Institution: King's College London		
Unit of Assessment: 19 Politics and International Studies		
Title of case study: Strengthening Global Nuclear Security		
Period when the underpinning research was undertaken: January 2014 – Dec 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Professor Christopher Hobbs	Professor of Science and International Security, Co-Director, Centre for Science and Security Studies	From Feb 2006
Professor Matthew Moran	Professor of International Security, Co-Director, Centre for Science and Security Studies	From Sept 2011
Professor Wyn Bowen	Professor of Non-Proliferation and International Security; Head of School of Security Studies	From Sept 1997
Dr Hassan Elbahtimy	Senior Lecturer, Department of War Studies	From Aug 2014
Period when the claimed impact occurred: January 2014 – Dec 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Because of its potential for devastating humanitarian and environmental harm, an act of nuclear terrorism or the intentional or accidental use of nuclear weapons by a state have long been regarded as among the greatest threats to global security. Currently there are more than 10,000 nuclear weapons in the arsenals of nine states, while more than 30 countries have stocks of nuclear materials that, while produced for peaceful purposes, could potentially be weaponised by nefarious actors. In addition, over 50 countries operate either nuclear power or research reactors, which are potentially attractive targets for sabotage attacks by state and non-state actors.

Researchers at King's College London's Centre for Science and Security Studies (CSSS) have achieved extensive impact by supporting government and industry initiatives to reduce the risks associated with nuclear weapons, sensitive nuclear materials and civil nuclear facilities. Working closely with relevant practitioner communities in more than 20 countries, King's work has directly shaped policy and informed best practice. The research team has strengthened nuclear security globally, by enhancing security culture at nuclear facilities, improving the detection of smuggled nuclear materials and supporting the development of practical steps towards verified nuclear disarmament.

2. Underpinning research

Nuclear security has been at the forefront of the international security agenda for decades, with risks broadening over time from state-level nuclear weapons proliferation to include the possibility of their acquisition and use by terrorist groups, as well as the potential sabotage of civil nuclear facilities. King's research has furthered knowledge relating to the control of nuclear weapons and materials, with a particular focus on the functioning of nuclear verification and security systems at the operational level. The research team has advanced understanding of the human element within these systems and how this can influence both verification and security outcomes. King's research has identified a number of common challenges that are likely to inhibit the effectiveness

of these systems, as well as solutions for how these may be overcome through the adoption of new organisational approaches and technical tools that better support human performance.

To date few studies have examined the practicalities of nuclear disarmament and how future arms control treaties, aimed at reducing nuclear weapons stockpiles to low numbers, might be verified. Similarly, limited research has been conducted on the performance of nuclear security systems, both in relation to the detection of smuggled nuclear materials and the identification and mitigation of threats at nuclear facilities. In an effort to bridge these gaps, King's researchers conducted innovative empirical research, engaging with practitioners through surveys, interviews and highly-realistic simulations. The research developed new tools and frameworks that have advanced understanding of nuclear security related issues, informing the work of international organisations, governments and industry.

Strengthening security culture at nuclear facilities

Almost all incidents of nuclear sabotage or thefts of nuclear material can be traced to poor human performance compromising security at nuclear reactors or other facilities associated with nuclear material production or storage. As such, during the 2010 to 2016 high-level US-led Nuclear Security Summit, participants highlighted the importance of building an effective nuclear security culture within industry, recognising that this is centrally important to better security. However, there had been little research focused on understanding why weaknesses in security implementation occur and how nuclear security culture can be developed and sustained. King's CSSS Co-Directors Hobbs and Moran explored these issues through a UK-focused interview-based study, funded by the Nuclear Decommissioning Authority (NDA), and the analysis of broader international efforts. Utilising the management studies concept of organisational culture as an analytical framework, this research identified a number of common challenges: a pre-existing environment of secrecy with respect to nuclear security; clear disconnects between threat perceptions and reality within different occupational groups; and how certain leadership practices can unintentionally trigger security-related issues. King's research confirmed the need for new approaches to awareness raising, training and security management, and greater integration between security-focused initiatives and efforts to promote the closely related and more well-established concept of nuclear safety culture [1].

Enhancing the detection of smuggled nuclear materials

There exist hundreds of cases where nuclear and radiological materials have been intentionally trafficked across borders. In an effort to combat this, over the past two decades, tens of billions of dollars have been spent on establishing radiation detection systems for border monitoring, targeted at intercepting materials that could be used in an act of nuclear terrorism. Despite this investment, few studies had examined their likely effectiveness. In a project funded by the UK Government, King's researchers utilised surveys and interviews with front-line officials to uncover a fragmented global detection architecture where safety and commercial concerns frequently overshadow security drivers, undermining efforts to detect nuclear materials in the maritime environment. King's research identified a pressing need for the development of new international standards, guidance and technical tools to bring greater coordination to a system currently characterised by considerable divergence [2,3].

Building directly on this research, Hobbs and collaborators in King's Department of Informatics were funded by the International Atomic Energy Agency (IAEA) to explore how the incorporation of data science tools might enhance the operation of detection systems. Specifically, this work sought to strengthen the characterisation of initial alarms from Radiation Portal Monitors (RPMs), which scan millions of shipping containers every year for the presence of illicit nuclear and radiological materials. Currently, judgements on whether RPM alarms are triggered by threat materials as opposed to naturally occurring radioactive materials (NORM) or commercial goods, rely largely on the skill and experience of local customs officials, who must make a determination in just a few minutes. In a proof-of-concept study, which involved the comparative analysis of thousands of real-world alarming records, King's researchers demonstrated how a data-driven approach, could provide new automated insights into the cause of RPM alarms, without the need for new detectors or hardware. Following further development, this approach has the potential to provide important additional support to customs officials in their assessment of alarming cargo, increasing the likelihood that smuggled nuclear materials will be detected [4].

Supporting practical steps towards nuclear disarmament

In recent years, the promotion of nuclear disarmament has gained fresh political momentum. Yet political will is only part of the challenge. Equally important is the ability to develop processes that will allow for the verifiable dismantlement of nuclear weapons, should a decision be taken to do so. Funded by the governments of the UK and Norway, King's researchers conducted empirical research into the human factors influencing the technical process of verification in a simulated dismantlement scenario from 2014-2017. Conducted at an operational nuclear facility in Norway, the study explored how the inter-personal relationships between inspectors and hosts influence the outcome of technical assessments [5]. Exploring the interplay between trust and confidence within the verification process, the study was the first of its kind and produced evidence that challenged conventional views of nuclear weapons dismantlement as an objective, technical process. It identified and evidenced several key factors that contribute to shaping the relationship between parties involved in the verification process. This served to highlight the potential for this relationship to be managed or manipulated, as well as the impact this could have on verification outcomes.

3. References to the research

[1] Hobbs, C & Moran, M (2020), 'Exploring the human dimension of nuclear security: The history, theory and practice of security culture', *The Nonproliferation Review*, vol. 27, no. 5/6. Initial findings were presented in a restricted report to the Head of Security and Resilience at the UK's Nuclear Decommissioning Authority in April 2018.

[2] Hobbs, C, Downes, R & Salisbury, D (2019), 'Combating nuclear smuggling? Exploring drivers and challenges to detecting nuclear and radiological materials at maritime facilities', *The Nonproliferation Review*, vol. 26, no. 1-2, pp. 83-104

[3] Hobbs, C, Downes, R & Salisbury, D (2015), 'Maritime Security: State of Play' Wilton Park Report, King's College London Centre for Science & Security Studies [Restricted]

[4] Hobbs, C, McBurney, P & Oliver, D (2020), 'Data science in support of radiation detection for border monitoring: An exploratory study', *Science and Global Security*, vol. 28, no. 1, pp. 28-47

[5] Bowen, WQ, Elbahtimy, H, Hobbs, C & Moran, M (2018), *Trust in nuclear disarmament verification*. 1 edn, Palgrave Macmillan

4. Details of the impact

Beyond the nine states that maintain nuclear arsenals, more than 50 countries have developed either nuclear power programmes or reactors for research and other purposes. There are, in total, currently more than 600 nuclear reactors operating worldwide, with many more associated facilities involved in the production and storage of nuclear materials. While the security of these materials has attracted considerable attention, implementation varies considerably across states and facilities, with theft and sabotage incidents demonstrating how nuclear security systems can be circumvented. In terms of nuclear disarmament, the recently entered-into-force Treaty on the Prohibition of Nuclear Weapons (TPNW), has given new momentum to efforts to reduce nuclear weapons numbers to zero. It is clear that verification will be a critical component of new work towards this goal, yet there remain a number of both political and operational challenges that must be overcome for this to be realised. King's researchers have worked collaboratively with international organisations, governments and industry in an effort to address these challenges. This close relationship between researchers and research-users has ensured that this body of work has supported pressing policy needs and new operational requirements, with a focus on understanding and strengthening the 'human factor' within nuclear security systems. It has shaped the course of international initiatives, national guidance and practice at nuclear facilities around the world.

Strengthening security cultures at nuclear facilities

King's research [1] had concluded that while nuclear security culture had been widely promoted at the international level, there existed considerable scope for new initiatives to further strengthen engagement at the working level of industry. In April 2018, research into security culture at nuclear facilities was presented as a restricted report to the Nuclear Decommissioning Authority (NDA),

the UK non-departmental public body of the Department for Business, Energy & Industrial Strategy (BEIS). Created through the Energy Act 2004, the NDA establishes the overall approach, allocates budgets, sets targets and monitors progress in delivering safe, sustainable and publicly acceptable solutions to the challenge of nuclear clean-up and waste management. Following this presentation, the NDA disseminated the restricted report to the 14 licensed companies and subsidiaries within their estate, with resulting significant impacts on their policies and operational practices. [text removed for publication]. The new security policies, programmes and training initiatives launched by the NDA, as recommended in the King's report [1], have served to strengthen security culture within the various companies and subsidiaries that form part of their estate. In addition, the interview-based methodology employed in [1] was adopted by the NDA as a process with which to approach future assessments as it *"…complemented previous methods used to gauge security culture and provide[s] greater rationale behind why employees may act in the manner they do"* [A].

The research findings from [1] have also been integrated into international activities conducted under the UK's Nuclear Security Culture Programme (NSCP). Led and implemented by King's since its inception in 2014 as a new strand of the UK's Global Nuclear Security Programme and supported by a multi-million grant from BEIS, the NSCP includes a wide range of training courses, workshops, policy reports and security culture assessments [B]. According the Head of UK International Nuclear Security and International Atomic Energy Agency Policy, *"drawing on research by King's staff"* the NSCP has *"engaged with practitioners from government, regulators, industry and the scientific community in over twenty countries… to improve understanding on why weaknesses in security culture may occur and how they can be effectively identified and mitigated"* [C]. Over "*thirty impactful activities have been performed under this programme"* with many of the organisations engaged "*subsequently strengthening their internal nuclear security policies and practices"* [C]. For example, according to Lawrence Anikwe Dim, Director General of the Nigerian Nuclear Regulatory Authority, nuclear security training programmes organised by King's College London have *"in no small measure enhanced the regulatory practices of the authority with overall implications for nuclear security and safeguards culture in Nigeria"* [D].

Enhancing the detection of smuggled nuclear materials

Findings from King's research into the operation of radiation detection systems for border monitoring [2,3], were presented as a 'State of Play Report', at a Wilton Park (an executive agency of the former UK Foreign & Commonwealth Office) workshop in November 2015 to a closed government audience. According a member of the UK's Nuclear Non-Proliferation and Security Team, this research *"will help improve currently fragmented approaches to implementing nuclear security at ports throughout the world"* [E]. Recommendations from the report [3] regarding the management of innocent alarms, exchange of best practice and the development of new technical assessment tools, fed directly into a UK-US Best Practice Guide on this topic presented at the 2016 Nuclear Security Summit in Washington DC [E,F].

Hobbs' research with collaborators in Informatics, on the integration of data science techniques into detection systems, provided the UK's contribution to a 2015-2019 IAEA Project (completed in November 2020) on the 'Improved Assessment of Initial Alarms from Radiation Detection Instruments', involving more than twenty countries [4, G]. According to Charles Massey, Detection Science and Technology Team Leader at the IAEA, [4] *"was unique in that it was the first study to explore how data science tools could support the assessment of alarm""* [H]. As such it will *"directly inform future work conducted by the IAEA and others… with the potential to revolutionise the practice of radiation detection at maritime and other facilities"* [H].

Supporting practical steps towards nuclear disarmament

King's research has furthered the work of the UK-Norway Initiative on the Verification of Nuclear Warhead Dismantlement, by "*investigat[ing] factors that contribute to the building of confidence in an inspection process"* [5, I]. Findings were disseminated throughout the course of the project as closed government reports and public briefings for state delegates attending the 2014 Non-Proliferation Treaty (NPT) Preparatory Conference and the 2015 NPT Review Conference at the United Nations in New York. King's research has had a transformative impact at two levels. Nationally, the study has led the UK's Atomic Weapons Establishment (AWE) to adjust its scope of work to "*take into account the likely human factors at every stage of [the disarmament] process"*

[J]. At a multi-lateral level King's research has informed the work of the International Partnership for Nuclear Disarmament Verification (IPNDV), established in 2014 [G]. The IPNDV is a United States led initiative involving more than 25 countries, that seeks to identify and address challenges associated with nuclear disarmament verification. King's research [5] served to set the ground for new work on scenario development under the initiative, particularly with regard to the role of human and social factors in this process [J]. Collaboration between King's and AWE has been extended through the award of two William Penney Fellowships (2015-2018, 2019-2021) encompassing the provision of bespoke research, advice and training to AWE on nuclear verification related issues.

5. Sources to corroborate the impact

[A] Testimonial from: Paul Tonks, NDA Head of Security and Resilience, 'NDA-KCL Nuclear Security Culture Assessment Project' [via letter], 18 April 2019

[B] HM Government 2015, UK International Chemical Biological, Radiological and Nuclear Security Assistance Programmes, p. 7 and 9

[C] Testimonial from: Head of International Nuclear Security & IAEA Policy, UK Government Department of Business Energy and Industrial Strategy (BEIS) [via letter], 6 December 2019

[D] Testimonial from: Lawrence Anikwe Dim, Director General of the Nigerian Nuclear Regulatory Authority [via letter], 3 November 2016

[E] Testimonial from: International Nuclear Security and Non-Proliferation Team, UK Department of Energy and Climate Change (DECC) [via letter], 9 June 2016

[F] 'Nuclear Security Summit Enhancing the Security of the Maritime Supply Chain Gift Basket: Best Practice Guide for Removing Nuclear and Radiological Materials that are Out of Regulatory Control from the Global Maritime Supply Chain', Nuclear Security Summit, March 2016

[G] Hobbs, C, McBurney, P & Oliver, D 2020, 'Data Science in Support of Radiation Detection for Border Monitoring: An Exploratory Study', *Science and Global Security*, vol. 28, no. 1, pp. 28-47; UK contribution to Improved Assessment of Initial Alarms from Radiation Detection Instruments, International Atomic Energy Agency (IAEA)

[H] Testimonial from: Charles Massey, Detection Science and Technology Team, International Atomic Energy Agency (IAEA) [via email], 18 December 2019.

[I] 2015 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, 'The United Kingdom Norway Initiative: further research into the verification of nuclear warhead dismantlement', 27 April to 22 May 2015, p. 2

[J] Testimonial from: Keir Allen, Technical Authority for Arms Control Treaties and Assessments, Atomic Weapons Establishment, 22 October 2019