Nuclear Decommissioning Authority

Robotics and Artificial Intelligence Research and Development

Preferred Option (Gate B) – Issue 1

March 2018

Critical Enabler

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Contents

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March 2018

Executive Summary

Background

Robotics and Artificial Intelligence (RAI) is a broad area of technology. It includes interconnected, interactive, cognitive and physical tools, able to variously perceive their environments, reason about events, make or revise plans and control their actions. RAI technologies perform useful tasks for us in the real world, extending our capabilities, increasing our productivity and reducing our risks.

Through our work on emerging technologies, RAI technologies have been identified as technologies that could significantly improve the existing technical baseline for decommissioning the UK's nuclear legacy. Whilst our mission is already benefitting from the use of some RAI technologies, further improvements in RAI technology could significantly enhance the situation. This will require Research and Development (R&D). This Preferred Option paper outlines our preferred approach for delivering this R&D.

Strategic Objective

Ensure that NDA and its estate effectively exploit RAI technology to significantly improve the existing technical baseline for decommissioning the UK's civil nuclear legacy (e.g. faster, cheaper, safer, less environmental impact).

Approach

In August 2017, with the support of Sellafield Ltd, we identified a number of credible options for delivering this R&D strategy and a number of criteria for selecting a preferred option [7]. These options were based upon the conclusion that NDA, as a strategic organisation, was not the most appropriate organisation to lead or manage an RAI R&D programme but could maintain strategic oversight of the programme and monitor its delivery and overall impact on the NDA mission.

Our initial assessment was shared with a range of stakeholders from industry, government and academic organisations. Following their feedback we have restructured the options, included an option that had previously been excluded and completed our assessment of the options. The credible options are:

- **Option 1**: NDA strategic oversight, establishment of a new national RAI centre of excellence to lead and manage the programme
- **Option 2**: NDA strategic oversight, Sellafield Ltd led and managed programme
- **Option 3**: NDA strategic oversight, Sellafield Ltd led programme and managed by a partnering organisation:

- **Option 3a**: Managed by the National Nuclear Laboratory (NNL)
- **Option 3b**: Managed by Remote Applications in Challenging Environments (RACE)
- **Option 3c**: Managed by a University
- **Option 3d**: Managed by the Supply Chain
- **Option 3e**: Managed by the NNL and delivered in partnership with RACE and other relevant organisations

A baseline option of 'Do nothing' was also included in our assessment.

Our assessment concluded that option '**3e) NDA strategic oversight, Sellafield led programme, NNL managed and delivered in partnership with RACE and other relevant organisations**' is the preferred option to take forward.

The main reasons why Option 3e is preferred are:

- Appropriate role for NDA as a strategic organisation;
- Sellafield Ltd led as the NDA estate end-user most likely to benefit from RAI technology;
- Strong end-user engagement through Sellafield Ltd leadership of programme;
- Established R&D networks to allow Sellafield Ltd to lead on behalf of NDA estate;
- Ability through end-user involvement to influence cultural issues associated with the implementation of RAI technology;
- Knowledge and experience of NNL with regard to implementing technology on the Sellafield site;
- Location of existing NNL facilities close to Sellafield site;
- Combined knowledge and experience of NNL and RACE with regard to RAI technology; and
- Established NNL and RACE networks of academic and industry RAI contacts.

Whilst Option 3e is our preferred option, we recognise that achieving our strategic objective will be challenging. Our analysis has highlighted a number of recommendations that would improve the chance of success.

- **Recommendation 1:** NNL are ideally placed, due to their location and knowledge and experience of the Sellafield site, to ensure that RAI solutions benefit the Sellafield decommissioning programme. However, many new skills will be required and collaborating with RACE and other relevant organisations will be essential for success. NNL will need to develop appropriate contracting approaches to facilitate collaboration.

- **Recommendation 2:** Strategies are developed to recruit, train and keep individuals with the relevant skills and capabilities to address the RAI challenges created through the decommissioning of the UK's nuclear

facilities. Appropriately skilled and experienced individuals will be required by NDA, Sellafield Ltd, NNL, RACE and the wider industry and academic supply chain.

- **Recommendation 3:** NNL, under the leadership of Sellafield Ltd, co-ordinates the nuclear decommissioning RAI R&D activities with existing UK capability and maintains good connections with relevant government initiatives such as the new academic hubs for nuclear. Collaboration and co-funding of R&D programmes is encouraged.

- **Recommendation 4:** Appropriate knowledge management activities need to be put in place to ensure nuclear decommissioning RAI knowledge, both existing and new, is captured and transferred to improve business efficiency and the implementation of RAI technology.

- **Recommendation 5:** NNL and Sellafield Ltd make available appropriate facilities for nuclear decommissioning RAI R&D close to Sellafield Ltd which are appropriately equipped and can be easily accessed by academia and industry.

Way Forward

We have shared our development of this R&D strategy with our Research Board. We welcome comments from other stakeholders (research@nda.gov.uk). We will continue to work with Sellafield Ltd to ensure successful implementation of our preferred option for RAI R&D. We will monitor the delivery of this strategy and revisit this preferred option if the RAI R&D environment changes significantly.

Document Revision Record

Version	Stage	Record of Change	Date
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Draft 1	B	Internal comments	10/10/17
Draft 2	B	Internal comments	7/11/17
Draft 3	B	Comments from NDA Research Board	8/2/18
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Glossary

COTS	Commercial Off The Shelf
EPSRC	Engineering and Physical Sciences Research Council (www.epsrc.ac.uk)
KTN	Knowledge Transfer Network (www.ktn-uk.co.uk)
ISCF	Industrial Strategy Challenge Fund
NDA	Nuclear Decommissioning Authority (www.gov.uk/nda)
NNL	National Nuclear Laboratory (www.nnl.co.uk)
RAI	Robotics and Artificial Intelligence
RACE	UKAEA's Remote Applications in Challenging Environments (www.race.ukaea.uk)
RAS	Robotics and Autonomous Systems
RCUK	Research Councils UK (www.rcuk.ac.uk)
SL	Sellafield Ltd (www.gov.uk/government/organisations/sellafield-ltd)
SLC	Site Licence Company
SQEP	Suitably Qualified and Experienced Person
TRL	Technology Readiness Level

Robotics and Artificial Intelligence Research and Development
Preferred Option (Gate B) – Issue 1

March 2018

UKAEA	UK Atomic Energy Authority (www.gov.uk/government/organisations/uk-atomic-energy-authority)
UKRI	UK Research and Innovation (www.ukri.org)

Robotics and Artificial Intelligence Research and Development
Preferred Option (Gate B) – Issue 1

March 2018

1 Strategic Case

1.1 Topic Background and Context

Robotic and Autonomous Systems (RAS) are interconnected, interactive, cognitive and physical tools, able to variously perceive their environments, reason about events, make or revise plans and control their actions. They perform useful tasks for us in the real world, extending our capabilities, increasing our productivity and reducing our risks [1]. Robotics and Artificial Intelligence (RAI) extends this area to more explicitly include artificial intelligence, the demonstration of intelligence by a man-made system. In this paper RAI is used rather than RAS to reflect the terminology currently being used by Government.

The Strategic Objective is to ensure that NDA and its estate effectively exploit RAI technology to significantly improve the existing technical baseline for decommissioning the UK's civil nuclear legacy (e.g. faster, cheaper, safer, less environmental impact).

1.2 Current Situation

Developments in the microelectronics, data processing, and robotics technologies have been rapid over the last 10 years. The size of the market in the mobile phone, video gaming and internet sectors and the adoption and increasing use of autonomous operated systems across a wider number of industries or activities (e.g. agricultural and transport) is maturing this technology at an ever increasing rate. This has resulted in the technology becoming much more affordable and readily available. The benefits of improved productivity, increased safety and cost reduction frequently highlighted in using autonomous robotic technology in highly structured environments (e.g. automotive manufacturing) are starting to demonstrate benefits in more complex and unstructured environments like those of the rail, space, transport and nuclear sectors. Robotic systems are now starting to be able to sense environments in real time and process information to deliver a goal not just a task i.e. can act with a degree of autonomy.

Governments, academia and many industries are recognising the technology as a game changer to the way we live and work. Within the UK increased utilisation of robotic technology is seen as one way to significantly increase productivity with consequent growth in the UK economy. This has resulted in significant amounts of funding becoming available from UK Research and Innovation (UKRI) related organisations to support the research, development and commercialisation of RAI technologies. Across the world, similar initiatives are underway, enabling rapid improvements in performance.

Challenging environments, such as offshore, deep mining, space and nuclear, have been identified as a sector where there are obvious safety benefits from using RAI technology by removing the human operator from the hazard.

Presently RAI type technologies used within nuclear decommissioning are typically commercial off the shelf (COTS) technology modified to allow operation in a nuclear decommissioning environment and managed at a project level, with a focus directly at delivery of individual projects.

Currently there is limited coordination between projects or sites. There is some cross-sector engagement typically coordinated around Research Councils UK (RCUK) and Horizon 2020 calls and networks set up with the support of the Knowledge Transfer Network (KTN).

1.3 Case for Change

In order to determine whether RAI technology could have a positive impact on the decommissioning of the NDA estate, the future lifetime plan of our site with the largest liability, Sellafield, was reviewed. This high-level review showed that there are situations where remote technology is the baseline technology and multiple opportunities (e.g. broadfront decommissioning, decommissioning waste segregation and treatment) where RAI technology could be used to reduce the lifetime cost, accelerate decommissioning, improve safety and reduce the impact on the environment by reducing primary and secondary wastes [2]. Some additional opportunities were identified at other Site Licence Companies (SLCs) but not to the same extent, mainly because they are closer to completion and therefore have less time and scope to implement any changes. Delivering the baseline technology and realising the opportunities will require both generic RAI R&D and some application specific R&D (e.g. system integration, radiation tolerance). If the current approach is used it is likely that many of the opportunities will be missed and that there will be duplication of effort due to both lack of coordination within nuclear and between nuclear and other sectors.

1.4 Aspirational Outcomes

There are a number of outcomes that NDA would wish to see as a result of the greater implementation of RAI technology:

- **Improved Safety** – Move the operative away from the hazardous part of the task. Reduce both radiological incidents (e.g. worker contamination) and conventional accidents (e.g. falls).

- **Increased Productivity** – Reduce the time associated with decommissioning tasks resulting in cost and schedule improvements.

- **Job Enrichment** – Remove dull and repetitive tasks allowing workers to carry out more value adding tasks.

- **Reduced uncertainty in the nuclear provision** – The current nuclear provision includes significant uncertainty associated with the cost of

developing required remote technologies. Development of RAI technologies against opportunities should have the additional benefit of reducing the cost uncertainties associated with required technologies.

- **Economic Growth** – Develop technology that UK companies can sell either directly or through the provision of services to the wider UK and international nuclear decommissioning markets as well as other sectors (e.g. Oil & Gas).

In other sectors (e.g. automotive industry) the impact of RAI technology has been significant and increases in productivity greater than 10% have been achieved. A recent parliamentary review into RAI indicated that the increase in productivity could be has much as 22% [3]. If savings of 5% to 10% could be achieved at Sellafield then savings of between £4.4 billion to £8.8 billion could be achieved (In 2017 NDA forecast that future clean-up across the NDA estate will cost around £119 billion over the next 120 years, with Sellafield costs accounting for 74% or £88 billion of the total cost [4]). Identifying specific technology insertion points for RAI technology and the associated savings will be a key component of any future RAI programme. The disruptive nature of the innovation can make direct cost comparisons difficult.

1.5 Scope and Boundaries

In keeping with our latest Strategy for R&D [5], we must ensure that we conduct sufficient and appropriate research to support and technically underpin the delivery of our overall mission. The scope of this topic covers RAI R&D. We aim to harmonise our research requirements in this area with those of other organisations to ensure a coherent and coordinated approach to enabling and supporting relevant R&D.

Our normal operating model of delivery through others means that we do not wish to directly carry out the research associated with this topic. We also do not consider ourselves best placed or equipped to directly manage this area of work, as to do so effectively, we would need to recruit additional suitably qualified and experienced staff. Also, it is generally agreed that closer integration with delivery is beneficial to the implementation of innovation.

We consider that the current review is important and is sufficiently well understood to allow us to determine a preferred option for this R&D strategy.

1.6 Constraints

Decommissioning the UK's civil nuclear legacy is funded primarily through Government funding. All programmes must provide value for money and be affordable. Given the current challenging fiscal climate the programme will need to avoid duplication with other RAI programmes, generate early benefits and where appropriate leverage external funding.

Decommissioning the UK's civil nuclear legacy involves delivering complex projects to time and within budget in a highly regulated environment. The use of innovative technology can challenge existing regulations and be perceived as an additional project risk. In some areas this has led to a cultural barrier to the take up and subsequent implementation of new technology. To address this issue an excellent understanding of the existing constraints is required and a willingness, where appropriate, to challenge them. An end-user champion of the new technology is beneficial to help convince a wide range of stakeholders of the benefits of any new technology. An enterprise view of risk is also beneficial to balance individual project risk with future opportunities in other projects. Experience across the NDA estate has shown that the demonstration the new technology in a relevant environment can help to address these issues. A demonstration close to or on the appropriate site typically allows the greatest range of stakeholders (e.g. management, regulators, operators) to view the demonstration.

1.7 Risks

Significant progress is being made across the NDA estate in decommissioning the UK's civil nuclear legacy. Delays in developing RAI technology will reduce or eliminate the associated benefits (e.g. sunk costs, partial implementation). This risk can be mitigated to some degree through the application of a stage-gated process, R&D portfolio management and the application of appropriate innovation tools (e.g. technology road mapping). Innovation, by its very nature, does involve some risk as there is always the potential that suitable technology will not be developed in a timely manner.

There is considerable debate regarding the potential impact of RAI technology on employment numbers [6]. This may result in cultural barriers to the implementation of RAI technology. By engaging in this area we can try to understand the issues and where possible include appropriate mitigation within the overall programme.

RAI skills are currently in high demand and there is a risk that we may not be able to recruit people with the appropriate RAI related skills to work either on nuclear decommissioning related projects or at our sites.

Due to the long timescales over which nuclear decommissioning will take place and the isolated location of our sites, there is also a risk that the knowledge of implementing RAI on the different nuclear sites will not be effectively captured and transferred. There is therefore a need to ensure that appropriate knowledge management activities are in place to capture and transfer knowledge across the NDA estate and, where appropriate, more widely. Knowledge from past projects will help improve business efficiency by avoiding the duplication of work, avoiding common problems with regard to implementation and establishing good practice.

2 Preferred Option

The objective of NDA's RAI R&D strategy is to ensure that NDA and its estate effectively exploit RAI technology to significantly improve the existing technical baseline for decommissioning the UK's civil nuclear legacy. To address this objective we identified a number of credible options based upon the view that NDA as a strategic organisation was not the most appropriate organisation to lead an RAI R&D programme. A baseline option of *'Do nothing'* was also included in our assessment for comparison. We do not believe this baseline option of *'Do nothing'* is a credible option as the RAI technology area is growing rapidly and generally takes the form of developments focused on end user needs. This baseline option would rely on RAI technology becoming available for nuclear decommissioning at the right time to maximise its potential and in an application-ready format via the supply chain.

In August 2017, with the support of Sellafield Ltd (SL), we identified a number of credible options for managing our R&D programme:

- **Option 1**: Sellafield Ltd led and managed;
- **Option 2**: Sellafield Ltd led and National Nuclear Laboratory (NNL) managed;
- **Option 3**: Sellafield Ltd led and Remote Applications in Challenging Environments (RACE) managed;
- **Option 4**: Sellafield Ltd led and University managed; and
- **Option 5:** Sellafield Ltd led and Supply Chain managed.

These options were considered against a number of selection criteria in our Credible Options paper [7] which was shared externally for comment. Additionally we have engaged our Research Board to understand their views on this important topic and understand the strategies being developed by other members of the Board (e.g. AWE).

2.1 Stakeholder views

We received comments on the Credible Options paper from a range of industry, government and academic organisations either directly or through our Research Board. Their comments included:

- A request for a clearer statement of the roles of NDA, SL and what we meant by a management organisation in this context.
- Collaboration between many organisations would be required for success. In particular the benefit of collaboration between NNL and RACE was highlighted.

- The suggestion that the establishment of a new national nuclear RAI centre of excellence to lead and manage the programme would be a credible option.
- The need to highlight the cultural change needed to maximise the potential of RAI.
- The need to connect and work with the Government Industrial Strategy Challenge Fund (ISCF) and other Government initiatives.
- The view that significant stable funding in the long term is required along with existing funding streams (e.g. ISCF).
- The need to improve decommissioning related RAI equipment and the accessibility of existing facilities.

2.2 Updating of credible options

Based upon stakeholder feedback and with the support of Sellafield Ltd we updated and restructured our credible options:

1) *NDA strategic oversight, nuclear RAI Centre of Excellence led and managed programme*

   This would be a new organisation set-up and charged with developing RAI technologies for the full range of nuclear activities within the UK. There would be engagement by a range of 'nuclear' organisations including organisations outside of the NDA estate such as AWE and EDF. This would aim to resolve common needs while sharing costs, expertise and facilities. Funding for the new centre would come from a range of organisations.

2) *NDA strategic oversight, Sellafield Ltd led and managed programme*

   This option is about the establishment of a nuclear decommissioning RAI R&D programme and infrastructure within SL. It would require both technical (e.g. RAI Subject Matter Experts) and non-technical (e.g. project management) capability. It would also require a wide range of facilities to allow the development, integration and demonstration of RAI technology. SL would be required to engage with a wide range of stakeholders including the NDA estate, industry and academia.

3) *NDA strategic oversight, Sellafield Ltd led programme, managed by another organisation*

   This option is about the establishment of a nuclear decommissioning RAI R&D programme led by SL but managed by another organisation. SL would provide a small leadership team but the majority of the technical (e.g. RAI Subject Matter Experts) and non-technical (e.g. project management) capability would be provided by an external organisation or its supply chain. The external organisation would also provide access to a wide range of facilities to allow the development, integration and demonstration of RAI

technology. SL would engage with the NDA estate but the main route for engagement with industry and academia would be through the management organisation.

For all of these options, NDA would maintain strategic oversight of the R&D programme and monitor its delivery and overall impact on the NDA mission.

2.3 Identification and Application of Screening Criteria

To decide our preferred option for this strategy we have evaluated the main credible strategic options against a range of criteria. We decided to evaluate these high level options against a set of criteria that have been derived from our Value Framework [9]:

- **Health and Safety** – The approach is required to have a capability to create RAI solutions that can safely be used in facilities on a nuclear licenced site and fulfil the requirements of a Site Licence Companies' facility safety case.
- **Security** – There will be a requirement to operate in a nuclear environment and manage materials and information securely.
- **Environment** – Important from a technology selection perspective but limited applicability with regard to selecting different managent approaches. Not included in analysis.
- **Risk and Hazard Reduction** – Important from a project prioritisation perspective but limited applicability with regard to selecting different managent approaches. Not included in analysis.
- **Socio-Economic Impact** – The approach will be required to input into the economy local to Sellafield through local spends and by supporting or creating local jobs. The focus is on Sellafield as the main impact of the programme is at Sellafield.
- **Enabling the mission** – The approach will be required to consider and ensure that it supports delivery of the mission, develops capability and demonstrates leadership.
- **Finance: Capital costs** – Capital spends required by NDA estate on equipment and facilities.
- **Finance: Return on Spend** – The approach should have a mechanism for commercialisation of the developed technology in order to benefit the UK economy and potentially reduce the decommissioning liability.

- **Finance: Access funding** – The approach should be able to leverage funding, grants, industrial funds, partnerships for all or part of the R&D lifecycle.

- **Finance: On-going costs** – Revenue spends on care & maintenance, operating and research workforce.

- **Implementability: People** – Approach must have access to people with appropriate experience and qualification to develop and integrate RAI technology (e.g. Technology Readiness Levels (TRLs) 5-9) and ability to engage with organisations across the full range of TRL.

- **Implementability: Equipment and facilities** – Approach must have access to appropriate facilities and equipment.

- **Implementability: Access to supply chain technologies** – Approach must have access to the appropriate technologies and network of contacts both within academia and industry.

- **Implementability: Existing strategy** – Approach should be compatible with SL's existing approach to R&D.

- **Stakeholder confidence** – Stakeholders should have confidence that the approach selected has the best chance of delivering the desired outcome.

Our evaluation of the options against these criteria, employing a 'Traffic light' approach, is presented in Table 1 (**RED** = Significant negative impact, **AMBER** = Limited negative impact, **GREEN** = Positive impact).

	Health and Safety	Security	Socio-Economic Impact	Enabling the Mission	Finance				Implementability				Stakeholder confidence
					Capital Costs	On-going Costs	Return on Spend	Access to External Funding	SQEP people	Equipment and Facilities	Access to Supply Chain Technologies	Existing Strategy	
Do Nothing	G Doing nothing there is no risk to people.	G Doing nothing there is no issues to be concerned about.	R No improvement.	R Mission not accelerated, no additional UK capability developed.	G No costs incurred.	G No costs incurred.	R Nothing to commercialise.	R No additional funding attracted.	N/A	N/A	A Relies on self-developing supply chain.	R The mission will not be delivered if nothing is done in the technology area.	R Stakeholder expectation is to make best use of technology to manage site hazards, part of the site licence requirement and the site mission.
Option 1: NDA strategic oversight, new nuclear RAI centre of excellence	G New processes will need to be put in place pulling-in relevant experience from elsewhere.	G New processes will need to be put in place pulling-in relevant experience from elsewhere.	A This cannot be located close to all the problem holders.	A Governance of the programme and end user engagement will need careful consideration to ensure nuclear decommissioning needs are fully considered.	R Potential set-up costs unless existing equipment and facilities could be used through partnership with other organisations. Access arrangements would need to be negotiated and may not be ideal. Location probably not ideal for all partners.	A Cost savings through co-funding potentially reduced by additional costs of stand-alone organisation.	G An appropriate business model could be set up to allow commercialisation of technology.	G An appropriate business model could be set up to allow access to external funding.	A Skills and capability would need to be brought in which might prove difficult.	A Existing equipment and facilities available close to Sellafield. Access arrangements would need to be negotiated and may not be ideal.	A Academic and industry links would need to be generated by this option.	A Existing NDA R&D strategy is delivery through SLCs and their supply chain.	A New organisation. Would need to gain stakeholder support for both funding and governance arrangements prior to establishment. May take considerable time to establish.
Option 2: NDA strategic oversight, SL led and managed	G Processes already in place.	G Processes already in place.	G SL based team.	G Leadership, staff and capability development will be established and programmes to deliver the mission will be in place.	R Potential set-up costs unless existing equipment and facilities could be used through partnership with other organisations. Access arrangements would need to be negotiated and may not be ideal.	A SL team is required to be in place and facilities cost incurred.	R SL focused on decommissioning mission and not commercialisation of technology.	A Limited access to funding due to the status of SL.	A Skills and capability would need to be brought in which might prove difficult.	A Existing equipment and facilities available close to Sellafield. Access arrangements would need to be negotiated and may not be ideal.	A Limited supply chain links for this technology.	A Existing strategy is to deliver it through the partnership agreement with NNL or existing lead organisation.	A Stakeholder expectation is to develop the capabilities with current national and international specialists.
Option 3: NDA strategic oversight, SL led and managed by another organisation	G A partnering organisation could be chosen with the processes already in place.	G A partnering organisation could be chosen with the processes already in place.	G A partnering organisation could be chosen with good socio-economic impact.	G Leadership, staff and capability development will be established and programmes to deliver the mission will be in place.	A Partners are available which could minimise the costs but no organisation has the full range of facilities.	A Partners are available which could minimise costs but there is still a need for specialist staff and facilities.	G The right partner could maximise return on Investment.	G Good access to external funding would be possible providing the right commercial model can be found with the participating organisation(s).	A Some organisations have a good range of skills and capability but not all within single organisation.	A Some organisations have a good range of facilities and equipment close to SL site but no one has all the facilities required and they are not available to all that could benefit from them.	G Good academic and industry links could be possible with a number of organisations.	A Only one of the possible partnering organisations – NNL would fit with existing strategies.	A This would depend on which organisation was chosen no option would satisfy all stakeholders.

Table 1: Assessment of high level Credible Options 1-3 along with the ‘Do Nothing’ Option

	Ability to bring socio-economic benefit to Cumbria	Nuclear Decommissioning / Operating Experience	Access to External Funding	Availability of SQEPed personnel	Training, education and skills development	Equipment and Facilities	Access to Supply Chain Technologies	Interfaces with other capabilities inc. supply-chain, National labs, Sellafield staff, etc.	Stakeholder confidence (credibility)
Option 3a: NDA strategic oversight, SL led, NNL managed	G Currently NNL provides significant socio-economic value to Cumbria, through employment and a siginificant STEM programme.	G Experience operating facilities on Sellafield site. Processes already in place and requirements fully understood. Experience of implementting RAI technology on Sellafield site.	G Experience accessing external funding through UK government including research councils and from organisations outside the UK.	A Limited current RAI technology capability, good Sellafield site knowledge.	A SL and NNL have good graduate and apprentice training programmes and links to NDA graduate scheme. However this is not RAI focussed and it has been difficult to fill posts in this area.	A A good range of facilities and equipment available close to SL site but access to them by others can be limited and they do not have the full range of equipment required.	G Good academic and industry links.	G Good access to Sellafield staff.	A Partnership agreement relatively new, culture changing.
Option 3b: NDA strategic oversight, SL led and RACE managed	A RACE has no presence in Cumbria	A Good fusion experience but limited processes to manage the high levels of Health and Safety and Security arrangements required on a nuclear licenced site. No experience of delivering new technology on a nuclear decommissioning site.	G Experience accessing external funding through UK government including research councils and from organisations outside the UK.	A Limited capability in nuclear decommissioning and related waste management activities.	A Good general RAI skills development but not focussed on nuclear decommissioning and working on a nuclear licenced site.	A Good range of facilities and equipment available but location limits interaction	G Good academic and industry links.	A Limited networks in nuclear decommissioning and distanced from Sellafield site.	A Limited nuclear decommissioning experience. Distance may limit interaction with end users.
Option 3c: NDA strategic oversight, SL led and University managed	A There is some university presence in Cumbria (e.g. Dalton Cumbrian Facility, University of Cumbria).	R Universities do not have the necessary nuclear operational or decommissioning experience to deliver the Health and Safety and Security arrangements required.	G Good access to Research UK funding.	A Limited capability in nuclear decommissioning and related waste management activities, particularly at an operational level.	A The universities are designed to train and develop students. However the Universities with the RAI skills are located away from Sellafield site and do not have operational experience or training.	R Only lab based facilities and equipment available.	A Main focus is on academic links with limited focus on industrial links.	A There is some university presence in Cumbria through the DCF, Centre for Innovative Nuclear Decommissioning Engineering and there are well established relationships in some areas.	A Generally have limited high TRL delivery, University focus is on low TRL research and academic excellenece.
Option 3d: NDA strategic oversight, SL led and Supply Chain managed	G There are local suppliers with some RAI knowledge and experience who undertake STEM activities locally.	G There are suppliers with considerable experience of working on Sellafield site with processes in place and a full understanding of the arrangements required.	A Limited access to funding due to commercial model.	A Limited RAI, nuclear decommissiong capability and SL knowledge within individual supply chain (Selection criteria).	A Larger organisations have training schemes and apprenticeship programmes but are not RAI focussed.	A Good range of facilities and equipment available local to site (Selection criteria)	A Potentially commercial issues associated with Intellectual Property.	G Good access to Sellafield staff for some organisations.	A Approach unknown due to limited certainty associated with competition process and capability of supply chain.
Option 3e: NDA strategic oversight, SL led, NNL managed and delivered in partnership with RACE and other relevant organisations	G Currently NNL provides significant socio-economic value to Cumbria, through employment and a siginificant STEM programme.	G NNL have significant experince with regard to Sellafield site.	G Both RACE and NNL have good experince accessing external funding.	G Combination of NNL and RACE provides good breadth and depth of SQEPed personnel	A Complementary training programmes but not currently combined.	G Combination of NNL and RACE provides good breadth and depth of equipment and facilities.	G Good academic and industry links.	G Good access to Sellafield staff.	A Collaboration between NNL and RACE needs to be further developed.

Table 2: Assessment of the Credible Options - Sub-options 3a-e

2.4 Further consideration of credible options

We consider the preferred high-level option to be '**3. NDA strategic oversight, Sellafield led programme and managed by another organisation**'. It is the only high-level option that has no significant negative impacts against any of the criteria. Option 1 was excluded principally because of the potential cost and complexity of setting up a new organisation. Option 2 was excluded principally because of the cost of setting up the programme within SL and lack of a commercialisation route for developed RAI technology.

The performance of Option 3 is in part dependent on the organisation which is chosen to act as manager. We identified five credible sub-options:

3a) *NDA strategic oversight, Sellafield Ltd led programme and National Nuclear Laboratory managed*

3b) *NDA strategic oversight, Sellafield Ltd led programme and Remote Applications in Challenging Environments (RACE) managed*

3c) *NDA strategic oversight, Sellafield Ltd led programme and University managed*

3d) *NDA strategic oversight, Sellafield Ltd led programme and Supply Chain managed*

3e) *NDA strategic oversight, Sellafield Ltd led programme, National Nuclear laboratory managed and delivered in partnership with Remote Applications in Challenging Environments and other relevant organisations*

We have evaluated these sub-options against a smaller more targeted range of criteria best designed to differentiate between different management organisations.

The criteria we chose to evaluate the sub-options against are:

- Ability to bring socio-economic benefit to Cumbria;
- Nuclear operational experience;
- Ability and track record in obtaining external funding;
- Skills and capability;
- Equipment and facilities;
- Ability and track record in accessing supply chain technologies; and
- Stakeholder confidence (credibility).

Our evaluation of the options against these criteria, employing a 'Traffic light' approach, is presented in Table 2 (**RED** = Significant negative impact, **AMBER** = Limited negative impact, **GREEN** = Positive impact).

2.5 Preferred option

Having reviewed the potential options, and taking into account the views of stakeholders we have concluded that option '**3e) NDA strategic oversight, Sellafield led programme, NNL managed and delivered in partnership with RACE and other relevant organisations**' is the preferred option to take forward. This option combines the skills, experience, facilities and equipment of both NNL and RACE to support SL delivery of a RAI R&D programme focused on nuclear decommissioning.

NDA will maintain strategic oversight of the RAI R&D programme. This strategic oversight role would include:

- Monitoring the delivery of the strategy and its impact on the NDA mission;
- Continuing to facilitate interactions between the SL RAI R&D programme and other organisations, both nationally and internationally;
- Funding through the NDA's Direct Research Portfolio multi-SLC RAI R&D where the business case is justified and NDA's existing contracting mechanisms represents the most efficient and effective mechanism; and
- Continuing to develop and trial new approaches to procuring technical innovation, including RAI technology, and demonstrate the benefits associated with innovative approaches to the procurement of R&D (e.g. Small Business Research Initiative [8])

SL would be the lead organisation for the NDA estate with respect to RAI technology. The leadership role would include:

- Intelligent Client for RAI technology on Sellafield site;
- RAI technology or service selection with respect to decommissioning Sellafield site;
- Co-ordination with NDA and rest of the NDA estate on RAI related topics using established networks;
- Management of active demonstration of RAI technologies on Sellafield site;
- Articulation of issues / problems / opportunities from an end user perspective;
- Governance and assurance of the RAI R&D programme;
- Appropriate knowledge management activities to capture and transfer both existing and new RAI knowledge. This should include both the technology and the approach to implementation.
- Monitoring and communicating risks to the successful delivery of the RAI programme; and
- Funder of relevant RAI projects.

NNL would be the management organisation for the RAI R&D programme. This would involve the development and delivery of a portfolio of RAI R&D projects using technical (e.g. RAI Subject Matter Experts) and non-technical (e.g. project management) capability from NNL, RACE and other relevant organisations. The management role would include:

- Working with the end-users to identify and prioritise decommissioning challenges which could be solved with RAI technology;
- Helping facilitate cultural change and acceptance of RAI technology;
- Supporting appropriate RAI skills initiatives;
- Maintaining a broad knowledge base of RAI technology;
- Having facilities to trial and develop integrated RAI systems;
- Successfully influencing UK strategic funding of RAI programmes;
- Providing links to other nuclear RAI R&D programmes in UK or internationally;
- Collaborating with RACE, industry and academia across the TRL spectrum to aid NDA estate in delivery of its mission;
- Providing opportunities for the RAI supply chain to deliver projects/tasks on nuclear licensed to sites to help build their experience and knowledge
- Taking a “lead and learn” experience from current programmes and ensure benefits are realised in the broader UK nuclear programme; and
- Co-ordination of activities to provide coherent R&D programme and appropriate RAI R&D portfolio (e.g. risk vs reward, target areas, technology insertion schedule).

Although this is our preferred option there are still risks associated with successful delivery of the strategy. Key risks include:

a. *Availability of Suitably Qualified and Experienced Person (SQEP) personnel*

Individuals with RAI skills and experience are likely to be in demand in multiple sectors. Recruiting and retaining individuals with both RAI skills and experience and nuclear decommissioning knowledge will be important for all organisations involved in the programme.

b. Training, education and skills development

Improved skills and training could help improve the availability of SQEP personnel. SL and NNL have good graduate and apprenticeship programmes and links to the *nucleargraduates* scheme but these schemes do not include RAI related components. Programmes for retraining existing staff in RAI related skills are currently limited.

c. Knowledge management

Appropriate knowledge management activities need to be put in place to ensure nuclear decommissioning RAI knowledge, both existing and new, is captured and transferred to improve business efficiency and the implementation of RAI technology.

d. Equipment and Facilities

A number of stakeholders highlighted the availability and accessibility of suitable facilities and equipment. Although NNL has facilities and equipment close to the Sellafield site, access to these facilities is not always optimum for academics or industry.

2.6 Strategic Options Diagram (SOD)

A Strategic Options Diagram for the RAI R&D Strategy has been produced and is presented in Appendix A.

2.7 Stakeholder Engagement Plan

In developing our RAI R&D Strategy we have engaged with a range of stakeholders including the NDA Research Board, Sellafield Ltd and a range of individuals from industry, government and academia.

The importance of external stakeholder support has been identified as being critical to the success of any proposed strategy. We will continue to engage with stakeholders during the implementation of our strategy to ensure it remains appropriate.

2.8 Communications Plan

We will publish our Preferred Option paper on the NDA website. We welcome comments from other stakeholders (research@nda.gov.uk). We will use a range of existing mechanisms to communicate our RAI R&D Strategy, progress with its implementation and its impact on the NDA mission.

3 Summary

3.1 Summary of Our Assessment

Having reviewed the potential options, including taking into account the views of stakeholders we have concluded that option '**3e) NDA strategic oversight, Sellafield led programme, NNL managed and delivered in partnership with RACE and other relevant organisations**' is the preferred option to take forward.

3.2 Way Forward

We will continue to work with Sellafield Ltd to ensure successful implementation of our preferred option for this RAI R&D strategy. We will look to implement through our RAI R&D strategy and SL's programme the recommendations outlined below. We will revisit this preferred option if the RAI research environment changes significantly.

- **Recommendation 1:** NNL are ideally placed, due to their location and knowledge and experience of the Sellafield site, to ensure that RAI solutions benefit the Sellafield decommissioning programme. However, many new skills will be required and collaborating with RACE and other relevant organisations will be essential for success. NNL will need to develop appropriate contracting approaches to facilitate collaboration.

- **Recommendation 2:** Strategies are developed to recruit, train and keep individuals with the relevant skills and capabilities to address the RAI challenges created through the decommissioning of the UK's nuclear facilities. Appropriately skilled and experienced individuals will be required by NDA, Sellafield Ltd, NNL, RACE and the wider industry and academic supply chain.

- **Recommendation 3:** NNL, under the leadership of Sellafield Ltd, co-ordinates the nuclear decommissioning RAI R&D activities with existing UK capability and maintains good connections with relevant government initiatives such as the new academic hubs for nuclear.

- **Recommendation 4:** Appropriate knowledge management activities need to be put in place to ensure nuclear decommissioning RAI knowledge, both existing and new, is captured and transferred to improve business efficiency and the implementation of RAI technology.

- **Recommendation 5:** NNL and Sellafield Ltd make available appropriate facilities for nuclear decommissioning RAI R&D close to Sellafield Ltd which are appropriately equipped and can be easily accessed by academia and industry.

References

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8. SBRI: the Small Business Research Initiative, Innovate UK, July 2017

9. The NDA Value Framework, NDA, January 2016

Appendix A – Robotics and Artificial Intelligence R&D Strategic Options Diagram