasing industry skills and absorptive capacity, whilst finding solutions to technical challenges. One of the KTPs funded by the NDA, with LabLogic Systems Ltd., demonstrates how this mechanism can help develop skills and produce technical solutions for decommissioning. The Gamma Interlock Monitor offers increased reliability over the existing systems at the time, and was developed over a three year KTP project to

provide inbuilt fault detection and warning systems. The NDA's research manager linked to the project noted in a 2014 report

> *The delivery of LabLogics' KTP project demonstrates the mutual benefits for both academic and commercial organisations in collaborating on technical challenges that support decommissioning. KTPs are an effective way of developing the capability skills base at a more fundamental level.*

As the NDA's partnership with Innovate UK developed, so did their use of the mechanisms on offer to achieve nuanced outcomes. On the surface, Energy Game Changers was a feasibility studies call, but with new features to encourage a particular direction and type of innovation. There were three themes specified for the call: taking inspection to the limit; dealing with data; and engaging in energy. This provided some direction, whilst still leaving the scope open enough for a breadth of innovative solutions to come through.

The second key feature was the requirement for each project to be led by an SME whose main business lay outside the sector their project was addressing. This feature in particular directly addressed some of the NDA CC innovation programme aims around bringing new organisations into the field of nuclear innovation, as well as seeing existing products applied in nuclear decommissioning for the first time.

5.3 A move towards pre-commercial procurement

SBRI again offers a different approach for achieving the objectives of the NDA CC innovation programme. Competitions can be more specific but still with a degree of openness. IIND looked for solutions which integrated a range of technologies onto a platform to perform multiple decommissioning tasks. This provided a clear challenge for companies to focus on, but also a broad enough remit to realise wider commercial value, as demonstrated in the *Elephants to Ants* case study. The phased approach also offers the benefits of feasibility studies in that it casts a wide net with smaller projects, but then has a clear process for providing further funding to the most promising ideas.

The really distinctive aspect of the programme, and one which could prove particularly powerful in the field of nuclear decommissioning, is the ability to have the call directly aimed at an end-user challenge. This provides a clear 'market pull' for the R&D, meaning not only should it be more likely to meet the NDA's needs, but also provides a clear route to market for the suppliers. For the IIND call, NDA worked with Sellafield Ltd., who provided in-kind support, so that solutions could be directed at the specific challenges faced on the Sellafield site. Sellafield provided input to the scope and direction of the first two phases, and is providing partial funding and a site for an active demonstrator in phase 3.

However, this advantage of end-user input was also to the detriment in some aspects. Some consultees noted that the rules of engagement (i.e. for the 3 phase SBRI competition) – Sellafield Ltd. has to remain neutral between all projects, unable to engage directly and only able to respond to questions through an open response to all projects – meant there was less engagement with the end customer than normal.

"Having your main customer distanced from the project was not good – it was a constraint meaning we couldn't talk to the customer in the way we normally would, to solve challenges and produce a better solution"

IIND phase 2 awardee

A further issue raised by a number of consultees was that this competitive, stage-gated process meant that if you were unsuccessful at phase 2 or 3, it was a big deterrent to continuing to develop your solution, even if what you had developed was working and had good commercial potential.

When we were unsuccessful for phase 3, it almost precluded Sellafield as a market for [our solution] as they'll have more of a commitment to the two consortia who won the phase 3 projects. The logical and most easy to access market has gone.

IIND phase 2 awardee

5.4 Partnership with DASA

In broadening their partnership activity with DASA, through DSTL, the NDA Corporate Centre sought to reach a broader and more diverse audience, create additional routes to market alongside the Innovate UK mechanisms. Through partnering with an organisation focused on the defence and security markets, it also opened up further potential for technology transfer from others sectors and leverage R&D activities funding elsewhere.

There were further perceived practical advantages in working with DASA, as very long lead times were required in order to secure competition slots in the Innovate UK process. Using another mechanism that was owned by a central government department – in this case the Ministry of Defence as the parent Ministry of DSTL – was deemed a low risk approach to broaden the programme's approach.

As with the *Energy Game Changers* call, through partnering on a call which had a broader focus across multiple sectors, the *Telexistence* call provided an opportunity for technology transfer across sectors, and opened up a range of innovative companies that might not otherwise have worked in the nuclear sector (see *Bringing innovative SMEs into the sector* case study above). This included through opening up collaboration and networking opportunities.

Phase 1 [of the Telexistence call] was very important in building new connections and networks. We could reach out to other winners.

Non-nuclear SME, successful in phase 1

Building on the lessons learnt in the Innovate UK SBRI calls, the second Telexistence call is being run using an open call for phase 2, rather than restricting it to those successful in phase 1.

Throughout the development of the programme, the NDA Corporate Centre has demonstrated a willingness to continue to evolve, learning from the strengths and weaknesses of different mechanisms to continue to offer new routes for innovations to

come to market for nuclear decommissioning. This is now extending to cross-Government learning as lessons from Innovate UK approaches are applied at DASA.

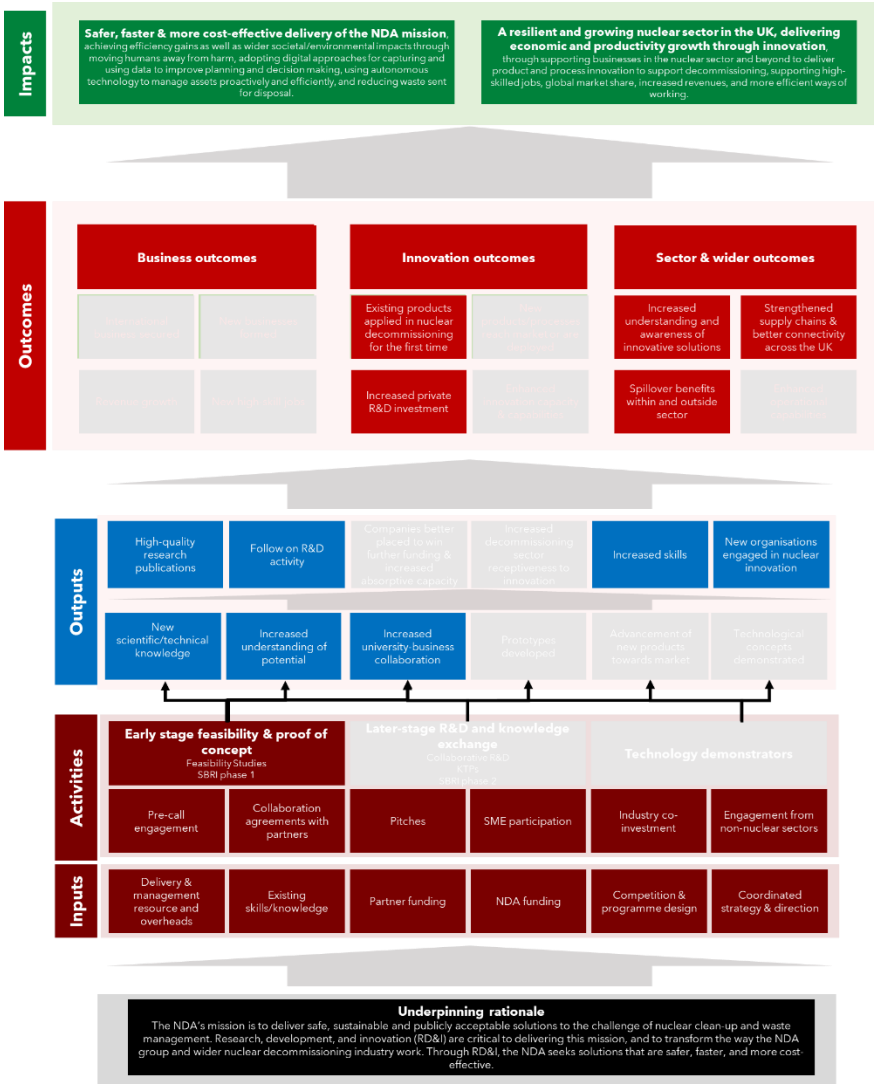
5.5 Alternative routes through the logic model

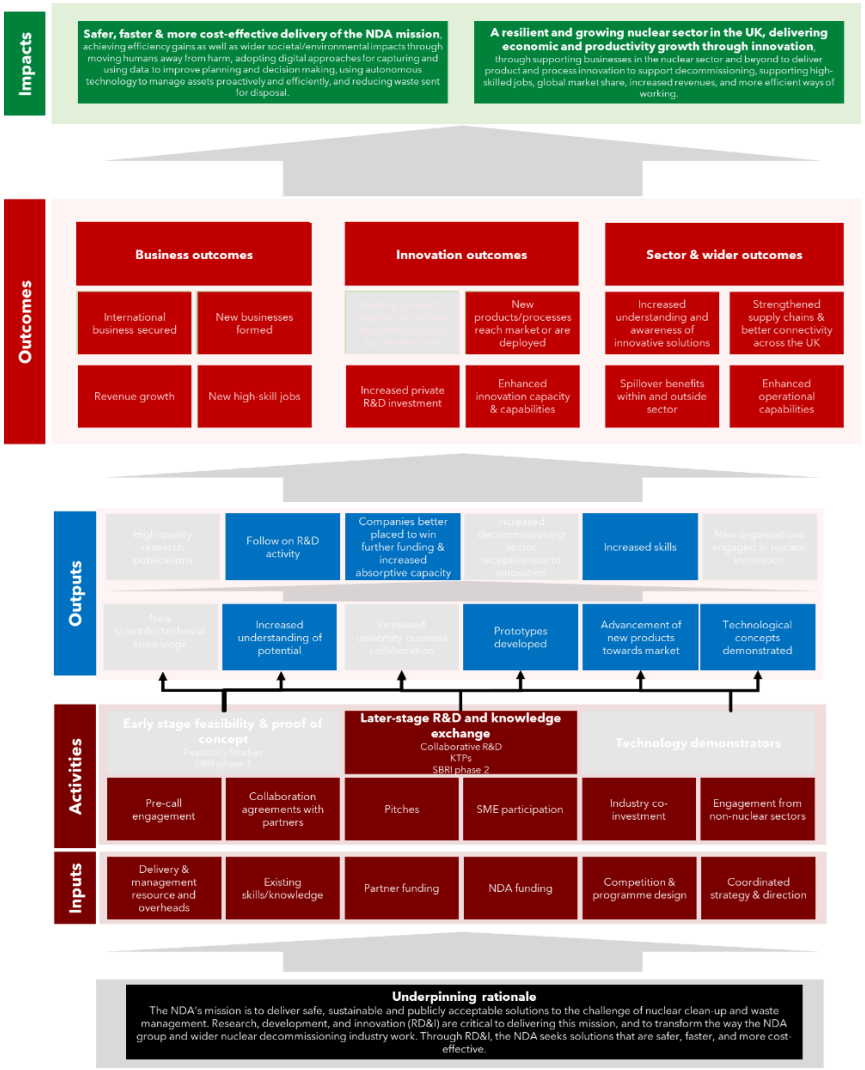
The different aims and processes provided for by the range of interventions described in this section can allow for a range of different routes through the logic model. In practice, different routes through could be found within each mechanism, but the more significant differences are driven by the actual design of each call.

Figure 17 below provides an illustrative example of what this could look like in practice. The left-hand picture shows what the logic model might look like for a feasibility study which does not immediately lead to further development and progress to market, with outputs and outcomes not realised greyed out. We can see that despite the lack of commercial success, a number of outputs are still realised, including increased knowledge, collaboration, and skills, whilst some outcomes could also be realised in terms of knowledge spillovers, increased investment, and increased understanding.

The right-hand picture is based on the *Elephants to Ants* case study in Figure 14. In this case, we see a number of outputs realised, particularly focused on demonstrating technologies and advancing them towards market. Almost all outcomes are realised to some extent in this example, with increased revenue, exports, a spinout formed, enhanced operational capabilities, as so on. In both examples, the two impacts could still be realised, although they would take much longer to occur in the case of the feasibility study, and might in practice be realised through another project in the future.

Figure 17 illustrative example of routes through the logic model for a feasibility study and a phase 2 SBRI





5.6 From innovating to implementing

A number of consultees noted difficulties in making the leap between an innovation project and a commercial agreement with OpCos. There was a strong perception that innovative solutions were considered too risky or costly to implement, and a suspicion that solutions which reduce the manual labour required for decommissioning were not welcomed due to the risk of reducing employment.

Small, large, and academic consultees all noted that a more conservative approach to innovation at Sellafield, in particular, hindered commercial outcomes and implementation, therefore affecting the ability to deliver the NDA's objectives. This also makes it very difficult for SMEs to get a strong foothold in the sector. Two small companies noted the difficulties they face in getting innovations adopted in the UK:

> *We couldn't get any work in the UK so we didn't have a choice but to follow the path of least resistance. Most of our business is now from overseas. UK SLCs are very unreliable clients, despite projects being successful. The way they manage commercial projects is horrendous!*
>
> Small engineering company

> *We developed a tool [to reduce waste] but it is an added complexity on the process, so have never been able to sell it as nobody is incentivized to reduce waste products. They are actively disincentivised from trying new things, or from investing now to save in the future. They take extra cost to not invest.*
>
> Small technology company

> *There seems to be an assumption that if you do the first bit [R&D] the second bit [adoption] will follow. There needs to be something that allows not just for testing of an innovation but it's actual use. There needs to be something from the NDA that promotes or encourages deployment. Proper trials. Seems like there's a gap there at the moment.*
>
> Large nuclear solutions provider

A consultee from a university who had worked on a number of NDA funded projects noted the difficulty small companies face in securing a commercially stable presence in the sector:

> *I was involved in a spinout company… [it was] founded in 2014 and had a commercial offering in 2015. Sellafield didn't buy it until 2020. The industry makes decisions very slowly, commits to funding very slowly, and doesn't give good continuity of funding. It's better for companies to serve other markets and then add nuclear to the portfolio… it's very difficult to focus on nuclear.*
>
> Academic specialising in nuclear research

Whilst other consultees also noted similar concerns, there was also some evidence that the situation is improving with time, not least because of the NDA CC innovation programme and the mechanisms it uses:

Historically it was very difficult for technology innovators to make business in the UK – the UK nuclear sector would be the last adopter. The NDA has managed to shift the culture, and create opportunities with companies that wanted to make that change. Now you can sell your product in the UK and the NDA finally sees some benefits – for the first seven years [2010 – 2017] benefits bypassed the NDA.

Small technology company

5.7 Existing evidence on the impact of innovation support mechanisms

Despite a wealth of evidence being available on the impact of public support for innovation more broadly, there is scarce evidence specific to nuclear decommissioning, or even the wider nuclear sector. Given the broad range of factors which could affect the impact of an innovation programme between sectors, including the variety and extent to which market and system failures are present, this broader evidence should only be used indicatively, rather than to draw any firm comparisons or conclusions.

There are four published evaluations which do include evidence directly relevant to this study. All were commissioned and published by Innovate UK to look at the impact of their funding mechanisms, which have formed a part of the NDA CC innovation programme through their partnership with Innovate UK.

5.7.1 Feasibility Studies Programme evaluation

Published in July 2013[30], the report found good evidence that the programme was successful in encouraging more business investment in R&D and commercial outcomes. 8% had already developed new products or services and 88% said they expected additional profits. Other benefits included higher profile (69%), value of business (58%) and in some cases (30%) ease of raising finance, all of which align to the NDA CC innovation programme logic model set out in chapter 2.

A calculation of the benefits of the programme found that £1 of grant had already produced £1.75 of additional GVA which could grow to £2.70 as the R&D projects continued over the following few years. There was also the potential for greater gains in future as the R&D was deployed in new products and services of up to £5.70 per £1 of grant.

Uniquely among the existing evidence, the report provides evidence specifically for the nuclear sector, based on the NDA-supported (but not funded) open call in June 2010. These projects accounted for 5% of the total awards covered by the evaluation, although they were larger than average in terms of value, worth 13% of the overall budget. The average project cost of £122k was more than double the average of £55k and the third highest sector in this regard. Additionality[31] for the nuclear projects was higher than

30 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/626872/TSB_Feasibilty_Studies_Programme_-_Evaluation_Findings_2013.pdf Accessed 13/09/2021

31 Additionality was defined as the proportion of respondents stating the definitely or probably would not have achieved the same results without the support of the programme.

average, at 78-86%, higher than for health, energy, materials & nano, space, and digital. Sector-level findings for GVA impacts were not provided.

The relatively high additionality of nuclear projects aligns with the findings of this report that a lot of activity supported by the NDA CC innovation programme simply would not have happened in the absence of the NDA's support. Based on our consultations, this is likely at least in part driven by the complexity of the sector and the relatively large and accessible sectors where nuclear solutions could be applied, such as defence or oil & gas.

5.7.2 Knowledge Transfer Partnerships evaluation

Two evaluations, published in 2010 and 2015, set out the impacts of Knowledge Transfer Partnerships.[32] Whilst there is no information in the reports specific to the nuclear sector (although the 2015 report does note the NDA had been a partner organisation for a competition), the findings provide the most relevant impact evidence for this element of the NDA CC innovation programme.

The reports recognised the importance of the wider benefits from KTPs that were not possible to capture in the return on investment calculation, such as increased capacity for innovation for businesses and spill-over effects from businesses to their suppliers. 94% of Associates reported a positive impact on their personal or career development and 82% of knowledge base respondents cited closer partnerships with industry as a result of participation in the KTP programme.

These impacts align to aspects of the logic model for the NDA CC innovation programme, with increased university-business collaboration, increased skills, and new high-skill jobs. KTPs were also noted as a particularly effective method of engaging with SMEs, and research-related benefits such as publications, enhanced teaching materials and new research projects and staff skills development suggest strong positive impacts in terms of knowledge creation and dissemination, aligning to NDA objectives around high-quality research publications as well as greater understanding and awareness of innovation opportunities in the nuclear sector.

Across the two reports, a total ROI for the programme, based on the impacts realized by KTP associates and beneficiary companies, was estimated to be £7.5-£8 of net additional GVA for every £1 of grant funding. They also found that on average, each partnership has created (or expects to create) 3 additional jobs excluding that of the associate.

5.7.3 SBRI evaluation

Published in November 2017, an evaluation of the SBRI programme predated any NDA sponsored competitions, and so findings should only be used as indicative of the type and scale of impacts the NDA's SBRI activity might have.[33] Results should also be treated with caution due to very low response rates to the survey which formed the primary research tool for the evaluation, which had an effective sample size of just 38 companies. Furthermore, analysis was conducted just two years after the award of an SBRI contract, meaning there had been limited time for impacts to materialise.

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[32] 2010: https://webarchive.nationalarchives.gov.uk/ukgwa/20140827133341/http:/www.innovateuk.org/_assets/pdf/corporate-publications/ktp%20strategic%20review%20feb%202010.pdf
2015: https://www.gov.uk/government/publications/the-knowledge-transfer-partnership-programme-an-impact-review

[33] https://www.ukri.org/publications/review-evaluation-of-the-small-business-research-initiative/

The programme showed high levels of additionality, with just 5% of projects proceeding unchanged without support, and 39% proceeding but with reduced scale or delayed. The SBRI process was found to be "catalytic", in that if offers an opportunity to develop and trial products that would normally remain on the drawing board. Econometric analysis showed turnover increases of around 12.7% across phase 1 and phase 2 competitions, with a benefit:cost ratio of 1.6 to 2.4. Given the limited time for impacts to materialise, this can be seen as a reasonably positive finding.

5.7.4 Collaborative R&D evaluation

Innovate UK (TSB) published an evaluation of their Collaborative R&D programme in September 2011 covering projects approved between 2004 and 2009, preceding NDA involvement with Innovate UK.[34] The evaluation found impacts of £6.71 Gross Value Added to the economy for each £1 of grant, excluding spillover impacts. Five percent of projects resulted in 87% of impacts, demonstrating the high degree of concentration of impacts resulting from innovation activities.

5.7.5 Evaluations from other sectors

Evaluations have been carried out in other sectors, which potentially have some relevance for nuclear decommissioning R&D and the NDA CC innovation programme. However, as with the evaluations discussed above, care needs to be taken when making direct comparisons due to differences in terms of scope, methodology and coverage.

An analysis of the return on public investments in the space sector found an average return on investment varying from £2-£4 (direct) to £6-£7 (direct), depending on the funding area (e.g. Earth Observation, Telecoms, Navigation). Spillover benefits are harder to calculate, but were often noted as typically 2-3 times larger than the direct returns (note: spillovers are not included in the Innovate UK evaluations discussed above).[35]

The DSTL Corporate Plan for 2021-2026 notes a return on investment of £6-£55 for every £1 spent, though the methodology for this is unclear.[36]

5.8 Summary & lessons learned

The range of mechanisms the NDA CC innovation programme has utilised provide a nuanced set of pathways through the logic model to achieve impact. It is not appropriate to consider whether some mechanisms are more effective than others, but instead to understand which are more effective at achieving certain outcomes. As objectives for the NDA Corporate Centre evolved over time, so did the mechanisms they used to achieve the desired outcomes. This has been a defining feature of the programme over time, and has likely helped increase the impact of the programme.

The existing evidence on the impact of these mechanisms does not directly cover the NDA-funded calls, but does demonstrate that the mechanisms being used in partnership

34 https://webarchive.nationalarchives.gov.uk/ukgwa/20130221185318/http:/www.innovateuk.org/_assets/pacec_evaluation_of_crandd_report_final260911%20%282%29.pdf

35 London Economics, October 2015, *Return from Public Space Investments*, study for the UK Space Agency. See also: Frontier Economics, July 2014, *Rates of return to investment in science and innovation*, study for BIS (now BEIS).

36 https://www.gov.uk/government/publications/dstl-corporate-plan/dstl-corporate-plan-2021-to-2026

with Innovate UK do, generally speaking, have an impact on innovation and business outcomes, including many relevant to the NDA's objectives. These include economic growth, skills development, increased knowledge transfer between academia and industry, increased R&D investment, increased trialling and demonstration of novel solutions, and increased participation in innovation by SMEs. Numerous examples from our consultations with businesses demonstrate how the mechanisms have successfully realised these outcomes.

All these impacts are crucial to realising the overall ambition of the NDA programme, and so the mechanisms used in the programme can be considered appropriate for its objectives. It is possible to estimate a return on investment of NDA activities to date if we make some assumptions regarding their impact relative to the findings of the Innovate UK evaluations. There are many assumptions required to do this and so findings should only be considered indicative of what might have happened. Grouping NDA calls together according to the mechanisms used to deliver them[37], and multiplying spend by the impact-per-pound findings of the evaluations, we could see **a return on investment to date of between £56m-£77m on the £18m invested by the NDA corporate centre** in Feasibility Studies, KTPs, Collaborative R&D, and SBRI-like mechanisms. This represents a **Benefit:Cost Ratio of between 3.1 and 4.3**. Calculations for this are set out in

Figure 18.

An advantage of partnership with Innovate UK was that the burden of sifting applications and monitoring projects was essentially outsourced. Innovate UK experiences thousands of applications and awards each year, and the application and monitoring processes for those funded by the NDA were processed through Innovate UK's business-as-usual systems. However, attention needs to be paid to potential disadvantages to not conducting these activities in-house, including the increased difficultly of retaining knowledge from the programme if non-NDA staff are collecting and storing project documentation. Access to project completion forms and contacts from funded projects for this report should be considered in any future arrangements with delivery partners as this would aid the assessment of any impacts realised from the projects.

Figure 18: Return-on-investment calculations for NDA calls under the CC innovation programme based on Innovate UK evaluations

Programme	NDA Spend (£m)	Evaluation ROI – low (£s per pound spent)	Evaluation ROI – high (£s per pound spent)	NDA CC Innovation programme ROI – low (£m)	NDA CC Innovation programme ROI – high (£m)
CDP & Feasibility Studies	3.3	1.8	5.7	5.8	18.8
CR&D & TDP	4.7	6.7	6.7	31.7	31.7
KTPs	0.5	7.5	8.0	3.5	3.8
SBRI & Telexistence	9.5	1.6	2.4	15.4	22.7
TOTAL	**17.9**			**56.4**	**76.9**

[37] Here we assume CDP calls are similar to the Feasibility Studies Programme, and the DASA Telexistence call is similar to SBRI. We further assume that the 'special project' in the first *Developing the Civil Nuclear supply chain* call was similar to CR&D, as was the TDP.

Notes: All figures are rounded to one decimal place. CDP calls are deemed to be comparable to the Feasibility Studies Programme and the Telexistence call is deemed to be similar to SBRI. Special Projects and the Technology Demonstrator Programme are deemed to be similar to CR&D.

Key lessons learnt regarding how the NDA CC innovation programme's design affects its impact are that:

- **Direct grants are an effective way to encourage innovation activity in the sector**. Some consultees noted that doing more of this directly by the NDA could be a good way to further develop in-sector experience and expertise, as well as to increase knowledge retention and sharing from supported projects. This would require appropriate funding and/or funding models to be implemented, and additional NDA resources / staff.
- **Having the stage-gating of SBRI was noted as a very valuable aspect** of the programme, enabling a broader range of ideas to be tested before taking forward those with most potential. However, where valid ideas with the potential to commercialise do not receive funding for the second or third phases, this acts as a significant discouragement to continue developing the solution.
- Similarly to the first phase of SBRI competitions, **feasibility study calls get lots of ideas moving, so can be an effective means to catalyse activity**. There is a potentially a higher risk of 'deadweight' - funding projects that would have happened anyway – where established companies in the sector receive small amounts of funding through these calls, but they are likely to be more instrumental for SMEs in other sectors to engage and they support an innovation pipeline of potential novel ideas, even if many, naturally, will turn out not to be feasible.
- **Working with the customer can be instrumental to accelerating development – but is sometimes hampered by SBRI terms**, which limited access to Sellafield during the competitive phases of IIND. The design of the Sort & Seg programme has sought to avoid this issue by running a 2- rather than 3-phase competition.
- **Calls should be kept broad enough to enable wider commercial opportunities to increase the overall value**. When the competition is overly specific about the solution or challenge, it hampers wider commercialisation, making it less attractive and impactful. An broader outcome's based specification enables applicants to consider broader commercialisation potential whilst still seeking to solve the problem at hand.
- Where collaborative projects are led by tier 1 companies in the sector, there is a **risk that the smaller companies are overlooked or marginalised**. One consultee suggested learning from the US, where project KPIs bring a focus on impacts in the SMEs involved in collaborative projects, or providing incentives for increased SME employment, for example.
- **Programme design needs to consider the gap between an innovation project and deployment on site**. Some companies reflected on technologies with the potential to help deliver the NDA's mission being left 'sitting on shelves' as the final step into active use is too difficult. However, this perspective needs to be balanced with the need for market-pull, as well as the end-user's perspective on the value and deployability of the solution.

6 Future monitoring and evaluation

6.1 Context and purpose

As discussed above, the ability to assess benefits enabled by and expected from the NDA Corporate Centre (CC) Innovation programme is constrained by the availability of project documentation and the nature of existing monitoring and evaluation (M&E) activity.

In this chapter, building off lessons learned from our analysis over the course of the project, the evaluations discussed in chapter 5, and the project team's broader experience in M&E for innovation programmes, we present some potential indicators and metrics that could be used by the NDA to track impact in future.

The development of a detailed plan for how M&E activity could be expanded goes beyond the remit of this benefits study, and would require a more detailed consideration of factors which include (but are not limited to):

- The purpose, objectives and questions for future M&E activity
- Links to existing programme and project management processes
- Identification of monitoring and other data requirements
- Data availability and regularity
- Responsibilities for reporting
- Attribution, additionality, and how to establish the baseline
- Resources available for data collection and reporting
- Processes for knowledge management and retention

While we hope the indicators set out here will be a useful starting point for future thinking and activity, they are not at this point presented as a set of indicators that we recommend should be implemented immediately. This would require further development. They will also need to be complemented by other, more qualitative evidence-collection – for example, impacts on understanding and awareness of innovative solutions, or reputational impacts - which may be difficult to measure with quantitative indicators, but are an important part of the impact story.[38]

For robust socio-economic benefits/impact assessment, many of these indicators will also require some elements of self-reported additionality of any observed changes in outcomes (e.g. 'what proportion of your increase in turnover would you attribute to the programme'?). This links to the importance of the baseline identification noted above, given that, conceptually, **impacts attributable to the programme will be (i) impact metrics after completion of the programme, minus (ii) impact metrics in the baseline projection**.

Indicators may also be useful to explore in terms of impacts realised to date, together with expectations for the next 3/5/10 years, as appropriate.

We present the indicators against Themes 1-4 set out above, for consistency and ease of reference.

[38] Though we note potential indicators could follow a 'proportion of firms reporting a positive impact on X' format.

6.2 Potential indicators

6.2.1 Safer, faster, cheaper decommissioning (theme 1)

These indicators are focused on the impact of the NDA CC innovation programme in terms of effect on the NDA's mission to deliver its mission safer, faster and at lower cost.

- Number of offsite trials of new products/services/processes
- Number of on/offsite active use of new products/services/processes
- Changes to baseline plan(s) resulting from projects
- Cost reductions in nuclear decommissioning resulting from projects
- Time savings in nuclear decommissioning resulting from the projects
- Safety improvements resulting from projects
- Waste reduction resulting from the project
- Environmental impacts resulting from the project
- Other impacts on health, welfare and/or social value

6.2.2 Technological progress (theme 2)

These indicators cover new products and services, IP, and technology transfer impacts. For wider 'spillover' benefits in particular, which as discussed above can form a substantial part of overarching impact, we recommend that the indicators presented here are complemented by more qualitative evidence collection.

- Technology Readiness Level at start and end of project (and beyond)
- Impact on time to market
- Patents applied for & granted
- Value of patents
- Number of publications
- Spinouts established
- Increased organisational R&D spend

6.2.3 Business growth (theme 3)

Clearly the NDA CC innovation programme has had a particularly strong impact in terms of helping companies grow their revenue, create and retain jobs, and gain follow-on funding. Suggestions for indicators here include:

- New turnover resulting from the project:
    - from within/outside the nuclear sector
    - from new exports
    - from innovative goods (those released in the last three years)
- Number/value of new markets accessed
- Value of new exports
- Increased market share
- New products brought to market / site use
- R&D employment (FTE created/retained)
- Other high-skilled employment (FTE created/retained)
- Skills / capabilities improvements[39]

[39] E.g. following the Innovate UK project reporting format: self-reported impact on technical skills, problem solving, business planning, strategic thinking, project management, fundraising, leadership, collaborating & partnering

- Follow-on funding from internal sources
- Follow-on funding for external public/private sources
- Private equity or Venture Capital investment in the company

6.2.4 A stronger sector (theme 4)

Finally, and reflecting in particular the strong focus of the earlier calls and programmes in the NDA CC innovation programme in growing the supply chain and positioning for future challenges, relevant indicators for assessing impact in growing and strengthening the sector could include:

- Number of new suppliers
- Number of project collaborations expected to continue
- New collaborations within the nuclear sector (with SMEs / Tier 1 companies / academia)
- New collaborations outside the nuclear sector
- Number of companies previously not active in the sector, who are now active
- Self-assessed improved R&D capability/capacity

7 Conclusion

The NDA Corporate Centre (CC) innovation programme covers a range of calls and competitions that have been run since 2006 and has evolved over time. Perhaps unsurprisingly, therefore, when asking stakeholders about their impressions of a series of very different projects and programmes, we received a wide range of views and perspectives. Still, many clear themes emerged.

There is a clear consensus that the programme is welcomed by industry and wider stakeholders, and that individuals and organisations across the sector welcome its aims and ambitions. People we spoke to were overwhelmingly positive in their views on the work of the NDA's technology and innovation team, and highlighted several successes that the funding to date has enabled. These are summarised against the four primary themes of benefits set out above, i.e. (i) safer/faster/cheaper decommissioning, (ii) technological, (iii) company growth, and (iv) stronger sector. 9 in 10 companies who responded to our survey said that they would be interested in submitting a proposal to any future NDA calls for applications in areas relevant for their business, for example.

However, many of those we consulted were keen to contextualise the size and activities within the programme with the wider challenge – and cost – of nuclear decommissioning in the UK. While the NDA CC innovation programme is only one part of wider NDA and OpCo R&D activity, which also aims to reduce decommissioning costs and so should be factored in to any weighing up of costs and benefits, the different calls and competitions that constitute the programme sum to less than £40m over 15 years (2006-21) – a figure which includes contributions from all public delivery partners and not just the NDA (the NDA contribution is approximately £18m of this). Set against the estimated £132bn cost of decommissioning over the next century, a common view that we heard was that there would need to be a step change in the level of ambition across the NDA Group for innovation – with associated funding increases – if a substantive dent is to be made. Indeed, we understand from our discussion with the NDA Corporate Centre finance team that the £132bn cost already 'bake in' some innovation and cost reduction assumptions, so some success of the innovation programme is perhaps already assumed within these numbers.

Still, one clear conclusion is inescapable: the size of the prize is substantial, and if the NDA Corporate Centre's innovation activities are able to successfully encourage the development, diffusion and deployment of new technologies across the NDA estate, then there is huge scope for cost savings and risk reductions – as well as new business opportunities for UK firms overseas.

Many others – both within and outside the NDA – were keen to stress that the amount of funding is only one factor, and an issue that is at least as important is the one of culture change. Many stakeholders offered the analogy of it "taking time to turn the oil tanker" and noting that innovation has historically not always been encouraged and incentivised consistently across the NDA estate and its precursors, recognising the broader landscape and risk appetite has changed over time. There was a strong consensus that it will be important to involve end-users and to think clearly about how innovative products and processes will be used by them in their day jobs, and what incentives they will have to use them.

In this study we set out to present the different benefits that the NDA's innovation programme has helped to deliver, and we did not have to look hard to find these. Our interviews, supplemented by evidence from the short survey, showed clear and tangible impacts in terms of the development of new products and services, revenues, international business and exports, skills and jobs, technology transfer and 'spillover' benefits, supply chain benefits, and – to some extent – already-realised benefits in terms of decommissioning cost/safety/speed improvements.

While this is not intended to be a rigorous cost-benefit analysis or value for money assessment, there is good evidence to suggest that the programme has already paid for itself in terms of the benefits it has unlocked. An important point is also that – particularly in the early days of the programme – aims were more around longer term positioning and supply chain development, rather than the pursuit of short-term commercial return. Reflecting the long-term nature of innovation (and nuclear decommissioning), it is likely that the majority of benefits are still to come and - set against the scale (and cost) of the challenge ahead – view that there is a strong role for the NDA CC innovation programme to play now and in the future.

Based on the project team's experience of research and innovation evaluations and our discussions with the supply chain in this project, as an independent consultancy we also provide some recommendations for the NDA CC innovation programme's evolution. These are intended to enable better evaluation in future, ensure future decisions are underpinned by the best available evidence, and maximise return on investment:

1. Reflecting the value observed in combining different approaches within the NDA Corporate Centre innovation programme, maintain a **portfolio approach with appropriate risk appetite**, recognising that failure is part of innovation. Many stakeholders were keen to point out that 100% success should not be an aim, that many good ideas will ultimately turn out to not be commercially or technically viable.

2. Seek to build a **culture of evaluation** across the organisation, identifying the right KPIs and metrics to monitor performance and progress, building off the theory of change and initial indictors listed in this report, and ensuring that data collection is built in from the very start of projects.[40] In this study, we were hamstrung to some extent by data availability, often relying on people's memories of projects that were funded many years ago. Proper evaluation plans and an evaluation strategy designed in line with HM Treasury Magenta Book[41] best practice principles would be helpful in this regard – perhaps with funding awards linked to requirements to provide data and evidence at appropriate points. Monitoring processes should also consider future access to key project documentation, and the potential need to differentiate between SMEs and larger organisations for reporting requirements. The indicators set out in Chapter 6 are intended to be a starting point for future thinking here.

3. Focus on **end-user involvement** and the **route to market / wide deployment** of new technologies, in particular being mindful of SMEs' short time horizons and the challenges posed by procurement rules. Calls need to offer commercial returns potential to businesses, and so need to be scoped with wider markets in mind.

[40] We present some potential indicators in Chapter 6 – intended only as a starting point for future thinking in this area.
[41] https://www.gov.uk/government/publications/the-magenta-book

4. Work with the wider NDA Group change programmes to encourage **culture change** for innovation to be embraced. Within this, recognise that there can be a tension between jobs and innovative technologies, and focus on **getting the right incentives in place** to get plant operators, technicians and others interested in adopting new ways of working.

5. Be **substantive** in its ambition, recognising the potential for innovation to drive down huge expected decommissioning costs over coming decades. While the NDA Corporate Centre innovation programme is only one part of wider NDA (and OpCo) R&D activity and so should be understood in this context, a small programme is only likely to be able to have a small impact even if offers high 'bang for buck' returns. While analysing lessons from other sectors falls outside the scope of this study, we note that examples such as the role of public R&D in driving decreases in the levelized cost of energy for offshore wind and other low carbon energy generation technologies may offer useful comparators and case studies.

Annex A: List of interviewees

26 interviews were held in total, with the 33 interviewees listed below (i.e. some interviews were held with multiple participants):

Role	Organisation
CEO	AB5 Consulting
CEO	Barrnon
Senior Technical Specialist	Cavendish Nuclear
CEO	Createc
Director, Principal Consultant (interviewed in context of role as Monitoring Officer for IUK projects)	Execulence
Managing Director	Holoxica
Project Technical Lead	Jacobs
Head of Research, Development and Innovation	Nuvia
Managing Director	Shadow Robot Company
Principal Project Leader	TWI
Director	Viridian Consultants
Remediation Capability Development Manager	Sellafield
Head of Robotics & AI	Sellafield
Robotics & AI Programme Manager	Sellafield
Head of Technical Strategy	Magnox
Engineering Manager	Magnox
Safety Case Manager	Magnox
Strategy and Permission Lead	Magnox
Head of Strategic Planning	Dounreay
Innovation Manager	Dounreay
Technology and Innovation Director	NDA
Head of Technical Assurance	NDA
Group Chief Operations and Performance Improvement Officer	NDA
Finance Team	NDA
Finance Team	NDA
Innovation Lead	Innovate UK
Former Innovation Lead (retired)	Innovate UK
Operations Team Lead	DASA/DSTL
Chief Scientist (NDA) / Chief Nuclear Advisor (BEIS)	NDA/BEIS
Knowledge Transfer Manager	KTN
Professor in Materials	University of Bristol
Professor in Process Engineering	University of Bristol
Strategy Manager	UK National Nuclear Laboratory

Annex B: NDA Corporate Centre Innovation Portfolio

This list covers all projects that were selected, though we have been informed that a small number did not ultimately proceed, for various reasons. Some calls, such as *Developing the Civil Nuclear Power Supply Chain,* had a broader focus than decommissioning and some listed projects therefore have correspondingly wider applications.

Project Title	Competition Year	Lead Participant Name	Award Offered (£)
Concept Development Programme – 1			
Development of an in-situ rheometer for ILW sludges	2006	BHR Group	49,800
Extraction of metals from non-metallic matrices with superheated water	2006	Critical Processes Limited	50,000
Low shear mixing/encapsulation system	2006	NSG Environmental	46,943
Non-invasive removal of the surface radioactive contamination within tanks, silos and ponds	2006	Professional Scientific Limited	45,148
Friction Stir cutting for nuclear decommissioning	2006	TWI Limited	50,000
Innovative use of phase change materials for safe post operational clean-out with minimal effluent production	2006	University Of Bristol	not available
Review of geophysical methods for the identification of radiological contamination	2006	Westlake Scientific Consulting Limited	14,200
Development of Dynamic Tool for Ecosystem risk assessment	2006	Westlake Scientific Consulting Limited	29,400
Recovery of Uranium	2006	PDS	34,250
Thermodynamic stability of depleted uranium in cementitious system	2006	The University Of Sheffield	49,998
An innovative approach to archiving oral testimony and related materials to create virtual mentors for future decommissioning of nuclear facilities	2006	EBM	44,651
Concept Development Programme – 2			
Computer modelling of organic forms from 3D point cloud data for downstream finite elements analysis	2007	Fortis Mechanical Design Limited	33,700
Development of an electromagnetic coil response device to determine the presence & chemical composition of solid objects buried within sludges	2007	Fortis Mechanical Design Limited	43,200
Subsurface penetrating sonar system	2007	James Fisher Nuclear (JFN) Limited	45,000
Large area dose planning and waste assessment tool	2007	React Engineering Limited	50,000
Application of MACSTOR to Advanced Gascooled Reactor (AGR) spent fuel and intermediate level waste storage	2007	Taylor Woodrow Construction	48,300
The development of an ultraportable, digital fast neutron x-ray assay technique	2007	Hybrid Instruments Limited	45,000
Underwater removal of concrete surfaces by laser scabbling	2007	TWI Limited	45,000
Non-destructive testing system for long-term condition monitoring of nuclear facilities	2007	TWI Limited	49,000
A methodology for the assessment of risk from ionising contaminants to populations of non-human biota	2007	Westlake Scientific Consulting Limited	37,900
Product stability by laser examination	2007	James Fisher Nuclear (JFN) Limited	38,000
Shear Cave Laser and Nvisage Scanning report	2007	React	not available

Strategic Environmental Assessment of the provision of a national facility from the incineration of radioactive waste	2007	Nuclear Technologies Plc	45,000
The decontamination of materials arising from decommissioning	2007	RM Consultants	40,000
Decontamination of waste oil	2007	Neales Waste Management Ltd.	47,350
The use of a variable freq sonar device to provide characterisation info	2007	Fortis Mechanical Design Ltd	31,900
Technology Demonstration Project			
Demonstration of concrete surface removal and remote pipe cutting using a fibre laser	2008	TWI Limited	915,300
Knowledge Transfer Partnership			
Target Value Design	2012	Infra-Projects Ltd	£87,208
Safety Integrity Level (SIL) systems for a Gamma Probe	2012	Lablogic Systems Limited	£84,143
3D carbon fibre weaving	2012	M Wright & Sons Limited	£87,665
Copper electroplating at mechanistic level and electrodeposited layers	2012	Bep Surface Technology Ltd	£128,615
Remote monitoring and control equipment for electrical trace heating products	2012	Heat Trace Ltd	£134,116
Condition monitoring techniques for power electronic offshore renewable applications	2012	Land Instruments International Ltd	£100,314
Hybrid modelling approaches using advanced data-fusion methodologies	2012	National Nuclear Laboratories Ltd	£107,975
Integrated heat exchanger design	2012	Turnbull & Scott (Engineers) Ltd	£106,963
3D measuring and cutting in pipe bending	2012	Unison Ltd	£82,986
Developing the Civil Nuclear Power Supply Chain - Phase 1 (CR&D)			
Fracture of Graphite Fuel Bricks	2012	EDF Energy R&D UK Centre Limited	40,351
Measurement and modelling of sludge transport and separation processes	2012	Sellafield Limited	48,998
REsidual Stress and structural Integrity Studies using Thermography (RESIST)	2012	Enabling Process Technologies Limited	56,533
On line and global structural health monitoring of high temperature steam lines	2012	Plant Integrity Limited	72,719
The Influence of Graphite Irradiation Creep on Plant Life Optimisation	2012	EDF Energy Nuclear Generation Limited	98,474
Environmental Impact on the Structural Integrity of Nuclear Components	2012	EDF Energy Nuclear Generation Limited	134,995
Intelligent Condition Monitoring for Civil Nuclear Structures	2012	Beran Instruments Limited	160,346
High temperature radiation hard detectors (HTRaD)	2012	Micron Semiconductor Limited	200,000
Plasma Vitrification of Intermediate Level Waste	2012	Costain Oil, Gas & Process Limited	200,573
Treatment of Irradiated Graphite – 'From Core to Capture'	2012	Bradtec Decon Technologies Limited	250,000
Decommissioning and waste	2012	C-Tech Innovation Limited	256,504
Monitoring Complex Assets using Patterns in Signal data (MCAPS)	2012	Cybula Limited	286,282
Optimisation of large concrete DfMA structures for the Nuclear Industry	2012	Laing O'Rourke Plc	430,096
Advancement of castings in the Nuclear Supply Chain	2012	Sheffield Forgemasters RD26 Limited	633,714
The Development of Novel Manufacturing Techniques for Nuclear Applications	2012	Sheffield Forgemasters RD26 Limited	728,499
Developing the Civil Nuclear Power Supply Chain - Phase 1 (FS)			

Mosaicing for Automatic Pipe Scanning (MAPS)	2012	Scryon (Centerprise International)	24,132
ViridiScan: a novel mobile NDT sensor for nuclear decommissioning and homeland security	2012	Viridian Partnership	42,000
Development of high fluidity, high radiation tolerant, inorganic encapsulant for difficult to treat radioactive waste	2012	Lucideon Limited	44,517
agBox™: A micro-fluidic based on-line alpha, beta and gamma spectroscopy instrument	2012	Microlab Devices Limited	45,000
Development of Arvia™'s second generation electrochemical technology for the treatment of high-alpha contaminated organic wastes	2012	Arvia Technology Limited	46,558
Permanent Ultrasonic Monitoring Array (PUMA)	2012	Kande International Limited	47,441
Remote Intelligent Survey Equipment for Radiation (RISER)	2012	Blue Bear Systems Research Limited	48,029
Depth Measurement Technique for Entrained Radioactive Contamination	2012	Create Technologies Limited	50,237
Visible Light Communications for Sensors	2012	Purelifi Limited	51,264
Augmented Reality Maintenance System (ARMS)	2012	Amtech Group Limited	53,500
Developing the Civil Nuclear Power Supply Chain - Phase 2 (CR&D)			
Net Shape Manufacture for Energy Efficient Reactors (NEER)	2014	Hauck Heat Treatment Limited	63,127
Mosaicing for Automatic Pipe Scanning (MAPS)	2014	National Nuclear Laboratory Limited	65,616
Immobilisation challenges with Post Operational Clean Out (POCO) residues	2014	Sellafield Limited	68,470
Thermal Treatment of Irradiated Graphite	2014	Costain Oil, Gas & Process Limited	129,042
Development of the first Detectable Permeation Grouting System (DETECTAGROUT)	2014	Bam Nuttall Limited	143,726
JellyMonitor: developing a jellyfish early warning system for coastal power stations	2014	Cefas Technology Limited	145,834
Flexible Charged Particle Detector for Nuclear Decommissioning	2014	Kromek Limited	182,916
D:EEP : Estimating Entrained Products	2014	Create Technologies Limited	198,248
Influence of creep and geometry on strength of irradiated graphite components	2014	EDF Energy Nuclear Generation Limited	205,777
UNION (Ultrasonic Nuclear InspectiON)	2014	Plant Integrity Limited	253,557
ViridiScan: a novel mobile NDT sensor for nuclear decommissioning	2014	Viridian Consultants Limited	286,177
Noise and Vibration Data Compressor (NVCOMP) - embeddable health monitoring solution to assist in the capture and replay of events to identify deterioration / damage in nuclear plant	2014	Beran Instruments Limited	299,462
SmartScan	2014	Symetrica Security Limited	474,849
Hazmelt	2014	Glass Technology Services Ltd	716,190
Fabrication and Erection of Steel Concrete (SC) Modular Construction for Nuclear Power Plant (NPP)	2014	Caunton Engineering Limited	727,293
Developing the Civil Nuclear Power Supply Chain - Phase 2 (FS)			
Stability of Piezoelectric Materials for Nuclear Applications	2014	Ionix Advanced Technologies Ltd	26,718
Interoperability for ultrasonic NDT data	2014	Ferroday Ltd	39,015
TransForge - Production of forged dissimilar metal transitions for improved reliability in new nuclear power plant	2014	Somers Forge Limited	50,974
Enhanced learning through the use of virtual, augmented reality and simulation	2014	GSE Systems Ltd	53,015

LaserPipe - Remote in-bore laser welding of nuclear pipelines	2014	Oliver Crispin Robotics Limited	57,935
SeeSnake	2014	Create Technologies Limited	62,626
Modular Radiochem Sample Analysis for Integrated Fast/Cost Efficient Workflow	2014	Microlab Devices Limited	65,550
Study of the feasibility of setting up and operating a pilot-scale nuclear molten salt reactor demonstration	2014	Energy Process Developments Ltd	73,247
Novel system for localised, real-time radiometric measurements of ground water at civil nuclear sites	2014	Lablogic Systems Limited	73,748
Development of a Robotic Spider for Remote Characterisation and Retrievals	2014	Forth Engineering (Cumbria) Limited	78,744
TRIBECA (TRItium detection By ElectroChemically Assisted radiometrics)	2014	Hybrid Instruments Limited	79,522
Composite model-based signal and image processing algorithms for semi-automated crack characterisation	2014	Sound Mathematics Limited	80,739
Feasibility study to develop DEnsification processing of a Ceramic MAtrix composite material for Nuclear waste containment (DECMAN)	2014	Fiberstone Products Ltd	82,559
New Techniques for the rapid characterisation of low-level waste and surface contamination	2014	Symetrica Security Limited	83,042
Development of a driftless thermometer to improve safety and efficiency in the nuclear power industry	2014	Metrosol Limited	84,373
Improving the decommissioning process with intelligent semantic Building Histories	2014	Tacit Connexions Limited	97,406
An investigation into the use of the Arvia Technology in treating radioactive organically contaminated resins	2014	Arvia Technology Limited	99,580
In-Situ Monitoring of Tritium and Carbon 14 in Groundwater	2014	Xcam Limited	104,538
Submersible treatment of pond waters	2014	Arvia Technology Limited	105,837
A condition-based structural integrity and remaining life model for austenitic stainless steels	2014	Metamet Consultants Ltd	107,428
Feasibility study into novel new materials for heat tracing applications inside nuclear containment	2014	Heat Trace Limited	110,193
Metrology using Optical and X-ray Inspection - MOXI	2014	Metrix Ndt Limited	110,446
High Dynamic Range Spectroscopic Radiation Detectors	2014	Kromek Limited	110,978
Project CLAIMS (Coolant Leak Artificially Intelligent Monitoring System	2014	STS Defence Limited	111,500
Large-scale hot-isostatic pressing of waste forms for the treatment of Magnox sludge and other wastes	2014	Georoc Ltd	112,000
Feasibility - pre-industrial research of horizontal sludge dredge	2014	Barrnon Limited	136,795
Energy Game Changer (FS)			
360 Nuclear Knowledge	2016	Stickyworld Limited	48,765
A fully autonomous, in-situ, moisture monitoring system for corrosion under insulation (CUITEST)	2016	3-Sci Ltd	68,627
A low-cost robotic inspection platform for remote operation in aggressive environments	2016	Cadscan Limited	66,308
Autonomous pipeline survey system	2016	Autonomous Surface Vehicles Limited	9,172
Compact and Energy Efficient Distillation (CEED) for Tritium Recovery	2016	S. & C. Thermofluids Limited	41,682
Corrosion under insulation imaging with atomic magnetometers	2016	York Instruments Ltd	20,457
EIS Board	2016	Inspection Technologies Ltd	51,326
Embedded sensors for inspection of corrosion under insulation	2016	Inductosense Limited	45,567

eXperium	2016	Clicks And Links Ltd.	66,640
Inspection-Bot	2016	Q-Bot Limited	68,151
INTEGRAL	2016	Imitec Limited	45,000
Monitoring of Nuclear Waste Using Raman	2016	IS-Instruments Limited	43,990
PrOBE - Predictive Obsolete Behaviour Engine	2016	Warwick Analytical Software Limited	63,366
pvRIS: Pressure Vessel Robotic Inspection System	2016	Ross Robotics Limited	34,196
RISER Tank Inspection	2016	Blue Bear Systems Research Ltd	32,516
Robotic inspection of offshore oil and gas pressure vessels	2016	Oliver Crispin Robotics Limited	57,657
Smart Map - Interactive Virtual Engineering	2016	Sensat Surveying Ltd	61,580
Stereo-Welding: Intelligent Vision for Energy facilities Inspection and Welding (IVEIW)	2016	I3D Robotics Limited	28,164
TRIBECA2 (TRItium detection By ElectroChemically Assisted radiometrics 2)	2016	Hybrid Instruments Limited	48,992
Integrated Innovation for Nuclear Decommissioning - Phase 1			
Project Title: Integrated Innovation for Nuclear Decommissioning	2017	Amec Foster Wheeler Nuclear UK Limited	50,000
Nu-Decom	2017	Nuvia Limited	49,584
Integrated Innovation for Nuclear Decommissioning	2017	Westinghouse Electric Company UK Limited	50,000
Hot Hatch Cell Recovery	2017	James Fisher Nuclear Limited	49,592
LaserSnake++	2017	Oliver Crispin Robotics Limited	50,000
Elephants to Ants: Innovation in Integration	2017	Create Technologies Limited	49,921
Sellafield In-Cell Decommissioning System (SIDS)	2017	Cavendish Nuclear Limited	49,976
Integrated robotic system for characterisation and decommissioning	2017	University Of The West Of England	49,991
A Flexible Measurement and Waste Led, Robotics-Based Decommissioning Project	2017	A.N. Technology Limited	48,890
Integrated & Transferable Decommissioning Toolkit	2017	Davy Markham Limited	49,750
Versatile Decommissioning System (VDS)	2017	Eadon Consulting Limited	47,400
Integrated Keyhole Remote Decommissioning System	2017	Rovtech Solutions Limited	50,000
Barrnon Integrated Decommissioning System	2017	Barrnon Ltd	59,988
Stabilisation, Excavation and Segregation	2017	Costain Oil, Gas & Process Limited	49,309
DecomSmart	2017	MDA Space And Robotics Limited	45,000
Integrated Innovation for Nuclear Decommissioning - Phase 2			
Elephants to Ants: Innovation in Integration	2018	Create Technologies Limited	1,500,000
Barrnon Integrated Decommissioning System	2018	Barrnon Limited	1,499,950
Nu-Decom	2018	Nuvia Limited	1,499,224
Sellafield In-Cell Decommissioning System (SIDS)	2018	Cavendish Nuclear Limited	1,398,328
Integrated Innovation for Nuclear Decommissioning	2018	Amec Foster Wheeler Nuclear UK Limited	1,497,239
Integrated Innovation for Nuclear Decommissioning - Phase 3			
Barrnon Integrated Decommissioning System	2019	Barrnon Limited	ongoing

Integrated Innovation for Nuclear Decommissioning	2019	Amec Foster Wheeler Nuclear UK Limited	ongoing
Telexistence			
Impedance Haptics for High Dexterity Defence and Security Applications	2020	Veolia Nuclear Solutions	48,033
TEL-E3	2020	Cyberselves Universal Ltd.	98,359
TEL-SUBSEA	2020	Cyberselves Universal Ltd.	99,651
Overseer	2020	Createc	58,831
Holographic 3D Telexistence with Light Field Displays for Remote Object Interaction	2020	Holoxica Limited	56,241
TeLeMan - Teleoperative Legged Manipulator for Explosive Ordnance Disposal	2020	University Of Leeds	99,578
HABITS - Haptic Bimanual Telexistence System	2020	TNO	97,746
Haptic Master: Defence	2020	Createc	52,796
Horus	2020	Sheffield Hallam University	46,341
EOD/CBRN Operations through Telexistence	2020	Digital Kinematics Ltd	42,782
Sort and Segregate Nuclear Waste - Phase 1			
WACPAC - Efficient packing of decommissioning waste which meets the waste acceptance criteria for disposal	2020	A.N. Technology Limited	60,000
OptiSort	2020	Cavendish Nuclear Limited	60,000
SASPaC - A modular, autonomous system for the sorting & segregation of nuclear waste	2020	Red Marine Engineering Limited	59,980
Segwayste	2020	Jacobs Clean Energy Limited	59,711
SORTED: scalable sort and segregation for nuclear waste management	2020	Chilton Computing Limited	59,743
Barrnon Limited Integrated Sort and Segregate Solution	2020	Barrnon Ltd	59,903
Digitalised Autonomous System for Nuclear Waste Sort and Segregation	2020	EDF Energy R&D Uk Centre Limited	59,606
Mobile Autonomous Sort and Segregate System	2020	Atkins Limited	59,954
Autonomous Sort & Segregate Imagery Software Technology (ASSIST)	2020	Delkia Limited	59,951
Blended Intelligence for Safe and Efficient Nuclear Sort & Segmentation	2020	Veolia Nuclear Solutions (Uk), Limited	60,000
GaViX - Fully Automatic Sorting Systems for nuclear waste	2020	AB5 Consulting Ltd	59,976
NuSORT - Innovative Application of Machine Vision and Robotic Control for Nuclear Waste Sorting and Segregation	2020	Nuvia Limited	59,354
SmartDecay – A next-generation nuclear waste segregation and sorting system	2020	Forth Engineering (Cumbria) Limited	59,994
ISOsort	2020	Create Technologies Limited	58,622
Sort and Segregate Nuclear Waste - Phase 2			
OptiSort	2021	Cavendish Nuclear Limited	899,975
Barrnon Limited Integrated Sort and Segregate Solution	2021	Barrnon Ltd	899,605
ISOsort	2021	Create Technologies Limited	899,837
Mobile Autonomous Sort and Segregate System	2021	Atkins Limited	900,000
Blended Intelligence for Safe and Efficient Nuclear Sort & Segmentation	2021	Veolia Nuclear Solutions	896,209

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