MARCH 2022

BASIC

The Case for a Proliferation - Resistant Medical Isotope Reactor

Enhancing Nuclear Medicine Globally, While Minimising Proliferation Risk

Report by Eva-Nour Repussard and Chris Spedding

Introduction

On 4th November 2021, BASIC hosted a multi-stakeholder roundtable at the National Liberal Club to explore the policy cases for a 'proliferation-resistant' medical isotope reactor. The purpose of the roundtable was to explore the merits of the policy challenge and whether the UK should take a lead in seeking to meet that challenge. The policy proposition has been developed by Professor William Nuttall, of The Open University, and colleagues, who attended the meeting alongside a combination of policy and technical experts from the British government, civil society, academia, the private sector, nuclear science and technology, non-proliferation and the wider nuclear policy community. The meeting was held under the Chatham House Rule. This report describes this proposed 'gift' to the international community, and summarises the discussions and debates held during the roundtable.

The Proposal

A 'proliferation-resistant' medical isotope reactor is a technology capable of producing isotopes for use in nuclear medicine, but designed in such a way as to make it extremely difficult for anyone to repurpose or deconstruct it in order to advance clandestine nuclear proliferation aims. During the roundtable, this concept was discussed primarily in the context of a proposal called 'PREMIER'

although it is possible that other technological approaches might meet the identified policy goals. The roundtable was therefore focussed on those goals and the comprehensive technology issues to be considered, and the technical specifics of the PREMIER concept were not discussed.

PREMIER is a theoretical, small-scale medical isotope reactor that would be designed and built in the United Kingdom – possibly with a partner country – for export to states in need of a more resilient supply of medical isotopes. Once imported, it could be used to produce short-lived medical isotopes to serve the growing health needs of the populations of these states.

The broader PREMIER concept is an industrial system, not just a reactor. This factory would produce PREMIER reactor modules primarily for use by developing countries, which would be simple to understand and operate but very hard to make. The modules, furthermore, would be relatively small and designed to fit a standard structure at each host's medical institute building, which would also be supplied by the UK.

The reactor would be near impossible to uprate, refuel or tamper with, and any attempt to do so would cause the reactor to break safely and become inoperable. The reactor module should be impossible to replace with something locally improvised, and should be of short, limited life (five years for example). Once they have expired, the modules would be returned to the UK and a new one would be issued only on safe receipt of the previous module. Fission targets will be supplied with similar care. The neutron flux and geometry of the reactor will be optimised for medical isotope production, but everything will be done to reduce the risks and difficulties arising from fertile materials being placed in such a flux.

The PREMIER proposal is interdisciplinary and multidisciplinary, requiring the combination of expertise and insight from nuclear policy, global health, industry, security, transport, international trade, development and foreign policy. Fundamentally, the proposal sits at the intersection of two disciplines that rarely speak to one another: nuclear non-proliferation and global health (and therefore also international development). The intention behind PREMIER is to do this in such a way — using an ingenious design and cutting-edge technologies — to ensure that the reactor poses the minimum possible nuclear materials proliferation risk.

The Global Context

Demand for medical isotopes will increase over the next century, as medical science advances, lower-income countries industrialise, and populations grow. Yet current global production is heavily centralised to just a few reactors, mostly in Europe, with the Netherlands being the number one producer. Some radionuclides used in nuclear medicine, however, have short half-life to the point that supply chains need to be fast-moving and reliable. The most important isotope in current use is technetium-99, which is derived from molybdenum-99 with a half-life of 66 hours.

This 66-hour window already poses a serious logistical problem for people in countries that cannot produce their own indigenous materials (the 'have-nots'), who must rely on an uninterrupted supply from supplier countries (the 'haves') – a problem heightened when the suppliers are not in their

region. According to the IAEA, although production of these isotopes has continued during the COVID-19 pandemic, hospitals risk facing shortages due to supply chain issues caused by the closing of borders, and the cancellation of flights. The current system is not resilient to shocks, and the argument for a more distributed and strengthened system of supply is therefore apparent.

In developed countries, medical attention is turning to even shorter half-life isotopes as these provide clinical benefits, but such developments do not necessarily take into other countries' needs. There is a real risk that states that currently lack access to these technologies will be denied modern medicines in the mid-21st century as a consequence of global healthcare infrastructure planning that has neglected them in the first decades of the century and that has failed to anticipate their emerging needs. Yet, all of this concern for global health must be balanced against the risk of proliferation that emerges whenever nuclear technologies — even those that have an ostensibly peaceful purpose — are exported.

The Policy Cases for British Action

A number of policy cases were put forward in favour of the United Kingdom's leadership — possibly with an eventual partner state — in developing and providing access to a proliferation-resistant medical isotope reactor.

Global Health

The development of a technology such as PREMIER could provide the United Kingdom with an opportunity to improve access to medical isotopes in the Global South by decentralising the supply chain. Alternative imaging-based options for diagnosis, such as positron emission tomography, computed tomography and magnetic resonance imaging, are expensive technologies that may be difficult to obtain for some developing economies in the Global South. Thus, locally produced medical isotopes might give developing countries a cheaper alternative for medical diagnosis.

Non-Proliferation

The proposal would strengthen the United Kingdom's non-proliferation objectives by reducing the pathways to the acquisition of nuclear weapons among would-be proliferators. By offering a viable and free alternative to the domestic development of medical isotope reactors, or to such a development supported by third parties unconcerned about proliferation risk, the United Kingdom provides the international community with enhanced insight into motives and decision making in emerging economies. Are the expressed interests of a developing country in a nuclear medicine institute equipped with a small reactor sincere? States that turn down PREMIER or a similar technology, should arguably be looked at with greater scrutiny within the international community — *if* they still seek to acquire medical isotope reactors by less careful means and at a greater cost.

Access to Peaceful Nuclear Technologies

The proposal would help the United Kingdom fulfil its responsibility, under Article IV of the Nuclear Non-Proliferation Treaty, to provide access to peaceful nuclear technologies, thereby bolstering the Nuclear Non-Proliferation Treaty regime. As faith in the Non-Proliferation Treaty regime is currently

under significant challenge, it particularly important to provide a new offering to strengthen the bargain between those who agreed not to develop nuclear weapons in return for assistance with peaceful nuclear technologies.

Maintaining the National Nuclear Skills Base

The United Kingdom was one of the first powers to develop civil nuclear technology in the 1950s. In England and Wales there is strong cross-party support for the building of new nuclear power stations, as seen at Hinkley Point C in Somerset; in this case, the United Kingdom is constructing a technology originally designed in France and Germany. The biggest task for UK civil reactor design is currently the plan led by Rolls-Royce for a 470MWe Small Modular Reactor (SMR) – although it must be said that the Rolls-Royce design is not so small. In addition, there are projects associated with Advanced Modular Reactors (AMR) dedicated to commercial energy generation. All these projects relate to national infrastructure and the UK industrial base, but are led by the private sector. In contrast, the proposed PREMIER reactor would be a public sector-led activity protected from the vicissitudes of the market. It also is a much smaller capital proposition than either the SMR or the AMR ambitions already described. The existence of such a public enterprise will underpin British skills and provide support to the wider nuclear cluster re-emerging in the United Kingdom.

Strengthening Bilateral Nuclear Cooperation

The development of a proliferation-resistant medical isotope reactor could be a collaborative endeavour between two technologically-advanced countries. In the case of PREMIER, it is recommended that the United Kingdom seek to partner with a country without nuclear weapons, to stress that it is an offer from advanced economies and not just an NPT-recognised nuclear weapon state(s) offer. Such a partnership would lower capital costs and reduce project risks, as well assisting with the global reach of the proposition to countries in the Global South.

Soft Power Projection

For the United Kingdom and its development partner have an opportunity to strengthen their soft power. In addition to contributing to the 'public good' of global health, any country accepting a PREMIER facility (for example) will hopefully be entering into a multi-generational partnership. Such a medical isotope institute might reasonably be expected to operate for 80 years or more. The users, regulators and developers of such competence will be a global community of partners, with the United Kingdom at its heart. The Commonwealth, for example, could be one organisation well suited to help spread the message of peaceful uses of nuclear technology.

Discussion

As hoped, the meeting addressed the policy proposition for a new United Kingdom-led offering from a variety of different angles due to the multi-stakeholder composition of its participants. The discussions have been grouped into five main categories: 1) global health; 2) proliferation and safeguards; 3) the United Kingdom's leadership; 4) prestige and education; and 5) framing the 'Global South' needs.

1. Global Health

The participants discussed the potential for a new UK contribution to the global health regime, notably highlighting that it could alleviate concerns regarding supply chain issues. Some participants further argued that the medical isotope reactor would give its user countries greater autonomy by providing them with an indigenous production of medical isotopes.

One participant, however, noted that the proposal should seek to not inflict the molybdenum-99 'monopoly' on the developing world. They argued that the United Kingdom should seek to start a new era of lighter isotopes that are cheaper, inherently more proliferation-resistant, and easier to regulate. However, it was argued that different technologies benefit the scientific and the global health community — and that both technologies are not necessarily competing with one another.

2. Proliferation and Safeguards

Participants were divided on the importance of the proliferation risk that a reactor like PREMIER could pose, with some suggesting that – given the quantities or enrichment levels involved – the risks of proliferation were very small. A participant noted that whilst there were papers noting the risk of proliferation pathways relying on the accretion of small quantities from many sources (for example, from smoke alarms), these are not always viewed as particularly credible when compared against other pathways. Professor Nuttall suggested that the main proliferation concern did not relate to the reactor modules or their fuels but rather to the uses that the resulting neutron flux might be put to. It was observed that, in principle, any machine that can make medical isotopes could make plutonium.

Participants raised that in order to facilitate the safeguards regime, a facility like PREMIER might better be set up in regional hubs rather than in individual countries — and if possible in countries which already have a level of nuclear activity and expertise in implementing safeguards which could reduce the burden on IAEA inspectors. Participants were divided on whether safeguards would need to be modified in light of such ideas, but Professor Nuttall indicated that he hoped it could be a design goal of PREMIER that no changes would be needed to either international safeguards or best practice in nuclear safety regulation.

Professor Nuttall suggested that the design goal should be for full and accurate disclosure of the core design and composition. The reactor modules and all equipment in the country would be accurately and fully described. Reverse engineering would render the module inoperable, but would confirm that that device is as described. It would also reveal that the module is extremely difficult to manufacture. The manufacturing facility in the United Kingdom or the second partner country would be a much more secretive enterprise with much hidden knowledge, both codified and tacit. It would, of course, be fully compliant with formal international requirements.

It was generally felt that a technology like PREMIER might face an up-hill battle to convince nuclear regulators, who are typically conservatively-minded, to sanction the operation of a fragile (though fail-safe) reactor design — although it was remarked that the UK's push towards small, modular reactors (SMRs) might make it the perfect place to develop such a concept, from a regulatory standpoint. Professor Nuttall stressed the importance of a distinction between an event that has the

potential to cause personal or environmental harm and an event that can render the reactor inoperable. The intention that PREMIER is 'fragile' relates to the latter idea.

3. The United Kingdom as a Leader

Participants discussed whether the United Kingdom is the right state to lead on such a proposal, from a technical point of view. Some participants saw an interest in having the United Kingdom lead the project, as it would be a long-term investment that could be coupled with ARTHUR: a shorter-term proposition oriented to meet the demand for medical isotopes within the UK's own National Health Service (NHS).

Like ARTHUR, which is expected to be profit-making in the long-run, a technology like PREMIER could be an economically and politically low-cost additional thread to emerging UK leadership in medical isotope technology. It was noted that the production of PREMIER modules could be co-located with ARTHUR and the two projects could benefit from synergies such as skills sharing. Moreover, by developing ARTHUR, the United Kingdom would improve the offer of PREMIER and vice-versa — and thus it would accelerate the UK's pathway to credibility from a technical point of view.

Some participants, however, still had concerns about the United Kingdom leading such a project. They noted that the United Kingdom's current lack of an indigenous capability indicated that it lacks the kind of expertise to develop this technology effectively, and thus also lacked the legitimacy necessary to sell the idea internationally.

Beyond the technical perspective, it was also discussed whether, from a political perspective, the United Kingdom should lead on the proposal. Some participants showed concern that the British government might use a 'gift' as a means to justify its nuclear modernisation programmes or the recent increase of its nuclear warhead cap. One participant further asked whether the United Kingdom had any prerogative — stressing the country's colonial past — to lead such a project. Such thoughts lead back to the suggestion that the United Kingdom should establish a relationship with a highly-capable partner country to develop PREMIER or a similar concept. It was suggested that the best partner state might be a non-western state.

Some discussion time was given to potential candidate partner countries that the United Kingdom could develop a technological offering in tandem with — but at this stage, the organisers feel it is premature to name names. Instead, participants focused the criteria that such a partner country should meet:

1. It should not be a nuclear weapons possessor state or a permanent member of the United Nations Security Council (P5).
2. It must have a strong domestic nuclear skills base.
3. It must have a history of proactive engagement with the NPT.
4. It should be a state that would gain material industrial benefit from the partnership.
5. Ideally, it would not be a Western or European state with a colonial past.

4. Prestige and Education

Participants discussed whether such a proposal from the United Kingdom might underestimate the prestige that some states attach to indigenously-designed and built reactors and other nuclear technologies. They argued that in many countries, there is a hunger for research reactors in terms of advanced technology, national prestige, training opportunities, and in order to teach young people to become nuclear scientists. Drawing a comparison from previous proposals to replace research reactors with particle accelerators for the production of medical isotopes, one participant stressed that some countries might in fact oppose an offering like PREMIER, as they do not want a 'cookie-cutter machine' but rather want a pathway to maturing expertise in the nuclear industry.

Participants considered the extent to which a new UK offer would provide education and training opportunities. Some participants argued that because potential partners would not know how to make it or repair it, there would be no educational value in 'pressing a button' and in sending back the reactor to the UK if the reactor broke down. One participant argued that, despite the external nature of the reactor design, development and repair, a technology like PREMIER would still provide educational opportunities as a lot of the expertise needed is in regards to the radiochemistry involved in making medical grade isotope doses (whether it is molybdenum-99 or another isotope). Overall, participants felt that a technology like PREMIER might provide expertise on the production of medical isotopes, but less with respect to reactor design, build, and operation.

5. Framing the 'Global South' Needs

Several participants highlighted concerns about how the relationship between Global North to the Global South is framed. The offer, they suggested, should be less a material 'gift' (object) and more an ongoing strategic partnership (subject-subject) that is tailored and responsive to the specific needs of individual countries. Rather than framing PREMIER, or a similar policy, as a prestigious gift, participants seemed to agree that for the proposal to work, both parties would need to sit at the table and discuss their needs. This partnership, they argued, should be accompanied by training from the UK, so that the users fully understand the technology and how to use it. Furthermore, in order to regulate and comply with safeguards, most countries without a history of nuclear technology will need regulators' training and to set up new structures and legislation. This would be a lengthy endeavour: hence rather than a gift, this is a long-term relationship that the UK offers with its proposal.

It was raised that for the success of such a partnership, the proposal should be designed right through to the decommissioning stage, including in the case of an accident. Discussions between the United Kingdom and its partner states would be needed to agree on who carries the liability for decommissioning and clean-up. Failing to do this might increase states' reluctance to take on such a reactor, lest it becomes a 'poisoned chalice'.

In addition, one participant highlighted that the 'Global South' is as diverse as its actors and the United Kingdom should seek to identify which countries from the Global South would be most interested in such a relationship. Pitching the proposal as a product for the 'Global South' risks offering a one-size-fits-all product to a diverse set of countries with heterogeneous needs.

Conclusion

In short, it was concluded that a proliferation resistant medical isotope reactor such as PREMIER could become an asset for the United Kingdom as well as for some countries in the Global South. Such a proposal would promote the United Kingdom as a leader in both the global health field and, by strengthening its first and third pillars, the NPT regime.

Furthermore, the PREMIER proposal — or a similar partnership — with some countries in the Global South could help lessen the divide between the 'haves' and 'have-nots' within the medical isotope field. However, any UK intervention to strengthen the supply of medical isotopes among such countries should start with an assessment of the specific needs or demand of individual countries, and what is or is likely to become possible given the state of the science and technology.

Acknowledgements

The proposition that the United Kingdom could simultaneously make a positive contribution to both the medical needs of the Global South and to the non-proliferation and nuclear security agendas through the development of a new medical isotope technology is the proposal of Professor William Nuttall (The Open University), which has been developed over several years with the assistance of a number of people. Professor Nuttall would especially like to acknowledge and thank Dr Michael Bluck (Imperial College London) and Sebastian Brixey-Williams (BASIC) for their contributions in advancing these ideas in the lead up to the meeting reported here.

This report has been prepared by Eva-Nour Repussard (lead writer) and Chris Spedding of BASIC. Chris Spedding is also thanked for his management of the event.

The funding for the roundtable and this report has been provided by The Open University and BASIC. The report summarises the comments expressed at the 4 November event on the topic presented and does not necessarily represent the views of the sponsors.