Building Effective Collaborations to Bring Innovation into Waste Management and Decommissioning – 16477

Mike Angus *, Anthony Banford *, Anthony Collins *, Ian Pegg **
* National Nuclear Laboratory
** Catholic University of America

ABSTRACT

A strong record of research collaboration has been developing between the UK nuclear industry and key universities with nuclear specialism over the past 15 years or so. The DISTINCTIVE program, focusing on decommissioning, immobilization and storage solutions for nuclear waste inventories is an example. It is a consortium of eleven universities funded by the Engineering and Physical Sciences Research Council, National Nuclear Laboratory, Nuclear Decommissioning Authority and Sellafield Limited. The motivation for industry collaboration with universities is explained and the current progress of DISTINCTIVE in the context of these motivations is assessed.

INTRODUCTION

With a programme of £70 billion (~$105 billion) for decommissioning and waste management at UK's civil public sector nuclear sites, there is a need for innovation to reduce lifetime costs. The nuclear industry looks to universities as an important source of knowledge, expertise and of innovative ideas which could contribute to successfully delivering this mission at reduced cost. The recently completed Research Excellence Framework review by the Engineering and Physical Sciences Research Council (EPSRC) 2014, confirms that UK research universities are indeed a source of high quality research, with 76% of the research assessed as world leading or internationally excellent [1]. A strong, collaborative partnership between universities and the nuclear industry should therefore allow universities to make major contributions to delivering the nuclear legacy mission. However, there are significant barriers to creating such partnerships. For example, much has been written about the so called "valley of death" [2], in which innovations often founder. This is typically explained as being due to insufficient funding, which is indeed a challenge, but in the case of the nuclear industry, there are other challenges;

- the academic community needs to be provided with good understanding of nuclear challenges since there are some very real, practical constraints,
- the nuclear industry is particularly conservative in implementing innovation, and the successful translation of research into deployable solutions, a challenge for all industries can be even more difficult for nuclear.

Successful university-industry partnerships need to address these issues. This paper describes progress in the UK in developing such partnerships, and specifically, the role of the DISTINCTIVE program (Decommissioning, Immobilisation and STorage solutIons for NuClear wasTe InVEntories), the most recent in a series of multi-partner collaborations in the nuclear field over the past 15 years.

INDUSTRY MOTIVATION FOR COLLABORATION WITH UNIVERSITIES

There has been a general move over recent years towards strategic partnerships between universities and industry and a report by the Centre for Science, Technology and Innovation (CSTI) Policy [3] sets out key lessons, insights and effective practices for developing and nurturing effective strategic university-industry partnerships. In the case of nuclear industry, the UK landscape has favored the formation of the multi-partner consortium model, due to the strong interconnections between major industry players such as the Nuclear Decommissioning Authority (NDA), Sellafield Ltd and the National Nuclear Laboratory (NNL), and the breadth of nuclear expertise among a wide range of UK universities. The CSTI report identifies six key categories of benefit realized by the industrial partners in a strategic partnership.

<u>Knowledge and Technology Development</u>: This is likely to be the main benefit to industry of partnership. A collaborative approach allows industry and universities to work together to shape the direction of research and ensure the research is aligned with the needs of industry. As described above, there are major opportunities for reduction in the lifetime costs of decommissioning and waste management if new game-changing innovations can be deployed based on improved understanding of the fundamental science.

<u>Enhancing the Efficiency and Effectiveness of Knowledge Acquisition and Absorption</u>: Industry needs to be able to identify, develop and absorb knowledge resources and expertise from within the university base. The UK "nuclear universities" in particular, have a vast amount of knowledge which industry needs to tap into. In 2012, a government review of the civil nuclear R&D landscape to underpin the UK's Nuclear Industrial Strategy identified 237.5 full time equivalent research staff with expertise in nuclear at UK universities [4]. This figure excludes post-doctoral researchers.

<u>Developing Talent, and Workforce Skills and Capabilities</u>: There are multiple benefits to industry, including opportunities for students to engage in industrial activities, improvement of relevance of student training, and also the opportunity to develop the skills and capabilities of industry staff engaged in collaborative projects. Despite the high number of academics working in the field, the predicted growth in demand in the UK for nuclear skills and an ageing demographic of the current research community means the availability of experienced R&D staff and subject matter experts has been recognized as a pinch point over the coming years by the Nuclear Energy Skills Alliance [5]. Industry is therefore collaborating with universities to accelerate the development of future subject matter experts [6].

<u>Enabling access to resources and infrastructure</u>: Partnership can strengthen the justification for funding of high cost equipment and infrastructure. The National

Nuclear Laboratory has encouraged academic access to its specialist nuclear facilities for high alpha and shielded facilities at its Central Laboratory, for instance, and with the support of the EPSRC funded "National Nuclear User Facility" [7], has installed a range of equipment to support research.

Facilitating entry into new national or regional innovation systems: Strategic university engagement can provide opportunities for gaining leverage into innovation investment programmes.

Supporting policy engagement and institution development: In the UK, industry, universities and government have worked closely to identify the research needs associated with future nuclear generation scenarios and this has included an assessment of the R&D required to develop the waste management technologies required to deal with any novel waste streams produced by advanced proliferation resistant recycle technologies [8].

For a successful partnership, universities also need to obtain benefits. These benefits, which include pathways to impact, access to resources and expertise in industry and career development opportunities for students, for example, are also analyzed in the CSTI report [3].

The Confederation of British Industry (CBI) publishes practical advice on how to achieve effective academic-industry collaborations, including guidance for industry on access to specific UK funding mechanisms and on dealing with the often challenging issue of intellectual property [9].

RECENT INDUSTRY-UNIVERSITY COLLABORATION IN THE UK

With EPSRC support, good progress has been made in building university engagement in legacy waste, decommissioning and disposal R&D programs. The KNOO program (Keeping the Nuclear Option Open, 2005-2009), closely followed by DIAMOND (Decommissioning, Immobilisation And Management Of Nuclear wastes for Disposal, 2008-2013), along with doctorate training programs (Nuclear First and Engineering Doctorates) were able to build on the early success of industry funded programs such as the BNFL University Research Alliances set up around 1999.

The impact of research in these programs has been greatest where university-industry collaboration has been strong. For example, major cost savings have been made by industry in immobilization of radioactive wastes. Research at universities, led by industry, but often with an EPSRC contribution through these programs such as these have contributed to improvements in high active liquor vitrification and intermediate level waste (ILW) cementation processes. They are also making significant progress towards the vitrification of ILW [10]. The scale of economic impact is large, with research in support of high level waste vitrification giving at least £100M and potentially £500M of avoided costs through improved waste loading, increased liquor feed and glass production rates, plant availability and extension of operational envelope. Similar cost savings in other immobilization processes are possible.

The DIAMOND program referred to above was the immediate predecessor of the current DISTINCTIVE program. A primary aim of the DIAMOND consortium was to train the next generation of UK scientists and engineers with skills and expertise in nuclear waste management and decommissioning issues. Arguably this was the most significant outcome of the program. Of the 35 PhD and postdoctoral researchers that formed DIAMOND, the majority found careers in the nuclear industry or its supply chain. The program encouraged industry collaboration with the appointment of mentors, a principle that has been further built on with DISTINCTIVE. The DIAMOND consortium published 52 peer reviewed journal papers, although only 15% of these had an industrial co-author. Research from DIAMOND also facilitated contact with many international bodies, including, Pacific Northwest National Lab (USA), CSIRO (Australia), ITU Karlsruhe (Germany), University of Melbourne (Australia), Ferlov Lab (Russia), Lawrence Livermore National Lab (USA), Stockholm University (Sweden), ESRF Grenoble (France), Notre Dame Radiation Lab (USA) and Dalian University of Technology (PR China). DIAMOND therefore established a good track record for industry-academic collaboration, but one that had opportunities for improvement.

DISTINCTIVE (**D**ecommissioning, **I**mmobilisation and **ST**orage solut**I**ons for **N**u**C**lear was**T**e **I**n**VE**ntories)

The DISTINCTIVE program [11] is a natural evolution of the extensive collaboration that has developed in the UK between industry and universities over the past 15 years or so. DISTINCTIVE links a set of 32 research projects within the broad area of nuclear waste management, decommissioning and disposal. The consortium was initially a collaboration of ten universities and a group of industry partners with funding of ~£8M provided by the universities, EPSRC and three key industry partners, NNL, NDA and SL.

The process of establishing the DISTINCTIVE programme is an example of the increasing collaboration between industry and academia. In anticipation of an EPSRC call for proposals in the area of "Decommissioning, Immobilisation and Management of Nuclear Waste", which was issued in June 2013, academic and industry partners participated in a workshop at which a series of high priority research themes were agreed and the detailed challenges within each theme were then developed. The research themes were;

- AGR, Magnox and Exotic Spent Fuels
- PuO_2 and Fuel Residues
- Legacy Ponds and Silo Wastes
- Structural Integrity

During the bid preparation phase, each partner university submitted a range of proposals. These proposals were reviewed and rated by the key industry partners. Three projects were then selected from each university partner, with industry ratings being used by the universities as one of the criteria for selecting projects. At this stage, industry advice was also provided on how projects could be improved. It was therefore possible for the university consortium to present a proposal to EPSRC with strong evidence of industry engagement.

The program, initially involving 18 established academics, formally started in February 2014 and is expected to run until November 2018. Recruitment of 10 postdoctoral research associates (PDRAs) proceeded in the following months, with 22 postgraduate students during the first year. One element of the programme that is of particular value to industry is the extent of funding support for secondments of both PDRAs and postgraduate students to work in industry, which has been made possible with a combination of EPSRC funding and support both financially and in kind from NDA and NNL. Following the programme's launch, one further university has joined the consortium and around 20 additional research projects have become associated with the programme.

On the establishment of the program, Lead Industrial Supervisors were appointed by the key industry partners, and a number of other industry links were also identified. The Lead Industrial Supervisors work with the Principal Investigator (PI) to ensure the project satisfactorily addresses industry challenges whilst providing sufficient novel research to satisfy academic requirements. This involves engaging within industry to ensure adequate two-way information flow, and may also involve coordinating arrangements for a secondment. The Lead Industrial Supervisor is also expected to;

- Work jointly with the PI to review and if necessary revise the programme at suitable intervals
- Raise awareness with students and PDRAs of careers within nuclear industry and make appropriate introductions (e.g. pass on *curricula vitae*)
- Provide background information from industry to PDRA/student (relevant publications, discussions, subject to clearance procedures).
- Identify interested parties within industry (NNL, SL, NDA and wider) and ensure flow of information to industry on progress
- Collaborate with the authorship of joint publications, preferably in peer reviewed journals.
- Meet with the student and academic at suitable intervals to review progress and provide advice

DISTINCTIVE –ASSESSMENT OF PROGRESS BY INDUSTRY PARTNERS

To evaluate the success of DISTINCTIVE to date, a survey has been created and distributed using Survey Monkey. Survey Monkey is a web application used to create customised online surveys which can be distributed by email to recipients. After distribution of the survey the data can be collected and analysed using the web application.

Each DISTINCTIVE project has a Lead Industrial Supervisor to whom the Survey was distributed. Additionally, the other known industrial links to the projects were invited to complete the survey. The respondents' views were sought on the project they were primarily involved with, with particular interest in the benefit provided to industry and the current state of the research. Respondents were not asked their names; instead they were asked which company they worked for, which university their project was with and whether they were a lead industrial supervisor.

The Survey comprised two sections. The first of these considered the individuals involvement in DISTINCTIVE specifically in context of the project they were most closely involved with. Questions covered the extent of the contact between industry and the researchers, as well as the respondent's opinion on the current state of the particular projects research. The assessment of the current state of the research was made using Scientific Readiness Levels (SRL®).

The SRL® process developed by NNL [12] considers the scientific/technical quality of the arguments employed to understand and predict physical processes. This assessment is made against definitions that have universal applicability. These definitions are set out in Table I. They represent a logical progression through different stages of the maturity of the scientific/technical arguments that underpin plant performance or prediction of complex technological phenomenon. They are similar in organisation to the Technology Readiness Levels (TRLs) that are widely employed in the Defence, Aerospace and Nuclear industries to assess the maturity of a particular technology [13,14]. As in the case of TRLs the value of utilising SRLs® is not only the assessment of scientific maturity, but also the consistent comparison of maturity between different applications. In the survey described here, the assessments are somewhat subjective, with most respondents unlikely to have had previous experience of the process.

The second section asked the respondent's opinion on the benefits to industry of DISTINCTIVE overall. Respondents were presented with a collection of statements organised under the categories used in the CSTI report [3]. Respondents were asked whether they agreed, disagreed or were unsure for each statement and were given the option to provide additional comments at the end of the survey.

Table I Scientific Readiness Levels

Level	Label	SCIENTIFIC READINESS LEVEL
6	Established (Investment primarily driven by needs of maintaining expertise)	Some deficiencies such that although understanding is well developed there are still minor judgements required to make predictions to regions not covered by the underlying data. Timely to consider funding for training successors.
5	Mature but needs some support	Good understanding of the controlling physical processes but some elements require further support to demonstrate their validity
4	Mature but needs underpinning	Good understanding of the controlling physical processes but major elements require support to demonstrate their complete validity
3	Judgemental (Investment primarily to fund a practical R&D programme)	Controlling physical processes have been identified but major assumptions required to make predictions for parameter space of interest. However, the research required to justify such assumptions can be specified and it is possible to detail a R&D programme to move up SRL's®. In addition there may be only a limited number of individuals capable of developing the required arguments.
2	Exploratory (Investment for speculative R&D programme)	The potential physical processes have been assessed, but we require exploratory research to confirm the controlling processes. Predictions require assumptions of both the controlling processes and detailed parameters.
1	Emerging issue (investment req'd to move up SRLs®)	Little to no confidence in making predictions but possible to identify physical processes that need to be understood and where expertise has to be established.

Discussion of Survey Results

The data used in this analysis is from projects covering the majority of the universities involved in DISTINCTIVE and each of the project themes.

Of the surveyed Lead Industrial Supervisors 86% felt they have had an influence on the technical direction of their projects although only 43% had been involved in developing the initial scope. Further to this 86% of Lead Industrial Supervisors have had at least one meeting with their student or PDRA researcher outside of conferences and theme meetings.

Possible improvement could be made in further engaging the other industrial links in DISTINCTIVE. Of the other industrial links who answered the survey 27% felt they had influenced the technical direction of their projects with 40% having had a meeting with their student or PDRA researcher outside of conferences and theme meetings.

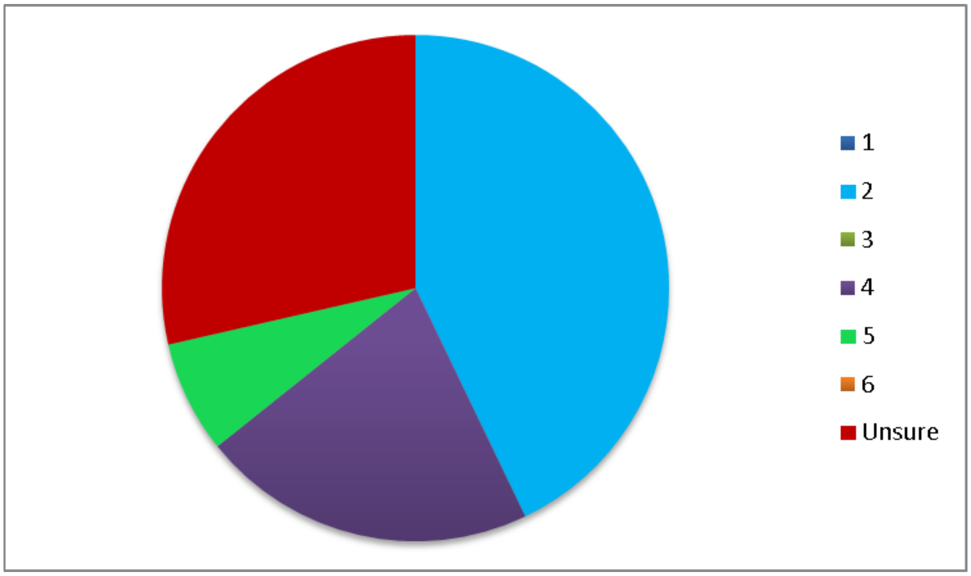

Figure 1. Assessed Scientific Readiness Levels of the Projects.

The Lead Industrial Supervisors were asked to assess the Scientific Readiness Level of their projects and their assessments are presented in Figure 1, with the values 1 to 6 and Unsure representing the SRL. The modal assessed SRL of the projects was 2 with a large number of respondents unsure what SRL value to give.

The DISTINCTIVE program has been running since February 2014. However not all of the projects have been running for the same length of time, with some projects beginning only in the few months preceding the survey. This is a conceivable explanation for why not all industry supervisors or links have met with their university contacts or were unsure of the SRL value to allocate for their project.

Figure 2 is a temperature gauge diagram of the level of agreement with statements in each of the six categories. The gauge has five colours with dark green representing strong agreement, pale green partial agreement, yellow undecided, amber partial disagreement and red a strong disagreement. The percentage agreements, A, which were used for the colour allocation were calculated from the number of agreements, disagreements or uncertainties for each statement in a category.

Respondents strongly agreed that DISTINCTIVE is enhancing the efficiency and effectiveness of knowledge acquisition and absorption, is enabling access to resources and infrastructure, as well as supporting policy engagement and institution development. However improvement could be made in facilitating entry into new national or regional innovation systems.

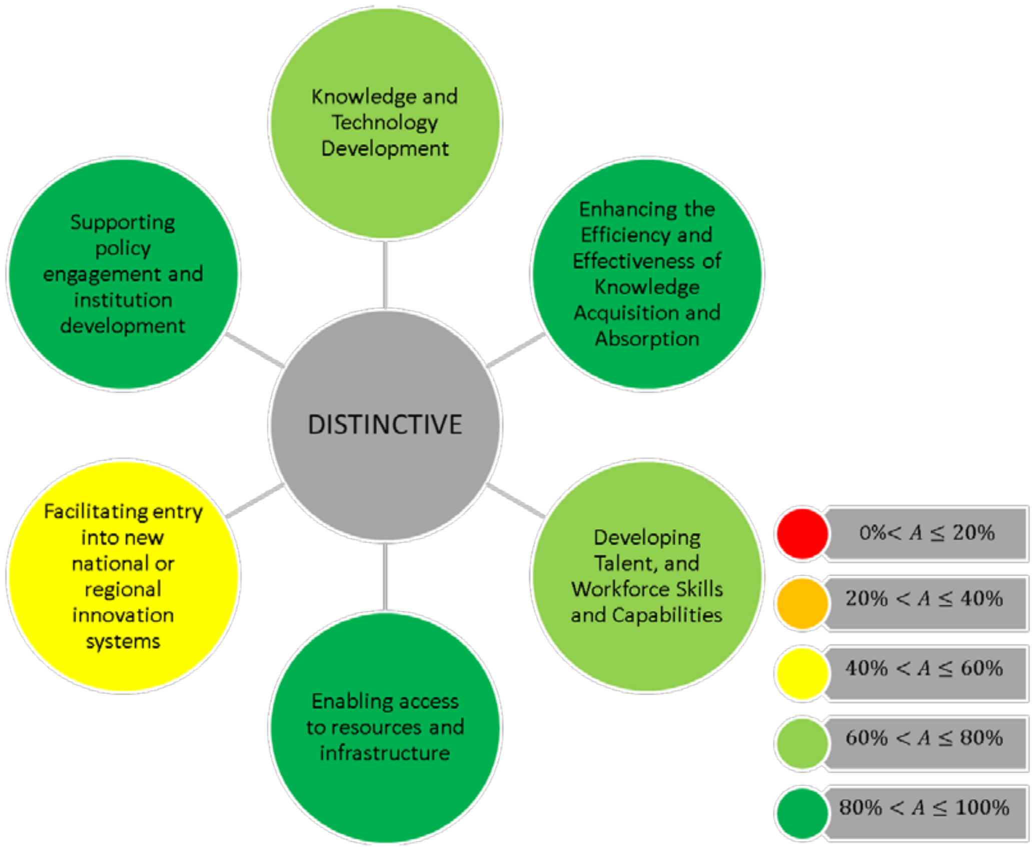

Figure 2. A "Temperature Gauge" of the Six Categories.

CONCLUSIONS

UK universities have substantial knowledge and expertise on nuclear topics shared amongst several hundred academics. Collaboration between key nuclear universities and industry has developed and evolved over the past 15 years, resulting in a healthy partnership culture within a multi-partner consortium model. This approach is delivering research output that has improved fundamental understanding of processes relevant to waste management and decommissioning and has supported the delivery of economic impact, for instance by underpinning reductions in waste processing costs.

Based on preliminary feedback from industry links, the DISTINCTIVE consortium has demonstrated in its first year that it is capable of delivering a range of benefits to industry. Results to date of a survey of these industrial links suggest there are a number of areas where there is opportunity for further enhancement of the industry-academic engagement, and this will be a focus for the consortium and its partners over the coming year.

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