Royal United Services Institute
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UK PONI
UK Project on Nuclear Issues

The 2019 UK PONI Papers

Edited by Sam Dudin and Chelsey Wiley

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Royal United Services Institute
for Defence and Security Studies
Whitehall
London SW1A 2ET
United Kingdom
+44 (0)20 7747 2600
www.rusi.org
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Editors' Note

The 2019 UK Project on Nuclear Issues (UK PONI) Annual Conference gathered established and emerging experts from academia, industry, government and the military to share insights and debate a broad range of civil and military topics. Emerging experts who gave presentations at the conference have adapted those presentations for this publication.

There are two primary factors which make this conference different from many others. First, UK PONI is a broad church – it prides itself on transcending many of the barriers between the various nuclear communities, including those between the deterrence and disarmament communities, and the technical and policy communities. The authors within this publication cover an extremely diverse array of positions.

Second, this conference specifically focuses on developing the next generation of nuclear experts in academia, industry, government and the military by giving emerging experts a platform to present and publish their research. And because these experts are emerging, their research is often more novel than that of established experts.

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I. Nuclear Power in a Changing UK

Stephen Beckett

NUCLEAR POWER IN the UK has a mixed history. As the first country to commercially generate electricity from nuclear reactors, the UK led the world in a new way to capture the power of the atom. This was followed by the design and manufacture of the Magnox gas reactor; and many of the derivative second generation Advanced Gas Reactors (AGRs) are still in operation at locations such as Hinkley Point B and Dungeness B. Build history since then has been chequered. Sizewell B, planned as the first of a new generation and completed in 1995, was the last nuclear power plant to come online since the 1980s.

It is widely acknowledged that the world needs to do its utmost to reduce greenhouse gas emissions and that nuclear power could contribute significantly to this aim:

> As a large scale energy source, nuclear power has a significant potential to contribute to GHG emissions reduction.[1]

In 2008, the UK concluded that nuclear power should form a significant part of the country's energy mix by allowing energy companies to submit proposals for new nuclear power stations.[2] However, recent funding approaches have led to several developments being abandoned, throwing long-term energy planning into jeopardy. This paper aims to look in more detail at the energy breakdown in the UK and methods that could be taken to improve the current, pessimistic outlook.

Current UK Demand

UK power generation in 1990 was driven largely by coal, but since then has shifted towards gas and later renewables following the introduction of the EU carbon emissions trading scheme.[3] This scheme aims to, amongst other things, make the most polluting forms of energy generation less profitable on the basis of their carbon emissions, thereby driving investment towards cleaner forms of energy.[4]

The use of renewable energy sources in the UK has increased significantly over the last 20 years and they now provide around 30% of the UK's electricity.[2] This is commendable, but there are questions

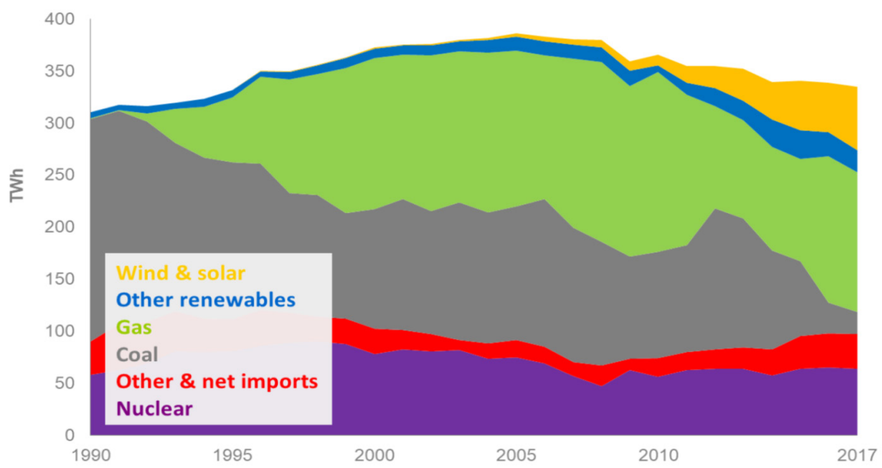
1. International Atomic Energy Agency, 'Climate Change and Nuclear Power 2018', 2018, p. 28.
2. Department for Business Enterprise and Regulatory Reform, 'Meeting the Energy Challenge: A White Paper on Nuclear Power', 2008, p. 37.
3. European Commission, 'The EU Emissions Trading System', 2016.
4. European Commission, 'EU Emissions Trading Scheme Handbook', 2015, p. 4.

around how much of a share of the power capacity renewables could take before additional infrastructure would be required to aid in flattening the inevitable peaks and troughs in the supply.[5]

The UK has three power lines importing approximately 3 GW from the Netherlands and France, in addition to the country's own generating capacity.[6] It is worth noting that the decline in the number of nuclear power stations in France (expected to be similar to UK decline) as they reach retirement age could increase energy costs in the rest of the EU as the French energy surplus decreases.[7] Countries that are partially dependent on French energy supplies include the UK and Germany, who may need to invest in greater power supply infrastructure than is currently envisaged just to maintain their supplies.[8]

There are eight operating nuclear power stations in the UK, with seven due to close by 2025. These generate around 20% of UK electricity needs despite representing only 9% of installed capacity, demonstrating the high use of nuclear power stations.[9] The breakdown of UK power over the last 30 years is shown in Figure 1.

Figure 1: Power Generation in the UK 1990–2017.



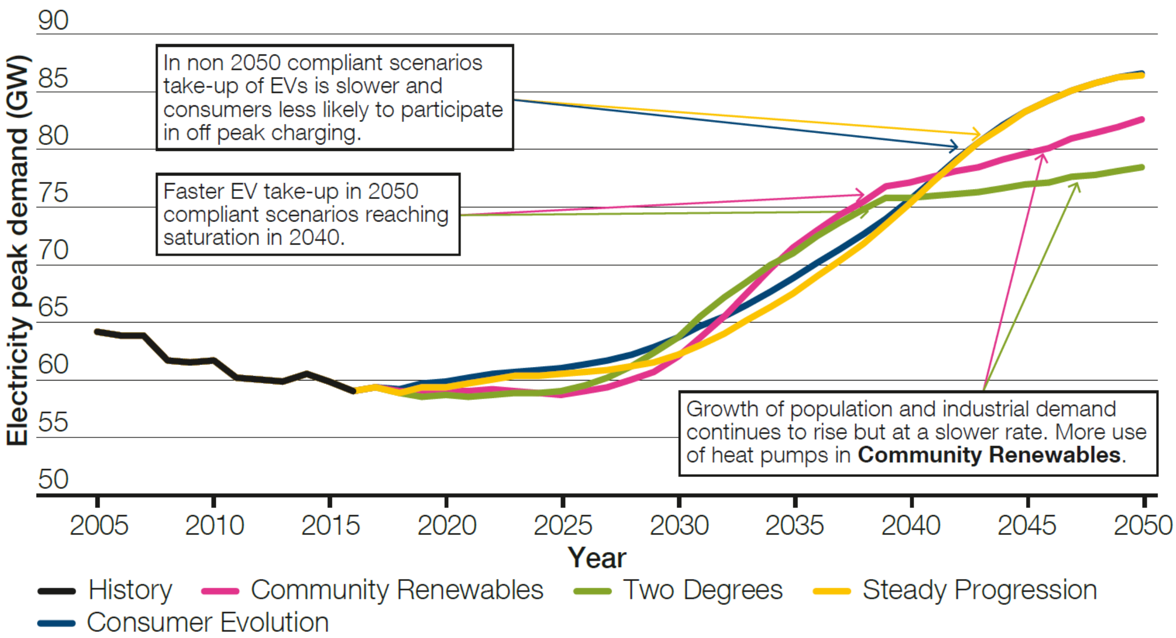
Source: Department for Business, Energy & Industrial Strategy, 'UK Energy in Brief 2018'.

5. Clara Franziska Heuberger and Niall Mac Dowell, 'Real-World Challenges with a Rapid Transition to 100% Renewable Power Systems', *Joule* (Vol. 2, No. 3, March 2018), p. 367.
6. Paul Bolton, 'Energy Imports and Exports Briefing Paper Number 4046', House of Commons Library, Commons Briefing Papers SN04046, 19 October 2018.
7. Dan Yurman, 'Will France Spoil its Nuclear Future for Short-Term Political Gain?', *Energypost.eu*, 10 January 2019, <https://energypost.eu/will-france-spoil-its-nuclear-future-for-short-term-political-gain/>, accessed 27 November 2019.
8. Ben Hall, 'France Grapples with its Nuclear Power Dilemma', *Financial Times*, 28 November 2018.
9. Department for Business, Energy and Industrial Strategy, 'UK Energy in Brief 2018', 26 July 2018.

Future Demand

A drive to meet an ambitious new target of zero net CO_2 emissions by 2050 requires that the UK changes its energy mix significantly while investing heavily in reduction of emissions from transport and heating.[10] This will require further advances in electrification and consequently in electricity generation, which runs counter to a decrease in operating nuclear power stations. Baseload capacity in the UK is expected to remain static for the next 30 years, but peak power demand is expected to increase significantly, as shown in Figure 2, which shows the four energy scenarios the National Grid has developed.[11]

Figure 2: National Grid Energy Scenarios.



Source: National Grid, 'Future Energy Scenarios 2018'.

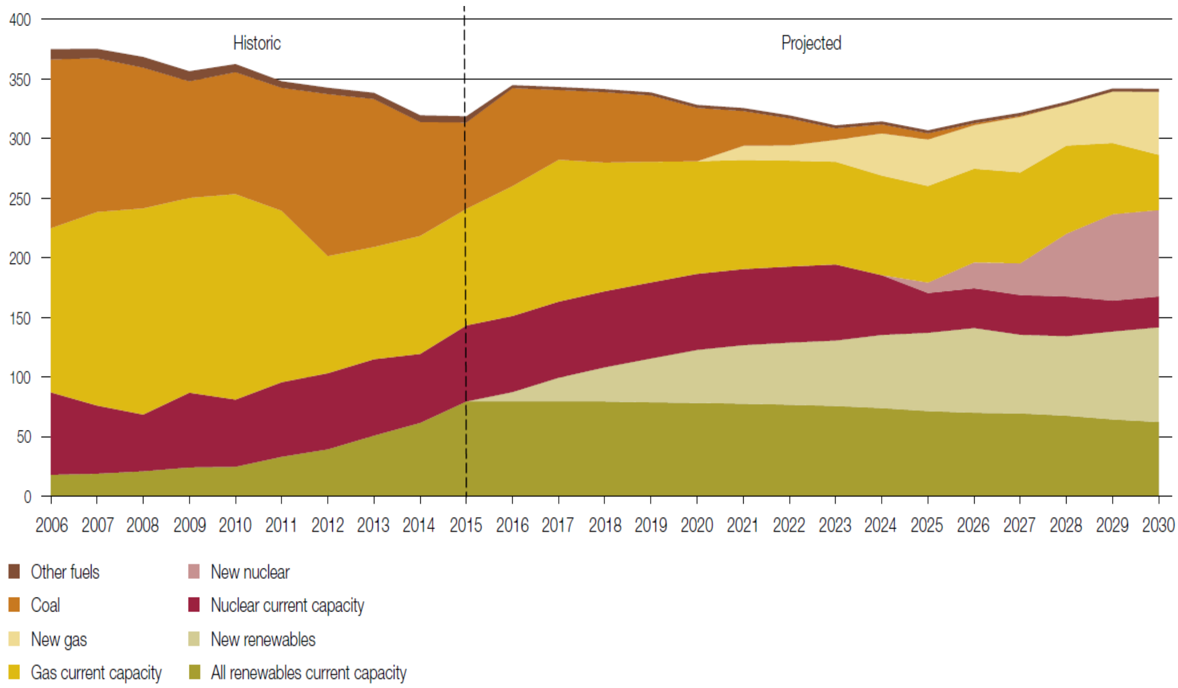
Two of these scenarios meet the 2050 target and two do not. The key point is that regardless of the scenario, peak electricity consumption is expected to increase by at least 30% from current levels. This will require significant investment in energy generation capacity, which, if not carefully managed will make it impossible to meet the 2050 net zero emissions target.

10. HM Government, 'UK Becomes First Major Economy to Pass Net Zero Emissions Law', 27 June 2019.
11. National Grid, 'Future Energy Scenarios 2018', 12 July 2018.

Future Capacity

Future generating capacity in the UK is predicted to remain relatively static at current levels; however, by 2035, the majority of capacity will be made up by sources that are not installed yet.[12] Figure 3 shows the change in installed capacity expected out to 2030.

Figure 3: Power Generation Capacity Until 2030.



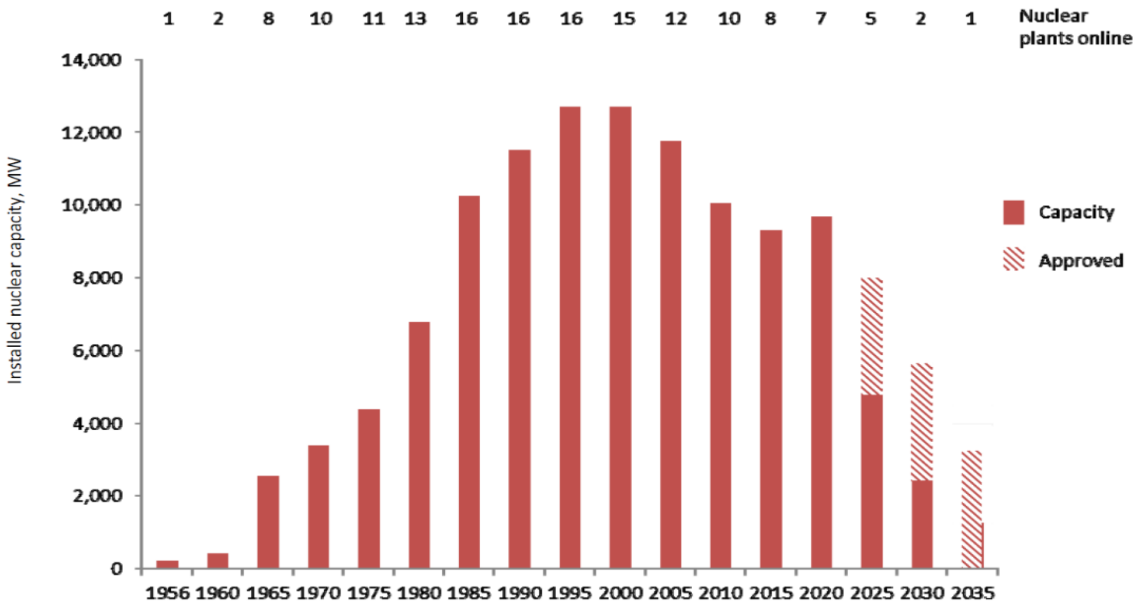
Source: National Audit Office, 'Nuclear Power in the UK'.

Currently operating nuclear power stations in the UK are generally reaching the end of their lives and all but one are predicted to close by 2025.[13] This will leave a 20% deficit in generation capacity, which was due to be made up from new build stations. The delay in building these stations has led to the prediction for nuclear capacity change shown in Figure 4.

Figure 4 shows that UK nuclear capacity is going to decrease significantly in the next 10 years. Hinkley C is currently the only plant forecast to come online and is also the only plant actually in a build phase. This is against original plans for six new nuclear plants in the UK by 2030. This indicates a clear issue with nuclear policy and planning in the UK, so what advances or changes could be made to incentivise the building of new nuclear power stations in the UK?

12. National Audit Office, 'Nuclear Power in the UK', 13 July 2016.
13. Department for Business, Energy and Industrial Strategy, 'Nuclear Capacity in the UK', 2018.

Figure 4: UK Nuclear Generation Capacity 1956 to 2035.



Source: Department for Business, Energy and Industrial Strategy, 'Nuclear Capacity in the UK'.

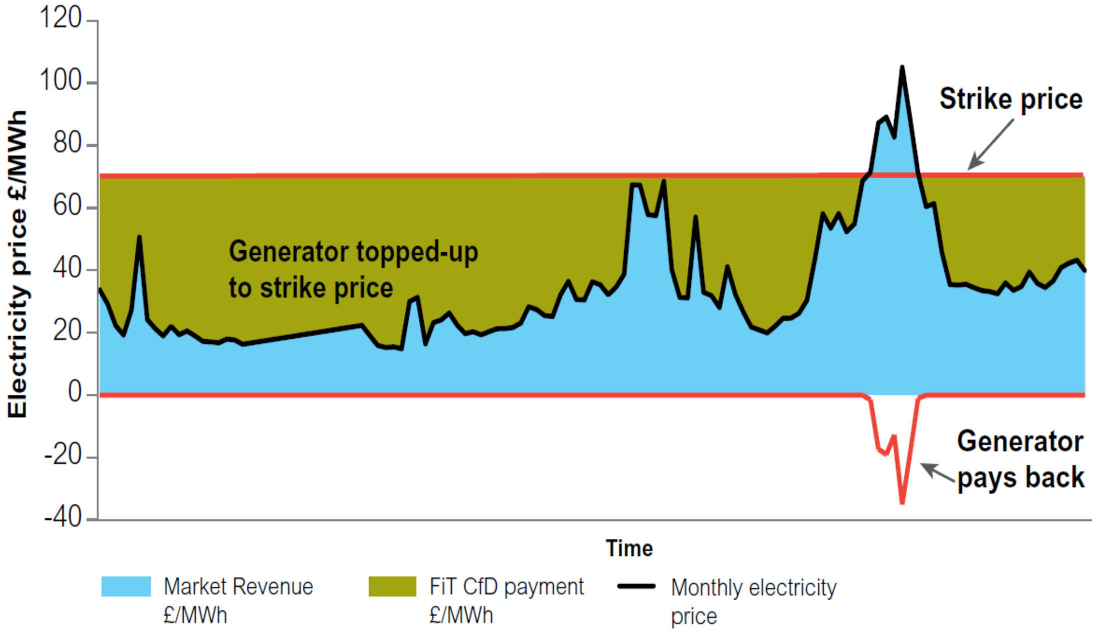
UK Nuclear Policy

Prior to 1996, nuclear new builds in the UK were publicly owned and controlled, originating from nuclear power's ties to strategic defence policy. Between 1996 and 2008, British Energy underwent privatisation before becoming part of EDF Energy in January 2009.[14] All the nuclear power plants in the UK are now run and owned by EDF Energy, who are also responsible for the only new nuclear build currently ongoing in the UK.

From 2008 to 2015, energy policy in the UK aimed to influence the marketplace to create favourable conditions for investment. This was exemplified by the Hinkley Point C deal, which culminated in the government taking no share of the financing or risk but instead guaranteeing a strike price of £92.50 per MWhr for 35 years via a contract for difference, as shown in Figure 5.[15]

14. World Nuclear Association, 'Nuclear Development in the UK', October 2016, <https://www.world-nuclear.org/information-library/country-profiles/countries-t-z/appendices/nuclear-development-in-the-united-kingdom.aspx>, accessed 27 November 2019.
15. National Audit Office, 'Hinkley Point C', HC40, 23 June 2017, p. 4; Department of Energy & Climate Change, 'Planning Our Electric Future: A White Paper for Secure, Affordable and Low-Carbon Electricity', July 2011, p. 38.

Figure 5: Contract for Difference Mechanism.



Source: Department of Energy & Climate Change, 'Planning Our Electric Future: A White Paper for Secure, Affordable and Low-Carbon Electricity'.

Contracts for difference are aimed at flattening out peaks in demand and supply to guarantee an income for the operator, thereby reducing the risk of initial investment, but rely heavily on the strike price being set appropriately, often covering very long timescales. The strike price for Hinkley C compares unfavourably with the most recent strike price for offshore wind, which is approximately £60 per MWhr.[16] The contracting mechanism for Hinkley C has been widely acknowledged as an expensive mistake.[17] Thus, when considering policy arrangements for the next new plants to be built by Horizon at Wylfa and Oldbury, the government offered to take a one-third stake in the equity and also considered financing the remainder of the debt. It then also offered a strike price of no more than £75 per MWh.[18] In turning this offer down (and losing more

16. Phil Summerton, 'Offshore Wind: The Distinction Between Strike Price and Subsidy Matters', Cambridge Econometrics, 12 September 2017, <https://www.camecon.com/blog/details-matter-what-you-need-to-understand-about-yesterdays-offshore-wind-stories/>, accessed 27 November 2019.
17. Jillian Ambrose, 'Hinkley Point's Cost to Consumers Surges to £50bn', *The Telegraph*, 18 July 2017; *BBC News*, 'Reality Check: How Much Would Hinkley C Cost Bill Payers?', 29 July 2016; Simon Taylor, 'Hinkley Point is a Costly Mistake, But Only France Can Pull the Plug', *The Guardian*, 14 March 2016.
18. World Nuclear Association, 'Nuclear Power in the United Kingdom', October 2019, <https://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-kingdom.aspx>, accessed 27 November 2019.

than £1bn in the process), Hitachi suggested that the only way nuclear power could be successful in the UK was if it was nationalised again.[19]

These two policy failures, albeit in different ways, indicate that UK nuclear policy needs significant rethinking.

Policy Development

It is clear to see that market intervention, as recently practised, cannot provide enough incentives for investing in new nuclear to compensate for the risk associated with nuclear new build. Therefore action must be taken to redress the risk to reward balance in favour of rewarding utility companies earlier in the lifecycle of a nuclear plant. Figure 6 highlights the current risk vs. reward balance and Figure 7 shows how it might be changed to incentivise nuclear new build.

Figure 6: Unfavourable Risk vs. Reward Balance.

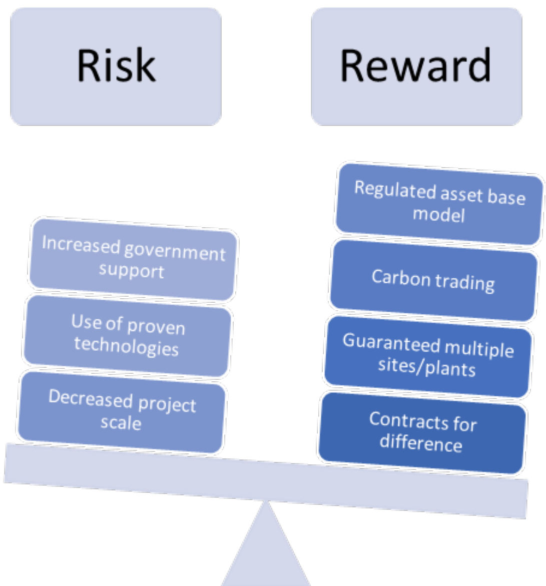
Source: Author generated.

Key amongst the changes that must be made to counter the long timescales for return on investment, high costs and difficulties in public opinion are mechanisms to begin funding power plants before they are complete. This has been shown to work on the London Super Sewer and Crossrail, both of which began to remunerate the operator prior to the completion of the project.[20] A similar approach for Sizewell B has been estimated to cost the taxpayer £6 per year and would strongly incentivise new build.[21]

19. *BBC News,* 'Hitachi Chairman's Wylfa Newydd Comments Criticised by MP', 6 February 2019.
20. *Financial Times*, 'Private Investors Raise Hopes of New Model for UK Nuclear Plants', 27 June 2018.
21. HM Government, 'Regulated Asset Base (RAB) Model for Nuclear', 22 July 2019.

Carbon trading has also played a significant part in decreasing the UK's reliance on coal and such schemes must be continued to incentivise low carbon energy sources, including nuclear. It has also been shown that costs for new nuclear plants decrease significantly once the first of a type is complete. The only current plans to build more than one plant are for EDF's European Pressurised Reactor, of which two are being built at Hinkley and two more are planned for Sizewell C[22]. The experience gained by EDF in building Hinkley C will be invaluable when it comes to building Sizewell C.

Figure 7: Favourable Risk vs. Reward Balance.



Source: Author generated.

Conclusions

Nuclear new build in the UK has stagnated from a peak in the 1980s, despite the country benefiting from this supply of clean and reliable nuclear energy. Many plants are now due to shut down and with them, the 20% of the UK's energy they generate will disappear. Against the need to achieve net zero carbon emissions by 2050 and the inevitable increase in electrification that this will require, the loss of this energy source is significant.

Nuclear new build in the UK appeared to be making significant ground in the years following the energy white paper in 2008 with six new plants planned. Unfortunately, the lack of appropriate contracting mechanisms for these plants has resulted in plans for three plants being shelved. This has threatened the UK's future clean energy supplies and without urgent action to redress these problems it will leave the UK with an energy supply issue through the coming decades.

22. World Nuclear News, 'New Dawn for UK Nuclear Power', <http://www.world-nuclear-news.org/NN_New_dawn_for_UK_nuclear_power_2409081.html>, accessed 4 November 2019.

In order to mitigate these potential problems, UK nuclear policy needs to reflect the long timescales to return on investment via a regulated asset base model with debt financing and plans for multiple sites. The government can no longer insist that its policy of influencing markets is enough to ensure that large energy infrastructure projects are undertaken, be they nuclear, tidal or energy storage.

Finally, since writing the majority of this paper, the government has announced a series of significant changes to nuclear power in the UK, including consideration of a regulated asset base model, funding for small modular reactors and other green technologies.[23] This shows that consideration of the factors mentioned in this paper has been ongoing and that nuclear is still considered essential in the UK's future energy mix.

23. HM Government, 'Regulated Asset Base (RAB) Model for Nuclear', 22 July 2019; HM Government, 'Innovative Funding Models and Technologies to Drive Investment in New Wave of Low Carbon Energy', 23 July 2019.

II. Tactical Nuclear Weapons and Deterrence Stability in South Asia

Syed Adnan Athar Bukhari

PAKISTAN AND INDIA, the two nuclear armed states of South Asia, introduced tactical nuclear weapons (TNWs), also known as non-strategic nuclear weapons, in 2011.[1] Pakistan tested *Nasr* (Hatf-9), which originally had a range of 60 km but was extended to 70 km in 2017. It also produced additional short-range missiles, including the 200-km range *Abdali* (Hatf-2), 300-km range *Ghaznavi* (Hatf-3), 700-km range *Babur* (Hatf-7), 450-km range air-launched cruise missile *Ra'ad* (Hatf-8) and 450-km range submarine-launched cruise missile *Babur-III*.

Pakistani official claims note that adoption of 'Full Spectrum Deterrence' (FSD) falls in line with its existing Credible Minimum Deterrence policy. This overarching strategy of FSD is aimed at ensuring deterrence at strategic and tactical levels.[2] At the same time, India also developed the 150–300-km range *Prahaar* cruise missile in 2011 as tactical support for its forces. Additionally, other short-range missiles, including the 700-km range *Nirbhay* and 290-km range *Brahmos,* ship-launched nuclear capable ballistic missile *Dhansuh,* with a range of 400 km, and the *K-15 Sagarika* submarine-launched ballistic missile, with a range of 700 km, have been produced by India. Pakistan's *Nasr* and India's *Prahaar* missiles can be considered TNWs. Other short-range missiles in their arsenals can also serve tactical purposes in their respective military operations. The range of the TNWs is between 2 km and 500 km. Their yield ranges anywhere from 0.4 kilotons (kt) to 150 kt. In the South Asian context, a TNW is considered to have a range of 50–150 km with a maximum yield of 5 kt.[3] However, the range may extend up to 500–700 km depending on the counterforce targeting strategy.

India and Pakistan became nuclear-armed states in 1998. The following year, both engaged in tit-for-tat violence at a limited level at Kargil, a mountainous battlefield in Indian-held Kashmir. It was realised then that violence may erupt even in a nuclearised context. However, neither Pakistan nor India have escalated local conflicts to full-scale war since then. There are multiple

1. Tactical nuclear weapons have a low yield and short range, and are aimed at counterforce targeting (an enemy's military targets). This is compared to strategic nuclear weapons which have greater yield and longer range, and are aimed at counter-value targeting (an enemy's centres of population).
2. Inter-Services Public Relations, 'Press Release No. PR-133/2013-ISPR', 5 September 2013, <https://www.ispr.gov.pk/press-release-detail.php?id=2361>, accessed 23 March 2019.
3. Zahir Kazmi, 'SRBMs, Deterrence and Regional Stability in South Asia: A Case Study of Nasr and Prahaar', *Regional Studies* (Vol. 30, No. 4, October 2012), pp. 69–101.

factors that contribute to this ‘ugly stability’ in South Asia.[4] Between 1998 and 2019, India and Pakistan went through five crises that did not culminate in war; the two-month Kargil conflict in 1999; the 10-month border stand-off in 2001–02; crisis after the Mumbai attack in 2008; the Uri attack and Indian alleged claim of retaliatory strikes; and the Pulwama crisis in 2019.[5] Two factors played important roles in defusing these crises: deterrence through nuclear weapons and third-party mediation.

After the 2001–02 border stand-off, there was serious debate in India on whether to carry out a limited war against Pakistan ‘under nuclear overhang’.[6] Indian military planners unveiled a military strategy in 2004, commonly known as the Cold Start Doctrine (CSD), to establish the capacity to launch a retaliatory conventional strike against Pakistan. The CSD, later refined as a ‘proactive strategy’, was designed to conduct a limited war in response to the threats of non-state actors emanating from Pakistan and to punish Pakistan’s lack of action against them.[7] This strategy has several key features:

- The CSD would be a limited war strategy based on conventional deterrence, comprising a dissuasive capability (deterrence by denial) along with an offensive capability (deterrence by punishment).
- The CSD has three objectives:
    - Capture a strip of territory of Pakistan and retain it as a post-conflict bargaining chip.
    - Limit the incursions of Pakistani forces into Indian territory.
    - Avoid triggering a Pakistani nuclear response.

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4. Ashley J Tellis, *Stability in South Asia* (Santa Monica, CA: RAND Corporation, 1997), p. 5. Tellis used this term to note that, although both India and Pakistan do not fight wars, there is no peace between them. Both are engaged in conflicts and crises that do not escalate into a war. He used the term ‘ugly stability’ to define this state of relationship between India and Pakistan.
5. See Moeed Yousaf, *Brokering Peace in Nuclear Environments: US Crisis Management in South Asia* (CA: Stanford University Press, 2018) for the 1999 Kargil conflict, 2001–02 border stand-off and 2008 Mumbai attack and following crisis. For the 2016 surgical strike claim of India and resultant crisis and 2019 crisis between India and Pakistan, see Ellen Barry and Salman Masood, ‘India Claims “Surgical Strikes” Across Line of Control in Kashmir’, *New York Times,* 29 September 2016; Adil Sultan, ‘“Pulwama” Crisis: Causes, Implications, and Lessons for the Future’, *Startfasia*, 10 April 2019, <https://strafasia.com/pulwama-crisis-causes-implications-and-lessons-for-the-future/>, accessed 24 April 2019; Syed Adnan Athar Bukhari, ‘Pulwama Attack: Can South Asia Afford a Nuclear War?’, *Starfasia,* 6 March 2019, <https://strafasia.com/pulwama-attack-can-south-asia-afford-a-nuclear-war/>, accessed 25 April 2019.
6. ‘Nuclear overhang’ refers to a limited conventional war in limited geographical space with limited objectives which should not escalate to a nuclear exchange. See Walter Ladwig III, ‘A Cold Start for Hot Wars? The Indian Army’s New Military Doctrine’, *International Security (*Vol. 32, No. 3, Winter 2007/2008), pp. 158–90.
7. Asim Ahmed, ‘Tactical Nuclear Weapons (TNWs) or Flexible Response Choosing on the Right Strategy’, *Policy Perspectives* (Vol. 13, No. 1, 2016), pp. 135–51.

- The operation would be carried out through eight integrated battle groups of defensive corps, possibly division sized and supported by artillery and air.[8]

India would use its strike capacity to harm Pakistan before the international community could intervene and deny Islamabad any chance to escalate a conflict to the nuclear level. For that matter, India needed to restructure its army from 'three large strike corps into eight smaller division-sized integrated battle groups [IBGs], combining mechanized infantry, artillery, and armour'.[9] The IBGs can launch multiple strikes into Pakistan along different axes with support from the Indian air force and naval aviation assets. The holding corps, also known as 'pivot corps', would take up defensive positions that may be used for limited offensive operations. The elements of the CSD operation would aim to make territorial gains of up to 50–80 km within 72–96 hours, which would then be used as a post-conflict bargaining chip to extract concessions from Pakistan. Thus, the key features of the CSD are speedy military operation and deployment.[10]

However, there are limitations to this strategy. The CSD would require extensive prepositioning of ammunition, fuel and spare parts to allow for a rapid and continuous offensive. Given inadequate logistical networks, low-quality maintenance facilities, and a shortage of nearly 13,000 officers, there are considerable flaws in the logistical phase of the CSD.[11]

Pakistan formulated two responses to the looming threat of India's CSD; the *Azm-e-Nau* exercise near Sialkot, Cholistan and Sindh in 2011 (areas that would likely be at risk if Pakistan and India went to war); and the development of short-range ballistic missile *Nasr* in 2011.[12] Pakistan's aim would be to regain lost territory by initiating the use of its anti-tank battalion with dispersal tactics. Pakistan would conduct a 'defensive offence' within 24–48 hours before India could launch its air–land battle concept.[13] Pakistan's strike corps at Mangla would provide the necessary offensive support to counter Indian IBGs.[14]

8. *Ibid*.
9. Walter Ladwig III, 'A Cold Start for Hot Wars?', p. 164.
10. *Ibid.*, p. 165.
11. *Ibid.*, pp. 187–90.
12. Sannia Abdullah, 'Pakistan's Evolving Doctrine and Emerging Force Posture: Conceptual Nuances and Implied Ramifications', *Pakistan Horizon* (Vol. 71, No. 1/2, January–April 2018), pp. 79–93.
13. Air–land battle concept is a military planning based on close and coordinated military operation of the army and air force for an integrated attack which uses the land and air components of military services. The land forces tend to defend the front lines whereas the air forces support the land forces and also serve as aerial defences. See AirLand Battle, <https://en.wikipedia.org/wiki/AirLand_Battle>, accessed 10 December 2019.
14. Abdullah, 'Pakistan's Evolving Doctrine and Emerging Force Posture'. See also Masood Ur Rehman Khattak, Muhammad Khan and Ghulam Qumber, 'Evolution of New Indian Military Strategy: Implications for Pakistan', Margalla Papers (No. 1, 2019).

Pakistan aims to combine FSD with its policy of credible minimum deterrence to increase the utility its battlefield weapon system, *Nasr*. FSD is aimed at deterrence, not only at strategic level, but also tactical. Abdullah maintains that FSD is aimed at deterring all forms of aggression through the combination of strategic and full-spectrum conventional forces.[15] Pakistan's full-spectrum strategy proved successful in two crises between India and Pakistan; first, in the 2016 crisis when India claimed to have launched a surgical strike against Pakistan (a claim Pakistan denies); and second, during the 2019 Pulwama crisis. In both these crises, India did not use its limited conventional war plans, and its response options were limited to aerial strikes during the Pulwama attacks. The presence of Pakistan's TNWs prevented India from starting a conventional war, even at limited scale. Pakistani policymakers made the following observations regarding *Nasr*:

- TNWs hindered India's CSD by lowering the nuclear threshold.
- TNWs are meant for deterrence rather than warfighting.
- Pakistan will employ a centralised command in deploying *Nasr* batteries.[16]

After the CSD plans were scuppered by the presence of Pakistan's *Nasr* short-range missile system and Pakistan's conventional defence, India came up with a new strategy in its Joint Military Doctrine 2017 based around surgical strikes.[17] The new Indian doctrine states that 'the conduct of future warfare will include combinations of conventional and unconventional, lethal and non-lethal, and military and non-military actions and operations'.[18] This strategy was employed in India's unsuccessful aerial operation during the Pulwama crisis of 2019.

Although TNWs remained successful during the two crises of 2016 and 2019, they may not prove to be a successful deterrent in future crises between India and Pakistan, especially in the context of India's plans of surgical strikes and limited conventional war. Shashank Joshi notes that 'repeat [surgical] strikes are not only possible, but also quite likely within the next few years. They have proven possible, politically successful, and internationally accepted'.[19] In such a scenario, Indian strategic thinking might endanger regional peace and stability. A surgical strike or limited incursion by India might escalate to full-scale war between nuclear-armed states.

There is an increasing need to take measures that would enhance deterrence in the region. These measures should include reviving and strengthening security and confidence-building measures, and reviving comprehensive composite dialogue and arms control arrangements between India and Pakistan.

15. Abdullah, 'Pakistan's Evolving Doctrine and Emerging Force Posture'.
16. *Ibid*., pp. 79–93.
17. Joint Military Doctrine Indian Armed Forces, 'JP-02/2017', November 2017, <https://www.ids.nic.in/IDSAdmin/upload_images/doctrine/JTD-14-NOV-FINAL.pdf>, accessed 27 April 2019.
18. *Ibid.*, p. 2.
19. Shashank Joshi quoted in Khattak, Khan and Qumber, 'Evolution of New Indian Military Strategy: Implications for Pakistan'.

III. Britain's Weapons Establishment and Tacit Knowledge: Selling Skills

Geoffrey Chapman

CAN NUCLEAR WEAPONS be uninvented? This was the proposition in a 1995 article by Donald MacKenzie and Graham Spinardi, in which they argued that the skills associated with nuclear weapons could be lost.[1] However, the authors acknowledged that their article reflected the contemporary concerns of US weapons designers in the post-Cold War world and the attempts to secure further design and testing work.[2] Elements of this debate have continued over resourcing for the Reliable Replacement Warhead and Stockpile Stewardship Programmes.[3] However, the concern that a national arsenal could be rendered inviable due to the loss of associated skills was not new. Britain's Atomic Weapons Research Establishment (AWRE) independently developed a strikingly similar argument predicated on retaining skills that it had used in the 1960s and beyond in attempts to acquire further work. This paper will trace how AWRE was able to influence nuclear weapons policy debates in the late 1960s which resulted in the Chevaline programme, by using their own 'uninvention' argument. It will be demonstrated that the weapons establishment's concern about the loss of skill is earnest, but can be used to justify strategically questionable programmes and is difficult to challenge from an outsider's perspective.

MacKenzie's and Spinardi's uninvention argument highlighted the role of 'tacit knowledge' in nuclear weapons development. Tacit knowledge is practical knowledge imbued within individuals, only transmitted interpersonally and gained by doing.[4] A similar argument can first be identified within AWRE in 1954, when select staff began to identify as 'weaponeers' on the basis of their special nuclear weapons skills.[5] AWRE was suffering from poor morale due to the uncertain future of the establishment. To remedy this, a diversified research portfolio was offered to ensure the staff's employment security.[6] This set a precedent where work was provided to placate staff.

1. Donald MacKenzie and Graham Spinardi, 'Tacit Knowledge, Weapons Design, and the Uninvention of Nuclear Weapons', *American Journal of Sociology* (Vol. 101, No. 1, 1995), pp. 44–45.
2. *Ibid*., pp. 65, 91.
3. Benjamin Sims and Christopher R Henke, 'Repairing Credibility: Repositioning Nuclear Weapons Knowledge after the Cold War', *Social Studies of Science* (Vol. 42, No. 3, 2012), pp. 324–47.
4. MacKenzie and Spinardi, 'Tacit Knowledge, Weapons Design, and the Uninvention of Nuclear Weapons', pp. 44–45.
5. The National Archives, 'Meeting Held at Aldermaston on 14th June, 1954 to Discuss Incentives to be Offered to Weapons Group Staff', File AB 16/1778, 1954.
6. *Ibid.*

Thereafter, Britain's thermonuclear programme necessitated that AWRE expand its workforce from 3,900 in 1954 to 7,600 by 1958.[7] That year saw the end of the British Grapple nuclear tests with the conclusion of a testing moratorium and the settlement of the Anglo-American Mutual Defence Agreement.[8] This created further work as effort was put into 'anglicising' American warhead designs, and numbers of staff grew again, approaching 9,000 in the early 1960s.[9]

The rapid expansion of AWRE had been needed to fulfil immediate requirements, so permanently high levels of staffing were unsustainable. Reductions became inevitable when Prime Minister Harold Macmillan's government became intent on making sweeping cuts to defence spending. From 1960, AWRE administrators began to warn of the need to provide staff with certainty regarding future nuclear weapons developments.[10] By 1962, the situation had only become worse for Aldermaston with the cancellation of several tactical nuclear weapons systems orders. Without further work, AWRE's staff strength was halved by 1967.[11]

Faced with this impending crisis, Britain's nuclear weapons establishment began to explicitly argue for the need for further nuclear weapons work premised on the need to retain skills.[12] In doing so, senior AWRE managers and UK Atomic Energy Authority officials presented an argument that is staggeringly similar to that presented by MacKenzie's and Spinardi's 1995 article: AWRE's workflow had to be maintained as otherwise uniquely skilled individuals would leave, and this would irrecoverably damage AWRE as an institution and make maintaining the deterrent impossible.[13] AWRE's management argued that the future of the deterrent would be compromised unless at least half of the currently employed staff were retained.[14]

In late 1962, Aldermaston was given a last-minute reprieve with the cancellation of the Skybolt missile programme. Its replacement, Polaris, required the development of a new warhead.[15] While this did not halt staffing reductions at Aldermaston, it prevented its precipitous decline. Nonetheless, AWRE's crisis of 1960–62 cemented the idea that a substantial minimum

7. The National Archives, 'Comparison of Actual with Estimated Strength', File AB 16/2302, 1960.
8. Richard Moore, *Nuclear Illusion, Nuclear Reality: Britain, the United States and Nuclear Weapons, 1958–64* (Basingstoke: Palgrave Macmillan, 2010), pp. 32–35.
9. *Ibid.*
10. The National Archives, 'Committee On Civil Work In The Weapons Group', File AB 16/2302, 1960.
11. The National Archives, 'Nuclear Requirements for Defence Committee, 17th July', File CAB 134/2239, 1962.
12. *Ibid.*
13. *Ibid.*
14. The National Archives, 'Impact on the Energy Authority of the Proposed Revised Nuclear Warhead Programme', File CAB 131/27, 1962.
15. Richard Moore, *Nuclear Illusion, Nuclear Reality*, pp. 237–39.

compliment of staff was needed to maintain the nuclear deterrent. This became an accepted argument that would be repeated throughout the 1960s.[16]

With much of their assigned R&D work being concluded, by 1966 the threat of significant reductions to Aldermaston had returned. It was within the context of employing staff to maintain 'competence' at AWRE that hardening Polaris against anti-ballistic missile threats was first proposed.[17] With elements of Harold Wilson's government supporting unilateral disarmament, justifying further nuclear weapons research and development spending would prove challenging. AWRE reiterated their need for 6,000 staff and how new work was needed to retain skills necessary for maintaining any level of deterrent.[18] Given the resources that would have to be devoted to Polaris's improvement in economically turbulent times, political indecision gripped Wilson's cabinet. Polaris upgrades highlighted a rift between the financially minded departments versus the Foreign Office and Ministry of Defence.

The compromise reached by December 1967 was that the minimum level of effort that would keep AWRE viable should be investigated further. This led to the establishment of the Kings Norton Inquiry which sat in 1968. The expectation from Treasury officials was that this would be a 'radical review' of AWRE, after which 'life will never be the same'.[19]

However, in the event, the majority of the inquiry panel accepted that the nuclear arsenal had to be maintained at the highest level of reliability and safety. As this could be done only at close to the current level of staffing, only minor reductions in support personnel were suggested. On the basis on retaining skills, AWRE were allowed to essentially dictate their own required staffing levels.[20] With the number of staff that would have to be retained for maintaining the stockpile, there would be a spare capacity problem.[21] Therefore, rather than supporting reductions, the panel backed the idea of a Polaris hardening programme. Although the Polaris hardening programme was never formally initiated under the Wilson government, the staffing levels forwarded by AWRE practically necessitated it. Lord Rothschild, who authored the minority report, criticised the findings but was unable to present a better method to determine the establishment's needs.[22] Not wanting to risk accidental uninvention and mired by political indecisiveness, little further ground was made on reforming AWRE by the 1970 election.

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16. For example, see The National Archives, 'Nuclear Requirements for Defence Committee, 1st January 1964, Annex A', File CAB 134/2241, 1964, citing the 'agreed' policy of 1963 for maintaining a post-design capability.
17. The National Archives, 'Future Nuclear Programme', File DEFE 19/197, 1966.
18. The National Archives, 'Defence Review Working Party: British Nuclear Weapons Policy', File CAB 134/3120, 1967.
19. The National Archives, 'British Nuclear Weapons Policy: OPDO(67)17', File T 225/2923, 1967.
20. The National Archives, 'Report of the Working Party on Atomic Weapons Establishments', File CAB 134/3121, 1968.
21. *Ibid.*
22. The National Archives, 'Minority Report By Lord Rothschild', File CAB 134/3121, 1968.

As with weapons establishments after the end of the Cold War, skill retention-based arguments were used by AWRE in the 1960s to justify maintaining the status quo or to acquire further resources. These are made from a position of authority and are inherently difficult to both communicate and challenge. As skill-retention arguments have been used to justify further weapons programmes, it is possible to suggest that they are being used cynically.[23] However, this ignores the repeated efforts that AWRE made to keep skills through retaining staff via incentives and diversifying their research programmes. In addition, in 1970 AWRE adopted a 'trickle philosophy' of nuclear weapons production where devices would be refurbished on a rotating basis to ensure that skills would be continually employed and transferred.[24] While MacKenzie's and Spinardi's article highlights how this argument continues to be used in the present day, ascertaining weapons establishments' requirements remains imprecise from those outside the institutions. Retaining skills was the justification for the increased capital spending incurred by the Capability Sustainment Programme in 2005 and featured as one of the justifications for retaining Trident in the 2013 Alternatives Review.[25] By threatening the possible uninvention of nuclear weapons, weapons establishments will likely continue to have a powerful lever of influence on governments.

23. This was not confined to Chevaline – the same argument was made for a further nuclear weapons development programme after Chevaline. For an attempt in 1976, see The National Archives, 'Nuclear Weapons Research', File DEFE 13/1768, 1976, and for the nuclear Tactical Air-to-Surface Missile programme in the 1990s, see The National Archives, 'US Arms Control Initiative: Implications for TASM', File PREM 19/3255, 1991.
24. The National Archives, 'M.7', File DEFE 13/925, 1970.
25. Nuclear Information Service, *AWE: Britain's Nuclear Weapons Factory: Past, Present, and Possibilities for the Future* (Reading: Nuclear Information Service, 2016), p. 15, <https://www.nuclearinfo.org/sites/default/files/AWE-Past%2C%20Present%2C%20Future%20Report%202016.pdf>, accessed 30 October 2019; HM Government Cabinet Office, 'Trident Alternatives Review', pp. 6, 36–37.

IV. Could Generation IV Nuclear Reactors Strengthen Russia's Growing Sphere of Influence?

Thomas P Davis

FOR ANY COUNTRY seeking to construct nuclear power stations, only one player offers a complete commercial package: Rosatom, Russia's state-owned nuclear utility company. Rosatom markets a full service that includes designing, commissioning, building, operating, decommissioning, providing training to regulators and engineers, and removing spent fuel and waste, along with full financial packages.[1] In essence, Rosatom supports the entire nuclear fuel cycle. The US, the UK, France, South Korea, Japan and China are not prepared to offer such a complete nuclear export package at present.

In 2005, President Vladimir Putin declared that Russia would become a world leader in nuclear energy.[2] The motivations behind this endeavour have not yet been publicly revealed by Putin nor any Russian diplomat or government official. However, China's nuclear strategy may offer insights into Russia's policy. In September 2016, the nuclear energy director of the China Atomic Energy Authority (CAEA), Liu Baohua, stated at a press conference that nuclear energy is 'an important cornerstone of strategic power, a vehicle for civilian–military integration, and a "China Card" to play in the country's international cooperation diplomacy'.[3] This principle provides an insight into the strategic advantage that a nuclear export programme could provide to a country: the 'host' country where the reactors will be constructed could become dependent on the suppliers. Providing a full commercial nuclear power package may create a 'Russia Card' and generate dependency on Russian energy in the nuclear export market. But doubts have been raised as to whether Russia is capable of financing 35 confirmed reactor orders over the coming decades due to the turbulent Russian economy.[4]

Russia's advances in their sphere of influence in Eastern Europe, the Middle East and Asia through the deployment of their mature nuclear reactor technology (mature references Generation

1. Ira Martina Drupady, 'Emerging Nuclear Vendors in the Newcomer Export Market: Strategic Considerations', *Journal of World Energy Law and Business* (Vol. 12, 2019), pp. 4–12; Névine Schepers, 'Russia's Nuclear Energy Exports: Status, Prospects and Implications', SIPRI Non-Proliferation and Disarmament Paper, Vol. 61, 2019.
2. Drupady, 'Emerging Nuclear Vendors in the Newcomer Export Market'.
3. Lili Liu, 核电消纳管理办法即将发布 [Administrative Measures for Nuclear Power], China5e, 9 December 2016, <https://www.china5e.com/news/news-971094-1.html>, accessed 19 July 2019.
4. Steve Thomas, 'Russia's Nuclear Export Programme', *Energy Policy* (Vol. 121, 2019) pp. 236–47.

III/III+ VVER-1200, as discussed in Section 2).[5] If long-term (2030–50) nuclear development is investigated, Generation IV reactors are likely to become increasingly important – as a part of a drive towards a low-carbon future and as a long-term strategic tool. This paper analyses the possible global transition to Generation IV nuclear reactors and examines how Russia is trying to use the deployment of these reactors for geopolitical gain.

Generation to Generation

Nuclear reactor technologies come in four 'Generations':[6]

- Generation I are the prototype power reactors that initiated the civil nuclear industry in the 1950s with the final reactor decommissioned in December 2012.
- Generation II references the 400+ operational commercial reactors around the globe.
- Generation III/III+ is an upgrade from Generation II that focuses on a 60-year operational lifetime, improving thermal efficiency, using passive (rather than active) safety systems and improving on fuel technology. These reactors are under construction today (such as the VVER-1200 Pressure Water Reactor [PWR] offered by Rosatom).
- Generation IV reactors have been under development since the 1950s. They aim to provide solutions to nuclear waste challenges,[7] improve safety,[8] decrease proliferation,[9] optimise fuel use,[10] widen the scope to include hydrogen production,[11] enable heat production,[12] enable water desalination,[13] and increase the long-term operational

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5. Drupady, 'Emerging Nuclear Vendors in the Newcomer Export Market'; Schepers, 'Russia's Nuclear Energy Exports'; Thomas, 'Russia's Nuclear Export Programme'.
6. Stephen M Goldberg and Robert Rosner, *Nuclear Reactors: Generation to Generation* (Cambridge, MA: American Academy of Arts and Sciences, 2011).
7. Sophie Grape et al., 'New Perspectives on Nuclear Power – Generation IV Nuclear Energy Systems to Strengthen Nuclear Non-Proliferation and Support Nuclear Disarmament', *Energy Policy* (Vol. 73, 2014), pp. 815–19.
8. Pascal Yvon (ed.), *Structural Materials for Generation IV Nuclear Reactors* (Sawston: Woodhead Publishing, 2017).
9. Hosik Yoo et al., 'Methodology for Evaluating Proliferation Resistance of Nuclear Systems and its Case Study', *Progress in Nuclear Energy* (Vol. 100, 2017), pp. 309–15.
10. Hunor György and Szabolcs Czifrus, 'Burnup Calculation of the Generation IV Reactors', *Progress in Nuclear Energy* (Vol. 81, 2015), pp. 150–60.
11. R S El-Emam and I Khamis, 'Advances in Nuclear Hydrogen Production: Results from an IAEA International Collaborative Research Project', *International Journal of Hydrogen Energy* (Vol. 44, No. 35, 2019), pp. 19080–88.
12. Charles Forsberg, Stephen Brick and Geoffrey Haratyk, 'Coupling Heat Storage to Nuclear Reactors for Variable Electricity Output with Baseload Reactor Operation', *Electricity Journal* (Vol. 31, No. 3, 2018), pp. 23–31.
13. Amani Al-Othman et al., 'Nuclear Desalination: A State-of-the-Art Review', *Desalination* (Vol. 457, 2019), pp. 39–61.

lifetimes (more than 60 years).[14] Generation IV nuclear reactors are categorised based on their cooling medium: sodium-cooled; lead/lead-bismuth-cooled; molten-salt; high-temperature gas; and supercritical water. The term 'fast reactor technology' is sometimes used as a reference to Generation IV nuclear reactors.

It should be noted that 99% of all the commercial nuclear reactors under construction fall within the Generation III/III+ classification. This percentage will remain static for the foreseeable future. However, the recent advances in Generation IV nuclear reactors have enabled privately funded Western corporations – such as Moltex Energy, Terrestrial Energy and Advanced Reactor Concepts – to create credible Generation IV nuclear reactor designs. These designs solve the shortcomings of Generation I, II and III/III+ technology, as well as providing credible solutions to the world's long-term energy supply, while producing near-zero greenhouse gases.[15]

The Western Generation III/III+ nuclear export companies (Westinghouse Electric Company in the US and Areva S.A. in France) are not competing against Rosatom.[16] However, the state of Russia's Generation IV nuclear reactor technology is not well known. These reactors could provide substantial longevity to Russia's nuclear export capacity.

Russian Generation IV Nuclear Technology

For any new engineering design or technology to be constructed and operated, it must be tested within an appropriate and representative environment. For nuclear reactors, this testing environment is pivotal for any nuclear regulator's approval. If a country is unable to test new and innovative reactor designs, no nuclear regulator will grant a nuclear site licence.

The UK and the US terminated their fast reactor programmes in the 1990s. These two countries, along with the EU, are still debating which Generation IV reactor design is optimal for the future. Russia is the only country that has continued research and development of sodium-cooled fast reactor technology (a type of Generation IV reactor) since the advent of nuclear power in the 1950s. Despite Russia's expressed interest in cooperating with China on fast reactor technology in 2016,[17] its fast reactor programme has not been widely considered as significant within the

14. Yvon (ed.), *Structural Materials for Generation IV Nuclear Reactors*.
15. Technically, nuclear energy does not emit any greenhouse gases when generating electricity. However, near-zero is an accurate description because it considers the 'lifetime emissions' – the greenhouse gases that are emitted when mining, fuel processing, producing construction materials such as concrete, and decommissioning. See Thomas P Davis, 'Dispelling Misconceptions of Nuclear Energy Technology', *St Anne's Academic Review* (Vol. 9, 2019), pp. 34–45; Steffen Schlömer (ed.), 'IPCC Working Group III – Mitigation of Climate Change, Annex III: Technology – Specific Cost and Performance Parameters', Intergovernmental Panel on Climate Change, 2014.
16. Drupady, 'Emerging Nuclear Vendors in the Newcomer Export Market: Strategic Considerations'; Thomas, 'Russia's Nuclear Export Programme'.
17. Mark Hibbs, 'The Future of Nuclear Power in China', Carnegie Endowment for International Peace, 2018.

current export market.[18] Recent research into fast reactor technology suggests that Russia's fast reactor programme could enable the longevity of the nuclear export market.[19]

Russian academic papers evaluate the country's sodium-cooled fast reactor technology and detail the maturity of their design.[20] Russia has already constructed, operated and decommissioned sodium-cooled fast reactors, namely the BN-350 (shut down), BN-600 (online), BN-800 (online), and soon BN-1200 (design stage). BOR-60 is the sodium-cooled fast test reactor that underpins most of the R&D (which many UK and US scientists use for their research).[21] The vast amount of construction, operation, design and research Russia has invested in the future of Generation IV nuclear reactors – including the ongoing construction of a new test reactor called the Multipurpose Research Reactor (MBIR) – reinforces Russia's global leadership in the R&D nuclear engineering space. Conversely, the UK, the EU and the US do not operate test or commercial sodium-cooled fast reactors at the present time.

Generating Dependency

Rosatom offers a full service, including designing, commissioning, building, operating, decommissioning, training of regulators and engineers, and maintaining nuclear waste, along with full financial packages. For countries wanting nuclear power, this package seems attractive, but it creates an environment conducive to unprecedented dependence on Russian nuclear energy. This generates a security risk if, for example, a host country depends on Rosatom for the removal of nuclear spent fuel and this service is withdrawn for diplomatic or political reasons. Since the host does not possess the infrastructure to manage spent fuel, Russia would gain significant leverage over them.[22]

The Generation III/III+ VVER-1200 reactor Rosatom offers is designed for a 60-year operational lifetime. Generation IV nuclear reactors are designed for a longer operational lifetime and could start construction between 2030 and 2050. These timescales position Russia to build and maintain dependency well into the 2100s. Moreover, according to the Russian Federation Energy Security Doctrine published in March 2019, energy exports will be defended with military force

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18. Thomas, 'Russia's Nuclear Export Programme'.
19. Thomas P Davis, 'Review of the Iron-Based Materials Applicable for the Fuel and Core of Future Sodium Fast Reactors (SFR)', Office for Nuclear Regulation, Vol. ONR-RRR-088, 2018, pp. 1–52.
20. A Tselishchev et al., 'Development of Structural Steel for Fuel Elements and Fuel Assemblies of Sodium-Cooled Fast Reactors', *Atomic Energy* (Vol. 108, No. 4, 2010), pp. 274–80; A A Nikitina et al., 'R&D of Ferritic-Martensitic Steel EP450 ODS for Fuel Pin Cladding of Advanced Fast Reactors', *Journal of Nuclear Materials* (Vol. 428, No. 1–3, 2012), pp. 117–24; Alexey I Izutov et al., 'Prologation of the BOR-60 Reactor Operation', *Nuclear Engineering Technology* (Vol. 47, No. 3, 2015), pp. 253–59.
21. Z Jiao et al., 'Microstructure Evolution of T91 Irradiated in the BOR60 Fast Reactor', *Journal of Nuclear Materials* (Vol. 504, June 2018), pp. 122–34.
22. Anna J Davidson, 'Do Svidaniya, Chernobyl: Russian Economic Statecraft in Turkey and Belarus', Bear Market Brief, 6 February 2019.

if conditions threaten or limit the use of domestic technology, and extraction or consumption of local energy (including nuclear).[23]

For the foreseeable future, Russia has no competitors within the Generation IV reactor space, and here lies the crux of this challenge: with no competitors, Russian expansion in Generation IV nuclear technology will further solidify and strengthen the country's already growing sphere of influence.

A Potential Solution

There is a solution to both deterring Russia's dominance in Generation IV nuclear reactor technology and exporting to a monopolised market: become the competition. A simple three-step programme could be proposed for the creation of a direct competitor to the future Generation IV Russian nuclear export activity:

- Step 1: Decide on the Generation IV nuclear reactor technology.
- Step 2: Construct, operate and test new innovations of this technology.
- Step 3: Provide state-based commercial exports of this technology.

Further, this programme could significantly increase the investment from government and industry, providing a large-scale energy source that emits near-zero greenhouse gases and develops specialist skills in manufacturing, engineering and science in the long term. The window of opportunity for this, however, is closing unless key strategic policy decisions are made today or in the near future.

This programme is required as the UK does not possess test or fast reactors and maintains minimal R&D investment in relation to Generation IV nuclear reactors.[24] The UK previously operated the Dounreay Test Reactor (1962–77) and the Prototype Fast Reactor (1974–94); the former a sodium/potassium-cooled fast test reactor, and the latter a sodium-cooled fast test reactor. Despite the UK's experience in designing, operating and decommissioning fast reactors, this is now diminishing as the fast reactor programme was terminated in 1994.

Recent US law enactments have allowed the commissioning of a new fast test reactor called the Versatile Test Reactor.[25] It also provides vast changes to the Nuclear Regulatory Commission to allow for the construction of Generation IV reactor types and provides support for privately funded Generation IV nuclear reactor companies. Although these changes enable the construction of Generation IV nuclear reactors, competing against Russia's state-backed

23. Russian Federation, 'Rossiskaya Doktrina Energeticheskoi Bezopasnosti' ['Russian Energy Security Doctrine'], 13 May 2019, <http://static.kremlin.ru/media/events/files/ru/rsskwUHzl25X6IijBy20Doj88faOQLN4.pdf>, accessed 20 July 2019.
24. Nuclear Innovation and Research Advisory Board, 'NIRAB Annual Report 2018/19 – Clean Growth Through Innovation: The Need for Urgent Action', April 2019.
25. US Congress, 'S.512 Nuclear Energy Innovation and Modernization Act 2019'.

nuclear export programme requires a similar programme from the UK and the EU, perhaps in collaboration with the US. A market-driven nuclear export programme has already been attempted and resulted in the US Westinghouse nuclear export company declaring bankruptcy in March 2017.[26]

Conclusion

Putin's prediction that his country would become a world leader in nuclear energy is now realised – Russia's dominance in the world's nuclear export market through Rosatom and the provision of a full commercial nuclear power package ensures the continuation of that domination and dependency on Russian energy.

Russia currently operates both BN-600 and BN-800 sodium-cooled fast reactors, BN-1200 is in the design phase, and construction of the new MBIR test reactor is underway. These factors have enabled Russia to lead the R&D space for Generation IV nuclear reactors, and for the foreseeable future, Russia faces no competitors.

The only solution to Russia's unchallenged and unrestrained progress is to decide on the technology, construct and operate test reactors, and create a fully state-backed nuclear export programme of Generation IV nuclear reactor technology.

26. Tom Hals, Makiko Yamazaki and Tim Kelly, 'Huge Nuclear Cost Overruns Push Toshiba's Westinghouse into Bankruptcy', *Reuters*, 29 March 2017.

V. Deterrence Goes Orbital

Jennifer Edwards, Jack Bowler, Oscar Liddiard and Lewis Lancaster

THE OUTER SPACE Treaty (OST) has successfully prevented weapons of mass destruction from being permanently stationed in orbit for more than 50 years. However, economic and social opportunities arising from the 'new age of space exploration'[1] illustrate how the control of space is quickly becoming increasingly important in military terms.[2] Despite no current nuclear-armed countries publicly expressing an interest in violating the OST,[3] weaponised satellites in orbit carrying lasers are already being considered by France as part of their future space defence strategy.[4] With the steady militarisation of space, nuclear states may once again reconsider placing nuclear weapons in orbit; either as an escalatory response to emerging threats, or because it is deemed that technological advancements are sufficient to pose a risk to the credibility of their current deterrence strategy.

This paper intends to address the technical challenges of placing a nuclear weapon in space and ascertain whether there is any significant benefit for a country currently possessing nuclear intercontinental ballistic missiles (ICBMs) to develop this technology.

Potential Space Weapons

For the purpose of drawing up a comparison of current and potential future technologies, as shown in Table 1, an investigation into different nuclear-armed 'space weapons' is conducted. Three weapon systems are considered: the current ICBM/submarine-launched ballistic missile (SLBM) which are transient through space; reusable space planes carrying nuclear warheads; and a permanently stationed orbital nuclear weapon constellation.

1. *The Economist*, 'A New Age of Space Exploration is Beginning', 18 July 2019.
2. *BBC News*, 'Trump Wants American Dominance with New Space Force', 18 June 2018.
3. Union of Concerned Scientists, 'International Legal Agreements Relevant to Space Weapons', 11 February 2004.
4. Lauren Chadwick and Jeremy Wilks, '"May the Force be with Vous": France Unveils Space Weapons Plan', *Euronews*, 26 July 2019.

Table 1: Summary of Nuclear 'Space Weapons' Considered and Key Features.

	ICBM/SLBM	Reusable 'Space Plane' Weapon	Orbital Nuclear Weapon
Apogee	1,200 km	Low Earth Orbit (LEO)	LEO
Duration in Space	Transient	200–600 days*	5–15 years**
International Position	Regulated by treaties	Questionable	Internationally illegal (OST)
Technology Readiness Level	Known capability	Several demonstration missions to date	New technology required

* Mike Wall, 'The US Military's Secretive X-37B Space Plane: 6 Surprising Facts', *Space.com*, 7 May 2017.
** Sandra Erwin, 'New Space Companies Confident about Future of Small Satellites', *Spacenews*, 16 July 2018.

System Lifetime

Examining the different technologies through their lifetime provides a comparison of the potential advantages and disadvantages of current and potential future space-based nuclear weapons. The authors consider three main phases during the lifecycle of the weapon: transit into space; orbital operation; and decommissioning.

Transit into Space

A key aspect when considering space-based nuclear weapons platforms is the controlled transport of hazardous items, such as explosive warheads and radioactive materials, safely into space. Any prospective payload is at risk, particularly during launch, and there has been a failure rate of 6.68% in unmanned launches in the past 20 years.[5] Significant design challenges would arise in mitigating any risks so that should a launch fail, the dangerous payload is prevented from inadvertently spreading hazardous waste into the biosphere.

To obtain similar global coverage to that of conventional ballistic missiles, a large constellation of satellites would be required, increasing the risk further. The research for this paper suggests that this would consist of at least 144 satellites (12 orbital planes each with 12 satellites) to provide global coverage of 42% and a repeat coverage time of two hours.

Despite the risks, nuclear material already has widespread use in space applications. Since the 1960s, radioisotope thermoelectric generators have provided a reliable method of power generation for numerous space missions.[6] Plutonium-238 (Pu-238) is not weapons grade, however, and nuclear weapons use a heavier isotope in Plutonium-239 (Pu-239). The isotopes have key differences: Pu-238 has a half-life (the time taken for the radioactivity of an isotope to fall to

5. Space Launch Report, 'Orbital Summary by Year', <http://www.spacelaunchreport.com/logyear.html>, accessed 1 October 2019.
6. NASA Radioisotope Power Systems, 'Safety and Reliability', <https://rps.nasa.gov/about-rps/safety-and-reliability/>, accessed 1 October 2019.

half its original value) of approximately 88 years, whereas Pu-239 has a half-life of approximately 24,000 years,[7] and is significantly more toxic. This means any catastrophic failure at launch could have substantial repercussions for the operating country.

Orbital Operation

Assuming the significant risks associated with transporting the weapons into space could be mitigated or reduced to acceptable levels, further issues would arise when the platform is stationed in orbit. Whereas the current ICBM/SLBM is transient only through the space environment, both the space plane and permanent orbital capability must survive the harsh environment for a significant period.

Any object in space is not protected by the Earth's atmosphere and is therefore subjected to a fluctuating temperature scale from -250˚C to 300˚C when in orbit.[8] If an object has to re-enter the Earth's atmosphere, such as a weapon launched from an orbital platform, aerodynamic heating can cause even greater temperature loads on the system.[9] This requires complex thermal protection systems to ensure systems are able to survive. Similarly, the system must be protected against high energy radiation, predominantly emanating from the sun, that can affect electronic systems, either through transient faults or errors or through the long-term effects of radiation damage.

Furthermore, the increasing risk of space debris – as shown in Figure 1 – reveals the rapid increase in the number of objects around the Earth, increasing the risk of holding an asset in orbit. This issue is especially relevant with an Indian anti-satellite weapon test performed in March this year posing a potential threat to the ISS, raising safety concerns over the practicality of keeping a nuclear weapon in orbit.[10] Due to large orbital velocities, the kinetic energy of even the smallest pieces of debris can have a huge impact when colliding with an orbital system, as demonstrated by recent European Space Agency tests.[11]

This issue is exacerbated by the increasing number of objects in low earth orbit (LEO). The scenario posed by Donald J Kessler in 1978 suggests that the density of objects in LEO has reached a point in which collisions between objects could cause a cascade – a worrisome theory for an orbital system.[12]

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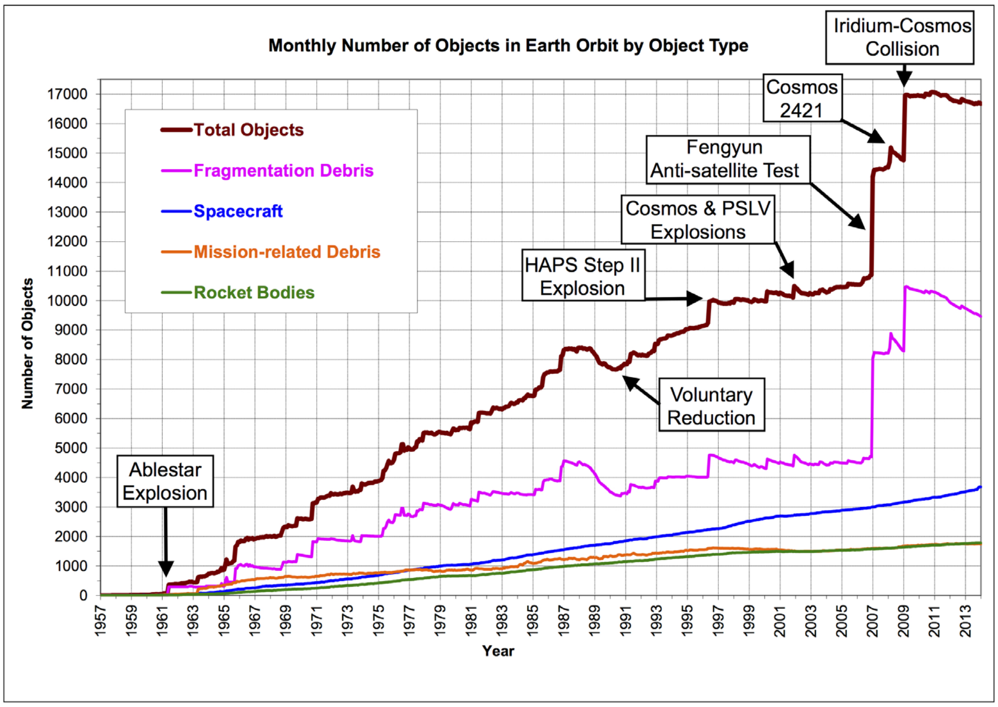
7. US Department of Energy, 'The History of Nuclear Power in Space', 9 June 2015.
8. Astrome Blogs, Miracle Israel, 'How Do Satellites Survive Hot and Cold Orbit Environments?', <https://www.astrome.co/blogs/how-do-satellites-survive-hot-and-cold-orbit-environments/>, accessed 31 October 2019.
9. NASA, 'Thermal Protection Systems', <https://www.nasa.gov/centers/johnson/pdf/584728main_Wings-ch4b-pgs182-199.pdf>, accessed 29 November 2019.
10. Avery Thompson, 'India's Anti-Satellite Test Could Threaten the International Space Station', *Popular Mechanics*, 2 April 2019.
11. European Space Agency, 'Hypervelocity Impacts and Protecting Spacecraft', 1 November 2018.
12. Michelle La Vone, 'The Kessler Syndrome: 10 Interesting and Disturbing Facts', <http://www.spacesafetymagazine.com/space-debris/kessler-syndrome/>, accessed 1 October 2019.

Figure 1: Catalogued Objects in Orbit.



Source: NASA Astromaterials Research & Exploration Science, Orbital Debris Program Office, <https://orbitaldebris.jsc.nasa.gov/>, accessed 11 December 2019.

End of Life/Decommissioning

Ageing weapons can fail or act unpredictably in a number of ways: the high explosives that compress their fissile material can chemically degrade, their electronic components can suffer from decay and the isotopes used by thermonuclear weapons may be chemically unstable.[13] This means any weapons system must undergo maintenance and have a safe end-of-life disposal plan.

For the current ICBM/SLBM and the theoretical space-plane weapon, the system can return to a base port/runway and be serviced as needed. Similarly, they can be stored and disposed of by their originator. A satellite, however, would require a secondary system that had the capability to service it in-orbit, driving up the cost and complexity of routine maintenance procedures. Likewise, there are increased complications when considering the decommissioning of a satellite. Any weapon system would need to either be boosted to a graveyard orbit (a region of space in which it lies away from common operational orbits) – current US guidelines require

13. *GlobalSecurity.org*, 'Stockpile Stewardship and Management', <https://www.globalsecurity.org/wmd/systems/nuke-stockpile.htm>, accessed 1 October 2019.

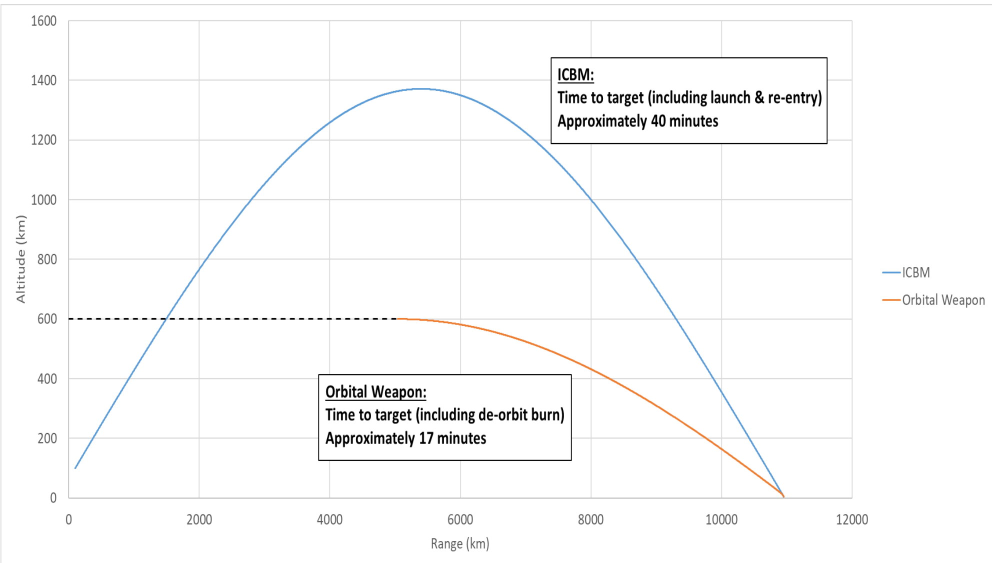
this to be at least GEO+300 km – or returned to Earth in a way that ensures safe burn-up (due to aerodynamic heating) or have design features that enable conventional landing methods.[14]

Further complexities arise if the weapon is to be used to engage a target. Although the Soyuz descent module has completed many successful missions returning astronauts to Earth from a similar orbit, a weapon used in anger faces several extra complications, such as an increased need for attitude control (ensuring the weapon strikes the correct target to sufficient accuracy) and a more complex thermal control system (as a warhead would need to retain as much speed as possible). This implies a more intricate system would need to be developed.

Time to Impact – An Operational Advantage

Internal trajectory analysis using Lockheed Martin software provides a numerical comparison between an orbital weapon in LEO vs. an example ICBM/SLBM. LEO was chosen over an orbital weapon placed in a geostationary orbit due to a lower orbital altitude as well as the consideration that a weapon permanently stationed over a different state would be highly aggressive. Neglecting political decisions, the simulation calculates the probable times to impact of each weapon. With some engineering assumptions applied, a 10,000-km range ICBM trajectory was compared with an orbital weapon re-entering from a 600-km altitude (LEO), as shown in Figure 2.

Figure 2: Graph Depicting Time to Impact for an Orbital Weapon in LEO Compared to an ICBM.



Source: Authors' analysis.

14. NESDIS, 'Graveyard Orbits and the Satellite Afterlife', <https://www.nesdis.noaa.gov/content/graveyard-orbits-and-satellite-afterlife>, accessed 31 October 2019.

In addition to the flight time, there is also an added time for the submarine to rise to appropriate height to launch (it was assumed that submarines are submerged to 800 ft with an ascent rate of roughly 100 ft/min) positioning flight and launch time, giving a total estimated operational time of 45–60 minutes for an ICBM/SLBM strike.[15]

Comparatively, satellites can receive a signal from Earth practically instantaneously, giving a total estimated operational time of a space-based weapon of less than 20 minutes. However, the space-plane weapon would require launch in advance to allow it to be in the correct position prior to strike. Furthermore, the calculated permanent orbital weapon constellation has a repeat coverage time of two hours, meaning that if the window of opportunity is missed, there would be a delay before an effective strike could be launched. Assuming these complexities can be accounted for, this reduced time could provide a significant advantage over a current ballistic missile system.

Ballistic Missile Defence and Anti-Satellite Weapons – Further Considerations

A reduced time to strike may provide a future orbital weapons system with the ability to overcome current ballistic missile defence (BMD) systems. Given the missile launch would effectively start from the mid-course phase, there would be a significant compression of the engagement timeline, giving less time for threat cloud discrimination – re-entry vehicle(s) and possible decoy(s). An orbital weapon would also not have a launch signature due to being launched in advance, and would have an asymmetric trajectory. Given that current BMD systems are believed to rely on these features provides further evidence that these orbital weapons could overcome current defence systems. Given that the US Missile Defense Agency has recorded that 87 of 106 hit-to-kill intercept attempts have been successful since 2001, a weapon that has the potential to overcome BMD systems is significant. Due to the changing nature of the threat profile, placing nuclear missiles into orbit could drastically change the layout and concept of a future BMD system.[16]

However, whereas a transient weapon such as an ICBM is in space only for a short period of time, an orbiting weapon would have to consider in-orbit activities and counterspace capabilities. Both India and China have recently demonstrated anti-satellite weapons successfully, and therefore any space-based weapon is likely to need effective defence mechanisms of its own.[17]

Additionally, the Russian Ministry of Defence is reportedly capable of employing their civil and commercial remote sensing satellites to supplement military-dedicated capabilities.[18] Given that it is likely that other nations have similar capabilities, it is probable that an orbital weapon could be tracked and monitored through its lifetime. While it may be possible to disguise an orbital

15. Calculated from Rod Powers, ‘Interesting Facts About Navy Submarines: How Deep They Dive, Using a Periscope, Lost Submarines and More’, *thebalancecareers.com*, updated 24 July 2019.
16. US Missile Defense Agency, ‘Ballistic Missile Defense Intercept Flight Test Record’, December 2018.
17. Doris Elin Urrutia, ‘India’s Anti-Satellite Missile Test is a Big Deal. Here’s Why’, *Space.com*, 30 March 2019.
18. National Air and Space Intelligence Center, ‘Competing in Space’, December 2018.

platform, this would mean that the system would cease to be a deterrent. Therefore, were an orbital weapon to be deployed, it would be a tactical or first-strike weapon.

Political Viewpoint

The 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (now known as 'The Outer Space Treaty' (OST)) is considered to have formed the basic legal framework of space law. As of January 2019, 107 countries are parties to the treaty, including all nine countries currently possessing nuclear weapons.[19] Of the nine countries that possess nuclear weapons, all but Pakistan have demonstrated an independent capability to launch satellites into orbit.[20] The OST bars states party to the treaty from placing weapons of mass destruction in Earth's orbit. However, the OST does not prohibit the launch of an ICBM from one point on the surface of the Earth to another.[21]

Any signatory to the OST must therefore consider that placing a nuclear weapon in orbit would be considered an extremely hostile act and may raise international tensions. Space-plane weapon capability could potentially fall into an area of legal ambiguity whereby nations would have to consider whether a weapon operating in space is classed as an orbital weapon. Despite current UN conversations and regulations, some states may try to argue that a weapon similar to a space-plane capability that does not have a set orbital time and may not be held in orbit for extended periods of time may be classed as transient.

Furthermore, currently the reusable space-planes have generated much speculation regarding their military purpose.[22] Although they are not currently believed to be weaponised, it is not inconceivable that a future comparable technology may be designed for this purpose. A capability similar to this could be launched as tensions increase and be part of an escalatory response in times of conflict, potentially leading to a quick way to raise international tensions. This would also likely change the tactical military outlook on rules of engagement and reactionary responses, given that it would compress the combative timeline.

In conclusion, while Earth-orbiting weapons could provide some advantages over current ICBM/SLBM technology, the current geopolitical climate and the risks associated with this technology outweigh the benefits posed by orbiting nuclear weapons. While it is technologically

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19. Nuclear Threat Initiative, 'Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies', updated 31 January 2019; Ploughshares, 'World Nuclear Weapons Stockpile Report', updated 23 August 2019, <https://www.ploughshares.org/world-nuclear-stockpile-report>, accessed 1 October 2019.
20. *Seafaring Japan*, 'First Satellites Launched By Spacefaring Nations', <http://www.spacetoday.org/Japan/Japan/FirstSat.html>, accessed 1 October 2019.
21. UN General Assembly Resolution 2222 (XXI), 19 December 1966.
22. Elizabeth Howell, 'X-37B Space Plane Returns: 5 Theories About its Secret Mission', *LiveScience*, 17 October 2014.

feasible that such a weapon could be developed, responsible nuclear weapons ownership is critical to global stability and it is likely that an orbiting system such as those described would lead to a rise in international tensions and destabilise global politics.

VI. New Futures for Nuclear Arms Control: Hypersonic Weapons

Madison A Estes

THE US AND Russia are approaching a crossroads on the path of cooperative nuclear arms control. The US has withdrawn from the Intermediate-Range Nuclear Forces Treaty (INF) and faces an unclear path ahead on the currently in-force New Strategic Arms Reduction Treaty (New START), which the Trump administration has not yet committed to extending. Meanwhile, these critical decision points are taking place against the backdrop of long-term technological trends that have improved weapons accuracy, remote sensing and data processing and communications, resulting in increased vulnerability of nuclear forces.[1]

Additionally, novel employment of dual-capable offensive technologies, such as hypersonic weaponry, have emerged alongside this increased vulnerability and threaten to exacerbate force survivability concerns. Although these emerging dual-capable systems are not always 'strategic' in the sense that has normally been associated with nuclear weapons, they have the potential to render strategic effect by further challenging the survivability of nuclear forces with the potential to overcome defensive measures, such as mobile systems and missile defence systems.

This paper will briefly identify the arguments surrounding the potential risks hypersonic weapons pose. It will offer some preliminary cooperation measures for mitigating those threats with the goal of maintaining strategic stability, or a stable deterrence relationship where neither party perceives there is an advantage to be gained by attacking first in the event of a crisis or conflict, serving as a guidepost.[2]

Hypersonic Weaponry

Hypersonic weapons are defined as any weapon that is capable of travelling at Mach 5 or above, and for the purposes of this paper, can be manoeuvrable along its trajectory.[3] Hypersonic

1. Keir A Lieber, 'The New Era of Counterforce', presentation at the CSIS PONI Nuclear Scholars May 2019 Meeting, Washington, DC, 24 May 2019; Keir A Lieber and Daryl G Press, 'The New Era of Counterforce: Technological Change and the Future of Nuclear Deterrence', *International Security* (Vol. 41, No. 4, 2017), pp. 9–49.
2. Thomas C Schelling and Morton H Halperin, *Strategy and Arms Control*, 1961 Edition (Mansfield Centre, CT: Martino Publishing, 2014), pp. 50–51, 58–59.
3. David Axe, 'How the U.S. Is Quietly Winning the Hypersonic Arms Race', *Daily Beast*, 16 January 2019. Manoeuvrability requirement was also derived to distinguish it from the hypersonic systems discussed in US Department of Defense, 'Nuclear Posture Review', February 2018, pp. 45–46.

weapons typically take the form of a hypersonic cruise missile, or a manoeuvrable re-entry vehicle that can be mounted on a ballistic missile, also commonly referred to as a hypersonic glide vehicle (HGV).[4] The US has chosen to focus its hypersonic development to strictly conventional use, while Russia has focused primarily on the technology's capacity for delivering its nuclear payloads.

There are several arguments for how hypersonic weapons can disrupt strategic stability between the US and Russia. These can be grouped into four overarching themes:

1. Further exacerbation of instabilities already present in the strategic balance.[5]
2. High speed of travel and manoeuvrable features bring escalation and crisis management concerns.[6]
3. Dual-capability causes warhead/payload ambiguity concerns.[7]
4. Manoeuvrability causes destination ambiguity concerns.[8]

Potential Cooperative Mitigation Measures

What arms control tools might help address these issues either on an individual basis, or, perhaps even simultaneously, to promote strategic stability? While there are several open possibilities, research conducted for this paper reveals that there are two present avenues available that could serve as logical and accessible starting points that also have the added benefit of providing solutions to the first three issues listed above. These two avenues are to leverage the existing US–Russia Strategic Stability Dialogue (SSD) forum and the New START Treaty.

Although currently moribund, the SSD has the potential to increase transparency on the strategic intent of hypersonic systems and build some predictability outside a formal and legally binding arms control agreement, a structure currently facing challenges in the US–Russia relationship as trust has devolved. This reciprocal transparency would be helpful for the first two issues in particular. If leveraged appropriately, it could provide both parties with information to be used to make predictions about its own force posture and survivability requirements, thereby curbing concerns surrounding force vulnerability. It could also give each party the opportunity to clarify their strategic intent for these systems, particularly since Russia has not yet indicated if it intends to deploy its nuclear-armed hypersonic weapons past niche capability levels.

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4. James M Acton, 'Hypersonic Weapons Explainer', Carnegie Endowment for International Peace, 2 April 2018.
5. Heather Williams, 'Hypersonics Disrupt Global Strategic Stability', *Jane's Intelligence Review*, 6 February 2017, p. 3.
6. Malcolm Claus, 'Russia Unveils New Strategic Delivery Systems', *Jane's Intelligence Review*, 11 April 2018, p. 8; 'Strategic Policy Issues', *Strategic Survey* (Vol. 118, No. 1, January 2018), pp. 23–67; Williams, 'Hypersonics Disrupt Global Strategic Stability', pp. 5–6.
7. M Elaine Bunn and Vincent A Manzo, 'Conventional Prompt Global Strike: Strategic Asset or Unusable Liability', INSS Strategic Forum (No. 263, February 2011), pp. 14, 18.
8. Williams, 'Hypersonics Disrupt Global Strategic Stability', p. 5.

Leveraging the provisions in the New START Treaty is another logical starting point, assuming it is extended past the 2021 deadline. Indeed, as of May 2019, the US indicated it may seek to do just that with both the *Avangard* (a HGV attached to an ICBM) and potentially the *Kinzhal* (a hypersonic air-launched ballistic missile) by using current treaty definitions and Article V to count them as existing types and also a 'new kind of strategic offensive arm'.[9] More recently, the deputy director of the Russian Foreign Ministry's non-proliferation and arms control department, Vladimir Leontiev, confirmed that the *Avangard* would in fact be considered a New START accountable system by Russia.[10]

The incorporation of these into the treaty will subject them to the agreement's limits and its verification and monitoring regime. This regime would include the ability to hold exhibitions, which could provide useful insight into the systems' technical features and distinguishing characteristics, as well as their basing locations, deployment status and potentially their aggregate numbers, depending on the agreed-upon counting rules.[11] Similar to the SSD, this reciprocal information exchange would be useful for the US and Russia to make judgements about their own force posture requirements and gain better insight to one another's strategic intent.

In addition to these two avenues, there are other ideas that warrant additional consideration and study to better gauge their utility and feasibility. One example for promoting predictability and curbing incentives to conduct a first strike is the re-establishment of a Joint Data Exchange Center (JDEC) to share early warning information and notifications of hypersonic weapon launches and their intended trajectories. This initiative could address the fourth issue of destination ambiguity, which stems from the weapons manoeuvrability feature.[12] The JDEC has the potential added value of being a standalone cooperation tool from the New START Treaty,

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9. Current plans for the *Avangard* have it mounted to an SS-19 ICBM, which is captured by New START and therefore would be considered an existing type. See Andrea Thompson, 'The Future of Arms Control Post-Intermediate-Range Nuclear Forces Treaty', Statement for the Record: Testimony Before the Senate Committee on Foreign Relations, 116th Congress, 15 May 2019. Incorporating a 'new kind of strategic offensive arm' is not as clearly defined, however, '[when] a Party believes a new kind of strategic offensive arm is emerging the party shall have the right to raise the question of such strategic offensive arms for consideration in the Bilateral Consultative Commission'; see 'Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms', <https://2009-2017.state.gov/documents/organization/140035.pdf>, accessed 2 October 2019. See also Amy F Woolf, 'The New START Treaty: Central Limits and Key Provisions', Congressional Research Service, 5 April 2019, pp. 14–15, 19; Franz-Stefan Gady, 'Russia Showcases "Kinzhal" Nuclear-Capable Air-Launched Ballistic Missile at Air Show', *The Diplomat*, 13 August 2019.
10. *TASS*, 'Foreign Ministry: Sarmat, Avangard Systems May be Included in New START Treaty', <https://tass.com/defense/1086515>, accessed 11 December 2019.
11. US Department of State, 'New START Treaty Aggregate Numbers of Strategic Offensive Arms', 1 March 2019, pp. 14–15.
12. Williams, 'Hypersonics Disrupt Global Strategic Stability', p. 5; Bunn and Manzo, 'Conventional Prompt Global Strike', p. 20.

should it not be extended, and prospects for becoming a multilateralised institution should the US and Russia want to incorporate other states with established hypersonic programmes, such as China.

There are two other cooperative designs that the US and Russia may choose to undertake jointly, or potentially unilaterally if deemed within their interests, outside the New START framework to address escalation concerns (issue two) and the ambiguity of the payload (issue three). One could be a unilateral or joint pledge of non-interference with space-based assets, which could be targeted to eliminate the threat of an incoming hypersonic weapon by targeting its space-based guidance system rather than the high-speed and difficult-to-track delivery vehicle. This may potentially help to avoid unintended escalation by lowering the risk to military command, control and communication assets through the process. A more ambitious idea would be to begin exchanging information on these assets, both conventional and nuclear. One such example is site declarations, such as those required in the New START Treaty. Such declarations of weapons locations could help analysts to more quickly determine the nature of the payload of the vehicle by providing a roster of known sites from which hypersonic weapons may be launched.

Another ambitious concept that may offer some strategic benefits to both Washington and Moscow would be the crafting of an asymmetric arms control framework for US and Russian hypersonic weapons, such as the one with adaptive limits proposed by Aaron Miles with ballistic missile defence and non-strategic nuclear weapons.[13] A simplistic and illustrative example of such a framework would be that for every nuclear-armed hypersonic missile Russia chooses to deploy, the US can reserve the right to deploy 10 (or however many policymakers deem sufficient) conventionally-armed hypersonic delivery vehicles or missile interceptors as a countermeasure, and that will be a risk Moscow will knowingly and willingly accept. Such an approach can be taken alongside reductions or on its own to help overcome disparities in both numbers of systems as well as types (such as conventional vs. nuclear), while simultaneously overcoming concerns about force survivability and the stability of the US–Russia deterrence relationship. Ultimately, the feasibility, mix of systems and logistics of such an approach will require further study.

Potential Challenges

Although the US and Russia have a rich history of engaging in transparency and confidence-building measures, pursuing new measures to encompass weapons systems that have normally fallen outside these frameworks means that policymakers will largely be starting from scratch. There are some existing mechanisms and best practices on which to draw, as demonstrated by the SSD and New START examples above. However, arms control measures for hypersonic weapons will confront their own set of unique challenges over a range of factors, such as size, production lines, dual-capability, sensitivity and legal protections. It is also worth

13. Aaron R Miles, ‘Adaptive Warhead Limits for Further Progress on Strategic Arms Control’, *RealClearDefense*, 6 February 2017.

noting the potential reconciliation challenges of disparate systems and quantities under a limitations/reductions framework, and potential obstacles to the development of a verification and monitoring regime that is acceptable to both sides. The viability of the previous proposals and their unique challenges will require further study that is beyond the scope of this paper.

Lastly, it is a necessary precondition that the parties discussed in this paper will have to determine whether it serves their interests to even engage in the pursuit of any of these cooperative measures, regardless of their feasibility.

Conclusion

The ideas briefly proposed in this paper are merely a starting point intended to stimulate creative discussion and lay the groundwork for additional study of potential options. As explained, there are several existing diplomatic mechanisms that offer logical, accessible and lower difficulty starting points for addressing the issues surrounding hypersonic weapons and their disruptive effects on strategic stability, but they are by no means the only solutions available.

The challenges of pursuing some of these proposals will be steep for the reasons previously described, but that does not preclude the US and Russia from doing their homework on what hypersonic weapon cooperative frameworks may serve their interests so that each is prepared for when the time for negotiation arises.

This paper was extracted from a longer article written by the author for the Center for Strategic and International Studies Project on Nuclear Issues annual journal.

VII. Conventional and Nuclear Applications of Artificial Intelligence: A Brief Examination of India and Pakistan

Sam Guthrie

ARTIFICIAL INTELLIGENCE (AI) is a powerful enabling technology that has the potential, if harnessed by India, to transform strategic intelligence and decision-making, with deleterious consequences for strategic stability in South Asia. The emerging ability of artificial systems to interpret 'structured or unstructured data, reasoning on the knowledge, or processing the information, derived' allows these systems to explore increasingly complex problems and make recommendations accordingly.[1] One promising application is in the medical diagnosis field, in which AI is already creating significant improvements in efficiency and accuracy.[2] This is especially noteworthy given the large volumes of unstructured data in the medical field and the substantial diversity between patients. Similar challenges are faced by the military forces of many states, which contend with a range of threats and an increasingly overwhelming volume of data to process and turn into actionable intelligence. For military decision-makers, the abilities of AI described above offer a solution to the cognitive burden presented by the sheer scale and complexity of the strategic issues they face.

Currently, both the US and China have demonstrated an interest in using AI to supplement their existing intelligence, surveillance and reconnaissance analysis, decision-making and conventional military capabilities.[3] Russian President Vladimir Putin has stated 'AI mechanisms provide … quick decision-making based on the analysis of huge amounts of information, which gives tremendous advantages in quality and effectiveness', and tied this to the defence and

1. AI High-Level Expert Group, 'A Definition of AI: Main Capabilities and Disciplines', European Commission, 8 April 2019.
2. Cade Metz, 'AI Shows Promise Assisting Physicians,' *New York Times*, 11 February 2019.
3. US Department of Defense, 'Summary of the 2018 Department of Defense Artificial Intelligence Strategy: Harnessing AI to Advance Our Security and Prosperity', 8 February 2019, p. 11; Elsa B Kania, 'Chinese Military Innovation in Artificial Intelligence', Center for a New American Security, 7 June 2019, p. 3, citing China's 'New Generation Artificial Intelligence Development Plan', published 8 July 2017, <https://flia.org/notice-state-council-issuing-new-generation-artificial-intelligence-development-plan/>, accessed 1 October 2019.

security of the Russian state.[4] As such, the interest of world powers in supplementing their military capabilities with AI is well documented.

India's research into the military applications of AI represents an interesting case study, as the strategic stability of the region is arguably weaker than that between Russia, the US and China. A crucially important factor is the lack of secure Indian or Pakistani second-strike capabilities. Military challenges arise from disputed borders, cross-border terrorism, and the ever-present risk of military confrontation. All of these are monitored extensively by Indian military and civil capabilities, likely generating an immense amount of raw data for analysis. The Indian Defence Research and Development Organisation (DRDO) maintains a Centre for Artificial Intelligence and Robotics, which conducts research into AI decision support to the military. A majority of this research is destined for application to the 'rich problem areas' of Indian defence, including military logistics and surveillance.[5] This suggests a current interest in conventional operations, rather than expanding the scope into other domains.

However, many of the AI applications DRDO is exploring not only have the potential to affect the conventional domain, but also the nuclear domain. Applications such as simultaneous localisation and mapping or object detection and recognition have significant utility in mapping or detecting areas of nuclear operations.[6] Two of India's neighbours, Pakistan and China, operate primarily land- and air-based nuclear missile forces. These nuclear forces rely primarily on concealment and dispersion for their survivability and thus their credibility as deterrents. AI-enabled processes could use simultaneous localisation and mapping to understand the deployment patterns of nuclear systems, which would rely on object detection and recognition. This has the potential to undermine Pakistan's, if not China's, confidence in the survivability of its nuclear forces. India may see a similar problem in China's investment into military innovation within AI and envisage their own research efforts as a hedge against strategic shock.[7]

Ultimately, Pakistan and China cannot be sure that Indian collection methods are not feeding into an AI-enabled process for better informing nuclear operations. Intelligence collection on these capabilities is likely to be nothing new, but AI can conduct high-volume computing tasks at a speed and accuracy which is prohibitive to achieve through other means. This can bring transformative effects, as demonstrated by exploratory work conducted by the University of Missouri's Center for Geospatial Intelligence. The team used an AI-enabled machine-learning algorithm to identify and rank potential Chinese surface-to-air missile sites 'with a 98.2% average

4. *TASS*, 'Putin Notes Importance of Developing AI Technology for Quick Decisions', 30 May 2019.
5. Ministry of Defence, Government of India, Defence Research & Development Organisation, 'Centre for Artificial Intelligence and Robotics', <https://www.drdo.gov.in/drdo/English/index.jsp?pg=homebody.jsp>, accessed 1 October 2019.
6. Edward Geist and Andrew J Lohn, 'How Might Artificial Intelligence Affect the Risk of Nuclear War?', RAND Corporation, 20 April 2018, p. 10.
7. Kania, 'Chinese Military Innovation in Artificial Intelligence'.

accuracy'.[8] The algorithms were trained using 'fewer than 100 positive training examples',[9] which represents a significant increase in efficiency. The processing of Indian intelligence data by such a system will, to some degree, undermine the concealment of nuclear weapons systems even if they are not the primary target of such collection and analysis. However, the eventual effectiveness of any developed system is likely to vary considerably. While this may mitigate some of the graver threats posed by AI, the uncertainty around India's actual capabilities may undermine Pakistan's sense of security.

This may be especially true considering India is already implementing what appear to be AI-enabled decision support systems for coastal surveillance tasks.[10] Pakistan has been developing nuclear-armed, submarine-launched cruise missiles for years, which may be deployed aboard its fleet of *Khalid*-class submarines as a more survivable alternative to its land-based systems.[11] One could imagine that during a crisis, locating and denying submarine access into Indian waters will be an Indian Ministry of Defence priority, to which these AI-enabled decision support systems may contribute. Given the shallow and congested waters of the Arabian Sea, Pakistan's nuclear-armed submarines may be uniquely vulnerable to tracking and monitoring through a variety of means, including AI-enabled intelligence collection.[12] If Pakistan suspects India has the will, and potentially the means, to continuously track its nuclear-armed submarines, it may need to take potentially destabilising measures to ensure the system's credibility, especially during a crisis when they may be most vulnerable. Because of this, India should maintain a clear separation of intelligence from manual sources, where verification procedures are more mature, and intelligence from AI-enabled sources, which may be less readily verifiable. Areas under observation by Indian AI systems should also be sufficiently constrained as to not undermine Pakistan's confidence in its deterrent, lest strategic stability suffer and harm India's interests.

Given India's stake in regional stability, their priority should be to manage the exploitation of AI for national security in a manner that will not undermine Pakistan's confidence in its nuclear forces or raise Pakistan's fears about the possibility of strategic surprise. Given that Pakistan has a less-developed AI enterprise, the potential exists for this capability to belong only to India, at least in the near future. As previously stated, AI is an enabling technology, and can be applied in a relatively short timeframe to a multitude of problems. Where these problems overlap with extant Pakistani concerns and vulnerabilities, India's unilateral advantages may pose strategic quandaries against which Pakistan is not well equipped to mitigate. India has the responsibility

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8. Richard A Marcum et al., 'Rapid Broad Area Search and Detection of Chinese Surface-to-Air Missile Sites Using Deep Convolutional Neural Networks', *Journal of Applied Remote Sensing* (Vol. 11, No. 4, October/December 2017).
9. *Ibid*.
10. Centre for Artificial Intelligence and Robotics, 'Products', Defence Research and Development Organisation, 19 July 2019.
11. Abhijnan Rej, *Pakistan's Sea-Based Nuclear Deterrent and its Asymmetric Escalation Strategy* (New Delhi: Observer Research Foundation, 2018), p. 1.
12. Iskander Rehman, 'Murky Waters: Naval Nuclear Dynamics in the Indian Ocean', Carnegie Endowment for International Peace, 9 March 2015.

to ensure this dual-use technology strays as little as possible into the nuclear domain, to avoid posing dangerous and unprecedented dilemmas to Pakistan’s decision-makers.

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VIII. The Impact of Artificial Intelligence on Strategic Stability, Escalation and Nuclear Security

James Johnson

GIVEN THE HYPE surrounding artificial intelligence (AI), it is easy to overstate the opportunities and challenges posed by its adoption in the military sphere. While AI could enable major improvements in many areas of warfare, including the nuclear domain, for the foreseeable future, developments will be far more prosaic than the common representation of AI in popular culture. Super-intelligent AI applications that can learn and teach themselves to resist human control – or Terminator-like dystopian scenarios – are not the type of technology policymakers and the general public should be most concerned about. In fact, highly speculative scenarios like these overshadow more urgent and plausible issues for international security.[1]

Above all, militaries may underestimate or disregard the limitations of current AI technology. In particular, its brittleness, opacity, unpredictability, bias and vulnerability are being overlooked. Thus, racing blindly down the path towards autonomous weapons could have dire consequences for nuclear stability. Given the hyperbole surrounding AI, it is easy to overstate the opportunities and challenges posed by its development and deployment in the military sphere. There remains much debate among AI researchers surrounding the significance of several major technical and operational challenges in the deployment of AI-infused systems (such as drone swarming, command-and-control decision-making support systems and a broader range of autonomous weapon systems).

While much analytical attention has focused on the impact of cyberspace on deterrence and stability, the potential implications of AI for nuclear stability have so far been under-researched. It is important to stress that many of the risks posed by AI in the nuclear domain today are not necessarily new. In other words, AI can be understood as a manifestation of an established trend in emerging technologies that leads states to adopt destabilising nuclear postures, such as launch on warning, rescinding no-first-use commitments and even adopting nuclear warfighting postures. Furthermore, recent advances in AI (especially machine-learning techniques) exacerbate existing risks to escalation and stability rather than generating entirely new ones. The main worry for nuclear stability, therefore, is that the militaries will either underestimate, overstate or ignore the potential shortcomings and risks associated with the use

1. James Johnson, 'Artificial Intelligence & Future Warfare: Implications for International Security', *Defense & Security Analysis* (Vol. 35, No. 2, 2019), pp. 147–69.

of the current generation of AI technology in the safety-critical military sphere and especially in the nuclear domain.

The central thesis of this paper is grounded in three core themes.[2] First, AI does not exist in a vacuum. That is, in isolation, AI is unlikely to be a strategic game-changer. Instead, it will mutually reinforce the destabilising effects of existing advanced capabilities, increasing the speed of warfare and compressing the decision-making timeframe. Second, AI's impact on stability, deterrence and escalation will likely be determined as much (or more so) by a state's *perception* of its functionality as its *actual* capability. Thus, AI will have a strong cognitive element in increasing the risk of inadvertent escalation as a result of misperception and misunderstanding. Third, the increasingly competitive and contested multipolar nuclear world order will compound the destabilising effects of AI and in turn increase future escalation risks. Moreover, the potential operational and strategic advantages offered by AI-augmented capabilities (especially AI and autonomy) could prove irresistible to nuclear-armed strategic rivals. Competition could cause them to eschew the limitations of AI and compromise safety and verification standards to protect or attempt to capture technological superiority.[3] The most pressing risk posed to nuclear security is, therefore, the premature adoption of unsafe, unverified and unreliable AI technology which could have catastrophic implications.[4]

How is Military AI Different?

The potential strategic effects of military AI are not unique nor exclusive to this technology. Therefore, the confluence of several trends weighs heavily on the pessimistic side of the instability–stability ledger. These trends include: the rapid technological advances and diffusion of military AI; the inherently destabilising characteristics of AI technology (especially heightened speed of warfare, inexplicability and vulnerability to cyber attacks); the possible multifaceted intersections of AI with nuclear weapons; the interplay of these intersections with strategic non-nuclear capabilities; and the backdrop of a competitive multipolar nuclear world order. The historical record demonstrates that security competition – motivated by the desire to control warfare – tends to be ratcheted up because of the complexity of military technology and operations over time.[5] As a result, the Clausewitzian conditions of 'fog and friction' will likely become a ubiquitous outcome of the uncertainties created by increasingly complex and inherently escalatory technologies.

2. *Ibid.*, pp. 148–49.
3. Edward Geist and Andrew J Lohn, 'How Might Artificial Intelligence Affect the Risk of Nuclear War?', RAND Corporation, 2018.
4. The paper does not assume, however, that militaries will necessarily be able to implement these augmented weapon systems in the near term, and acknowledges the disagreements among AI researchers and analysts about the significant operational challenges faced by states in the deployment of AI-augmented weapon systems.
5. Winner Langdon, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge, MA: MIT Press, 1977).

From this perspective, the increasing speed of warfare and co-mingling of military systems that has occurred within the broader context of the 'computer revolution' (such as remote sensing, data processing, acoustic sensors, communications and cyber capabilities)[6] and associated improvements to counterforce capabilities (including anti-satellite weapons, missile defence, cyber capabilities, precision munitions, UAVs and electronic warfare) do not rely on AI. Increasing speeds and co-mingling would likely occur whether AI is involved or not. AI is best understood, therefore, as a potentially powerful force multiplier of these developments. Put simply, military AI and the advanced capabilities it enables are a natural manifestation – rather than the cause or origin – of an established trend that could lead states to adopt destabilising launch postures.

Co-Mingled Military Technology and Inadvertent Escalation Risks

Four interrelated escalation pathways demonstrate how the co-mingling of nuclear and conventional technology could spark inadvertent nuclear confrontation:

1. Multifunctional intended targets of dual-use and dual-payload (armed with nuclear or conventional warheads) capabilities may cause misperception and miscalculation between adversaries, triggering an inadvertent escalation.[7]
2. Divergent views held by adversaries about the intended use, potential impact and the circumstances under which particular military technologies (especially dual-use) may be employed could trigger a negative action–reaction escalatory spiral known as a 'security dilemma'.
3. Development and deployment of certain types of strategic non-nuclear weapons and enabling capabilities (such as hypersonic weapons, cyber, missile defence, quantum computing, autonomous weapon systems [AWS], and AI machine-learning systems) that might influence an adversary's attitude to risk during a crisis, making it more or less prone to escalate a situation.
4. Non-nuclear enabling technologies used during a crisis or conflict could affect the uncertainties caused by situational awareness during a conflict (or the 'fog of war') in ways that could either increase or decrease escalation risks.[8]

Hyper-Speed Warfare

AI introduces a unique means to operate and respond at gigahertz speed in the use of military force. In military arenas where a premium on autonomy and speed exists – such as missile

6. Keir A Lieber and Daryl G Press, 'The New Era of Counterforce: Technological Change and the Future of Nuclear Deterrence', *International Security* (Vol. 41, No. 4, 2017), pp. 9–49.
7. See, for example, James S Johnson, 'China's "Guam Express" and "Carrier Killers": The Anti-Ship Asymmetric Challenge to the US in the Western Pacific', *Comparative Strategy* (Vol. 36, No. 4, 2017), pp. 319–32.
8. Ben Connable, *Embracing the Fog of War: Assessment and Metrics in Counterinsurgency* (Santa Monica, CA: RAND Corporation, 2012).

defence, AWS and cyberspace – faster reaction times will likely have outsized strategic effects.[9] In cyberspace, for example, would-be defenders or attackers operating at AI-enabled machine-speed would have clear tactical advantages in future virtual 'hand-to-hand combat'.[10] Furthermore, AI applications used to assimilate large volumes of intelligence data could increase the speed of decision-making in warfare or even compress the observe–orient–decide–act (OODA) decision-making loop.

Despite the tactical advantages of being able to operate in real time – especially in asymmetric contested environments – experts warn that massive increases in the speed of combat could result in machines reacting to combat situations at a pace that surpasses human comprehension. The impact could be to such an extent that commanders might not be able to control, contain or terminate events.[11] For example, if an autonomous drone came under attack from an unknown and unrecognisable adversary and the only way the AWS could defend itself was to inflict harm to humans, a decision to transfer control to a human supervisor would need to take place in almost real time. Because human commanders would be unable to react fast enough, the autonomous system in this scenario would face a challenging ethical and tactical dilemma.

Imagine, for example, if the Cuban Missile Crisis was truncated from 13 days to a matter of hours. Under the intense time pressures imposed on the OODA decision-making loop by AI-driven warfare, General Curtis LeMay's advice to President John Kennedy for 'direct military action' just three days into the crisis in 1962 might have doomed the diplomatic resolution that followed 10 days later.[12] In short, while AI-enabled autonomous early-warning systems will theoretically allow defence planners to identify and monitor threats faster and more reliably than before, absent human judgement and supervision – combined with the inherent brittleness of AI machine-learning algorithms – run the risk of destabilising accidents and raising false alarms.

For now, it remains axiomatic that human decisions escalate (or de-escalate) a situation.[13] However, military technology, such as AI, that enables offensive capabilities to operate at higher speed, range and lethality may move a situation more quickly – and possibly inadvertently or accidently – up the escalation rungs.[14] These escalatory dynamics would be greatly amplified by the development and deployment of AI-augmented tools functioning at machine speed. Military

9. US Office of Technical Intelligence, Office of the Assistant Secretary of Defense for Research and Engineering, 'Technical Assessment: Autonomy', February 2015.
10. Herbert Lin and Amy Zegart (eds), *Bombs, Bytes, and Spies: The Strategic Dimensions of Offensive Cyber Operations* (Washington, DC: Brookings Institution, 2019).
11. Jürgen Altmann and Frank Sauer, 'Autonomous Weapons and Strategic Stability', *Survival* (Vol. 11, No. 4, November 2017), pp. 117–42.
12. Tim Weiner, 'Word for Word/The Cuban Missile Crisis: When Kennedy Faced Armageddon, and his Own Scornful Generals', *New York Times*, 5 October 1997.
13. Not all escalation results from decisions, however. For example, indecision, accidents, procedures and protocols can all escalate situations *without* any actual decision-making having taken place.
14. Barry R Posen, *Inadvertent Escalation: Conventional War and Nuclear Risks* (Ithaca, NJ: Cornell University Press, 1991).

AI could potentially push the pace of combat to a point where the actions of machines surpass the cognitive and physical ability of human decision-makers to control (or even fully understand) future warfare. Thus, until experts can unravel some of the unpredictable, brittle, inflexible and inexplicable features of AI, this technology will continue to outpace strategy. Coincidentally, human error and machine error will likely compound one another with unpredictable and unintended effects.

Simply put, a new generation of AI-augmented advanced conventional capabilities will exacerbate the risk of inadvertent escalation caused by the co-mingling of nuclear and strategic non-nuclear weapons (or conventional counterforce weapons) and the increasing speed of warfare.[15] In doing so, the technology would be undermining strategic stability and increasing the risk of nuclear confrontation. This conclusion is grounded in three overarching themes that relate to how and why AI could affect strategic stability between great military powers – especially China and the US.[16]

15. James M Acton et al., *Entanglement: Russian and Chinese Perspectives on Non-Nuclear Weapons and Nuclear Risks* (Washington, DC: Carnegie Endowment, 2017).
16. James Johnson, 'The End of Military-Techno Pax Americana? Washington's Strategic Responses to Chinese AI-Enabled Military Technology', *Pacific Review*, 2019.

IX. A Troubling Forecast: Climate Change and the Future of Nuclear Deterrence

Jamie Kwong

NUCLEAR DETERRENCE WILL face severe challenges in the coming decades. With competition and tensions between major nuclear powers rising and advanced technologies threatening traditional conceptions of nuclear security, states have already started to reassess their nuclear strategies. In conjunction with their academic counterparts, policymakers are trying to anticipate the pressures these emerging patterns will place on strategic stability and deterrence in the 21st century.

But this forecasting overlooks a critical reality: climate change. If current trends continue, climate change will detrimentally affect nuclear weapon systems, infrastructures and activities, which, in turn, will have a significant impact on deterrence postures. Policymakers and scholars alike must therefore think critically about the intersection of climate change and nuclear deterrence *now* in order to mitigate its worst effects in the future.

This paper begins by explaining the intersection of national security and climate change, arguing that greater attention must be given to the effects of climate change on nuclear weapons. It then considers specific examples of ways in which climate change will affect nuclear weapon systems, focusing in particular on early warning systems. Finally, it presents recommendations for policymakers and areas of future research.

National Security and Climate Change

According to the Intergovernmental Panel on Climate Change – the UN's authoritative source on climate change science – worldwide temperatures are likely to reach 1.5°C above pre-industrial levels between 2030 and 2052 if global warming continues at the current rate.[1] Among other effects, this warming will lead to: rising sea levels as ice caps and permafrost melt and the intensity and frequency of heavy rainfall increases; the transformation – and potential loss – of ecosystems, with significant impact on resource availability; and even more extreme warming in particularly vulnerable regions such as the Arctic.[2]

Scholars and policymakers have started to acknowledge the potential far-reaching consequences of climate change on international relations. For at least a decade, scholars

1. Intergovernmental Panel on Climate Change, 'Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C Approved by Governments', 8 October 2018, p. 6.
2. *Ibid.*, pp. 7, 11, 13.

have explored the ways in which climate change can lead to greater instability and disrupt inter-state dynamics.[3] The UK Ministry of Defence (MoD) Development, Concepts and Doctrine Centre recognises climate change as a potential conflict driver that must be considered in defence and security planning.[4] Furthermore, the US Department of Defense (DoD) recognises that climate change is a national security issue, and has explored ways in which rising sea levels, droughts and famines induced by global warming will threaten military sites and installations, increase mission vulnerability and precipitate global instability.[5]

Yet even amid these efforts, security experts have failed to carefully consider the threats climate change will pose to nuclear weapons and deterrence postures. This gap is problematic for two primary reasons. First, many nuclear decisions and plans are made 50 years into the future, with systems designed for service lives of at least 30 years and careful forethought given to the changing geopolitical environment.[6] These plans, however, fail to consider changes in the *physical* environment. Second, recent government reports cite this as an era of exceptional geopolitical and technological uncertainty that requires a diversity of nuclear capabilities.[7] These issues will only be exacerbated by the effects of climate change – environmental uncertainty must not be overlooked.

Effects of Climate Change on Nuclear Weapons

The detrimental effects of climate change on nuclear weapon systems and infrastructures are all too conceivable. In March 2019, the Offutt Air Force Base – home to US Strategic Command (STRATCOM), which oversees the country's nuclear command, control and communications (NC3) systems[8] – faced severe flooding that current estimates project will cost $420 million to repair.[9] While STRATCOM headquarters were not directly affected, operations at the base have been seriously disrupted, demonstrating the vulnerability of a central node of the US deterrent to extreme weather patterns brought on by climate change.

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3. For a useful literature review on climate change and international politics, see Jeff D Colgan, 'Climate Change and the Politics of Military Bases', *Global Environmental Politics* (Vol. 18, No. 1, February 2018), pp. 33–51.
4. Ministry of Defence (MoD), 'Global Strategic Trends: The Future Starts Today', 6th edition, 2 October 2018, pp. 13–14.
5. US Department of Defense (DoD), 'Reports on Effects of Climate Change to the Department of Defense', 10 January 2019, p. 2.
6. Scilla McLean (ed.), *How Nuclear Weapons Decisions are Made* (New York, NY: Palgrave Macmillan, 1986).
7. See, for example, House of Lords Select Committee on International Relations, 'Rising Nuclear Risk, Disarmament and the Nuclear Non-Proliferation Treaty', HL Paper 338, Seventh Report of Session 2017–19.
8. Sandra Erwin, 'U.S. STRATCOM to Take Over Responsibility for Nuclear Command, Control and Communications', *Space News*, 23 July 2018.
9. *Air Force Times*, 'Cost to Rebuild Offutt After the Flood Now Estimated at $420 Million', 2 May 2019.

The legacy of nuclear weapons testing on the Marshall Islands will be made even worse by climate change. Most significant is the threat posed to the 'dome', a concrete structure storing 73,000 cubic metres of radioactive waste from dozens of US nuclear tests.[10] The unlined dome has already shown evidence of leaking, with fears that a severe storm combined with rising sea levels might crack the structure and release vast amounts of nuclear waste into the Pacific Ocean.[11]

Perhaps most immediate and consequential, though, will be the effects of climate change on nuclear systems in the Arctic, given the environmental vulnerability of the region and its strategic importance in the global nuclear complex.[12] The DoD's 2019 climate assessment has already identified Fort Greely, Alaska – the site of the vast majority of US ground-based interceptors – as susceptible to melting permafrost, a by-product of global warming.[13] Serious attention, however, has not been given to the potential effects of climate change on another critical Arctic asset in the US nuclear infrastructure: the North Warning System.

Made up of installations placed along the states' northernmost borders, the joint US–Canada early-warning radar system[14] plays a critical role in the deterrence strategy of both countries. As it stands, the current system needs updating, a costly endeavour as the 1980s technology must be updated to detect more advanced and diverse threats posed by 21st-century nuclear arsenals.[15] Yet its significance cannot be understated. Some have already recognised the critical importance of updating the system because of climate change – more ice-free months will increase activity in the region and thus require greater monitoring.[16] This analysis, however,

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10. Kyle Swenson, 'The U.S. Put Nuclear Waste Under a Dome on a Pacific Island. Now It's Cracking Open', *Washington Post*, 20 May 2019.
11. Maveric Abella et al., 'Background Gamma Radiation and Soil Activity Measurements in the Northern Marshall Islands,' *Proceedings of the National Academy of Sciences*, 15 July 2019, <https://doi.org/10.1073/pnas.1903421116>, accessed 2 October 2019.
12. Jamie Kwong, 'A Warning About Warming: Climate Change Threatens Arctic Nuclear Security', *Nuclear Reactions* (RUSI's PONI Blog), 11 December 2018.
13. DoD, 'Reports on Effects of Climate Change to the Department of Defense'.
14. Early warning systems are meant to detect and assess incoming ballistic missiles to give the proper authority sufficient time to launch a retaliatory strike. They are an integral part of the nuclear architecture of all nuclear-armed states – as well as some non-nuclear weapon states – and are central to a state's effective deterrent.
15. The US and Canada have initiated the process for replacing the current system, with plans to award a contract in the mid-2020s. Details on the cost of the replacement system are not yet available, but current projections estimate billions of dollars. See Vivienne Machi, 'United States, Canada Studying Options to Replace Early Warning Radars', *National Defense*, 27 July 2018.
16. Short-range radars, in particular, will be tasked with monitoring more (potentially nuclear) activity in the region as states devote more resources and assets to the Arctic as the strategic space becomes more accessible. See James Acton, 'Escalation Through Entanglement: How the Vulnerability of Command-and-Control Systems Raises the Risks of an Inadvertent Nuclear War', *International Security* (Vol. 43, No. 1, Summer 2018), p. 87; Ernie Regehr, 'Replacing the North

does not adequately address how the installations meant to do the monitoring will themselves cope with climate change.

Like its predecessors, the updated system would have a service life of 30–40 years. Climate change – particularly thawing permafrost – will significantly challenge this projection as the system must cope with an actively changing environment.[17] This reality must be a central consideration in the design and procurement of the new radar stations. If climate threats are not sufficiently addressed, the system may not remain operational for its entire intended lifetime, will amass significant operation and maintenance costs, extending resources that will likely already be stretched in the increasingly active region, and may become unreliable, threatening its role in ensuring a second-strike capability. In short, climate change will undermine the deterrent capabilities of the radar system.

This is just one direct way in which climate change can threaten deterrence. A changing operational environment, competition for scarce resources that have strategic impacts and disruptions to nuclear weapon systems are all likely indirect effects of climate change that can fundamentally challenge deterrence postures. The fact that all nuclear-armed states will be affected by climate change – likely some more than others – only exacerbates this uncertainty around nuclear weapons and climate change.

Addressing the Climate–Nuclear Intersection

More work must be done to think critically about the potential effects of climate change on nuclear weapons and deterrence. This should include a dedicated climate–nuclear assessment, a study that goes further than the DoD's climate report both in terms of scope and timeline.[18] This assessment should focus on the consequences of climate change on nuclear infrastructures, considering not only how those systems will be physically affected by climate change but also how this can affect nuclear deterrence postures overall.[19]

Warning System: Strategic Competition or Arctic Confidence Building?', The Simons Foundation: Arctic Security Briefing Papers, 1 March 2018.

17. Thawing permafrost 'decreases the structural stability to foundations [and] buildings' and 'requires costly mitigation responses that disrupt planning, operations, and budgets' (DoD, 'Reports on Effects of Climate Change to the Department of Defense', p. 7).
18. The DoD report assessed the potential effects climate change might have on 79 military instillations over the next 20 years. See DoD, 'Reports on Effects of Climate Change to the Department of Defense'.
19. While the DoD's previous work on the security of climate change suggests it might be suitable to conduct such a study, domestic political pressures in the US might prevent the Pentagon from pursuing such an endeavour. The UK stands to serve as an alternative leader in this arena, given both its commitment to combatting climate change and the vulnerability of its own nuclear weapons infrastructure to a changing environment.

Serious consideration should also be given to the ways in which climate change might affect extended deterrence patterns and relationships. How might NATO's extended deterrent be pressured amidst greater activity – and thus a changing operational environment – in the Arctic?[20] How might the extended deterrent of the US be stretched amidst greater competition for resources in the East and South China Seas?

To answer these questions and more, scholars and policymakers must engage in serious dialogue on the intersection of deterrence and climate change. Focused research and planning should be a defence priority, pressuring governments to develop plans for mitigating the worst effects of climate change on nuclear weapon systems, infrastructures and activities.

20. Especially considering the US and the UK are undergoing extensive modernisation programmes that will already likely induce strains on current systems awaiting retirement.

X. UK Political Understanding of the Term ‘Nuclear Deterrence’: Addressing a Deficiency

Sophie McCormack

NUCLEAR DETERRENCE HAS been a central pillar of international security policy since the end of the Second World War. Research on the concept portrays deterrence as multifaceted and dynamic, with emerging technologies further complicating what it means to deter.[1] By contrast, political understanding is dominated by conflated terms such as ‘nuclear deterrence’ and ‘the nuclear deterrent’, arguments of historical precedent and an attachment to Cold War biases, leading to an overall lack of policy analysis from MPs. Regardless of academic discussions and advice, it is politicians who have primary control over the direction of UK nuclear policy. Therefore, it is imperative that politicians and their advisers have a deeper understanding of nuclear issues, to the ultimate benefit of UK nuclear policy and national security.

This paper will begin with a discourse analysis of the 2016 UK Parliamentary debate on renewing Trident. Second, it will focus specifically on public statements made by former Prime Minister Theresa May during her time in office on nuclear deterrence, to highlight that similar conflations and assumptions present within the House of Commons debate were also made by the person with the prerogative over nuclear use. Third, the implications on nuclear policy and national security from a lack of nuclear awareness and policy analysis will be assessed. Finally, within this context, recommendations that fit within the government’s priority of securing a ‘Global Britain’ will be discussed.[2]

Findings

From a discourse analysis of the 2016 UK Parliamentary debate to renew Trident, this paper highlights three key themes in political understanding. First, there is a repeated tendency to conflate the term ‘nuclear deterrence’ with ‘the nuclear deterrent’. ‘Nuclear deterrence’ refers to the process of using nuclear weapons to deter nuclear war and large-scale

1. Michael Mazarr and James E Goodby, ‘Redefining the Role of Deterrence’, in George P Shultz, Sidney D Drell and James E Goodby (eds), *Deterrence: Its Past and Future* (Stanford, CA: Hoover Institution Press, 2011), p. 12; Simon Beard, ‘APPG for Future Generations: Drones, Swarming and the Future of Warfare’, University of Cambridge Centre for the Study of Existential Risk, 4 July 2019, <https://www.cser.ac.uk/news/appg-future-generations-drones-swarming-and-future/>, accessed 5 July 2019.
2. HM Government, ‘Global Britain: Delivering on our International Ambition’, updated 23 September 2019.

interstate war, whereas 'the nuclear deterrent' refers to Trident – the weapon system and its *Vanguard*-class delivery system.[3] 'Nuclear deterrence' can be used to justify deterring a range of actions that are unacceptable to nuclear-armed states (for example, Saddam Hussein's desire to use chemical weapons in the Gulf War).[4] But its contingent nature is demonstrated in its chequered success, including the 1998 Kargil War fought between nuclear states India and Pakistan.[5] The conflation of deterrence and deterrent hinders constructive political debate. By using Trident as a substitute for the concept of 'nuclear deterrence', it assumes that the possession of nuclear weapons is all that is required to achieve nuclear deterrence. This neglects to analyse the role of nuclear posture, conventional deterrence and limiting external factors, such as US anti-missile defences. A handful of MPs raised elements of these arguments at the Parliamentary debate, but at no point were the meanings of such contingencies discussed, or their evolving effect on UK nuclear policy. As a consequence, political understanding tends to neglect both contemporary security realities and academic work, leaving a political 'nuclear deterrence dogma'.[6]

Second, the debate is largely grounded in historical arguments. Repeated comments – such as 'nuclear deterrence has preserved the security and stability of this country for half a century … It was the right approach then and it is the right approach again today' – demonstrate an understanding which is dependent upon a nostalgic historical attachment, rather than contemporary analysis.[7] Adequate contemporary scrutiny would include how nuclear deterrence works today and its limitations. Such a mindset also resulted in the debate being framed by a dominant tone of pride. MPs referenced the 'pleasure' at speaking in such a consensual debate and the 'awe' felt around Trident.[8] But having a debate dominated by sentiment further harms the ability of politicians to analyse nuclear policy. Moreover, it cannot be said with certainty that the right lessons are being drawn from the Cold War. Deterrence prevents 'non-events', so it is not definite that nuclear deterrence was responsible for the lack of Soviet attack, or at least not solely responsible.[9] Also, can it be said with certainty that Cold War mechanisms – such as hotlines and test ban treaties – remain suitable for dealing with contemporary nuclear threats? To answer these questions and build more robust nuclear policy requires a shift in political awareness and discourse.

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3. Lawrence Freedman, *Strategy: A History* (Oxford: Oxford University Press, 2013), p. 155; Bernard Brodie, 'The Development of Nuclear Strategy', *International Security* (Vol. 2, No. 4, 1978), p. 66; Michael Quinlin, 'Thinking About Nuclear Weapons', *RUSI Journal* (Vol. 142, No. 6, 1978), p. 4.
4. Benjamin Buch and Scott D Sagan, 'Our Red Lines and Theirs', *Foreign Policy*, 13 December 2013.
5. Scott D Sagan, 'For the Worse: Till Death Do Us Part', in Scott D Sagan and Kenneth N Waltz, *The Spread of Nuclear Weapons: An Enduring Debate*, 3rd Edition (New York, NY: W W Norton & Company, 2003), p. 143.
6. Robert Green, 'The New Nuclear Deterrence and Disarmament Crisis', *Open Democracy*, 3 April 2019.
7. *Hansard*, House of Commons, 'UK's Nuclear Deterrent', Debate, 18 July 2016, Column 609.
8. *Ibid.*, Columns 591, 634.
9. Ken Booth and John Baylis, *Britain, NATO and Nuclear Weapons: An Alternative Defence Versus Alliance Reform* (London: Macmillan, 1989), p. 72.

Third, those attempting to analyse what 'nuclear deterrence' requires in practice were labelled as undermining national security.[10] One MP asserted that anyone in the debate raising points of policy scrutiny were attacking the 'sovereignty and control of our nation'.[11] The resultant unquestioning environment sets a very dangerous precedent: one only has to look to the findings of the Iraq Inquiry to see why. These findings concluded that groupthink (an unquestioning policy environment) results in insufficiently considered policy, with potentially dire consequences.[12] Having this crucial facet of defence policy go largely unquestioned may mean the guarantor of UK security is not as robust as is assumed. It is also a matter of concern that analysing nuclear policy was assumed only to be a disarmament argument. Such an assumption must be overcome in order to remove a primary barrier to deepening political understanding of nuclear issues – the current political consensus is for the UK to retain nuclear weapons, so politicians are unlikely to advocate something associated with promoting disarmament.[13]

Furthermore, the political belief that straying from the nuclear status quo is 'a bar to being elected' could constitute a further block to politicians' analysis of nuclear policy.[14] As nuclear weapons are widely perceived to be the guarantor of UK security, and the electorate expect the state to deliver 'security', nuclear weapons are thought to be 'backed by the public'.[15] A YouGov poll from spring 2019 detailed that the lowest public approval rates for Labour Party policies were on nuclear disarmament; in fact, the numbers were not dramatically dissimilar from responses of US citizens.[16]

Understanding of the Prime Minister

Key nuclear decision-makers (for example, the prime minister and the secretary of state for defence) should have a comprehensive understanding of relevant issues, as they are the individuals ultimately responsible for deciding UK nuclear policy. The prime minister holds the ultimate say over nuclear use, so should have a sufficient grasp of key nuclear terms and approaches. The author focused on May's discourse, as at the time of writing, May was prime minister. Analysis of May's public statements on Trident and nuclear deterrence made during her time as prime minister revealed a similar pattern of findings to those of the 2016 debate. Specifically, May repeatedly reverted to historical precedent to justify her views. By talking of the 'necessity for us to have a nuclear deterrent, which has been an insurance policy for this

10. *Hansard*, 'UK's Nuclear Deterrent', Column 598.
11. *Ibid.*, Column 599.
12. John Chilcot et al., *Chilcot Report: Executive Summary* (Kingston upon Thames: Canbury Press Ltd, 2017).
13. *Hansard*, 'UK's Nuclear Deterrent', Columns 612, 626.
14. *Ibid.*, Column 626.
15. *Ibid.*, Column 631.
16. YouGov, 'Eurotrack: Corbyn's Policies Popular in Europe and UK', 9 January 2019, <https://yougov.co.uk/topics/politics/articles-reports/2019/01/09/eurotrack-corbyns-policies-popular-europe-and-uk>, accessed 22 August 2019.

country for nearly 50 years', May relied on a 'because it has been' argument.[17] Presuming that the previous 50 years will be the same as the next 50 in terms of deterrence requirements is not only misplaced, but also demonstrates a marked lack of policy analysis. Further, assuming the last half-century has been a static length of time in deterrence nature and requirements also demonstrates a gap in political awareness. Emerging technologies, an increased number of nuclear states and evolving international power structures all affect how nuclear deterrence is (and can be) achieved today. Further, a lack of political appreciation for how 'nuclear deterrence' and 'deterrence' differ – as well as how these different realms interact with each other – presents a direct threat to UK nuclear policy, undermining its funding and leaving it relatively one dimensional.

The tendency to conflate 'nuclear deterrence' with 'the nuclear deterrent' was also present in May's public statements.[18] By referring to 'our nuclear deterrent', it presupposes that the possession of nuclear weapons is the sole condition to achieving nuclear deterrence. The uncritical assumption of this causal link makes political debate of nuclear deterrence irrelevant. For the person in charge of nuclear use to lack the awareness of the complexities of nuclear deterrence presents a concerning dynamic in UK nuclear policy.

Implications

There are three key takeaways from these findings. First, there is a marked separation between the political and academic communities on 'nuclear deterrence'. Academics portray deterrence as highly contingent, yet politicians describe it as a largely binary concept. Think tanks and policy analysts attempt to bridge the gap between the two communities, but on 'nuclear deterrence' it appears something is failing. A lack of academic funding for political outreach, nuclear lexicon being full of jargons and complicated terms, and politicians regarding nuclear policy as a 'political graveyard' are just three contributing factors to the gulf between political and academic engagement with nuclear issues.[19] UK nuclear policy and political analysis are inevitably suffering from the chasm between political and academic understanding.

Second, politicians' public statements are drafted by their researchers and politicians are briefed by their staff, so it appears a lack of nuclear understanding goes beyond just MPs. This

17. *Hansard*, 'UK's Nuclear Deterrent', Column 562.
18. Conservatives, 'Theresa May's Speech to the Conservative Party Conference in 2017', 4 October 2017.
19. Peter Thomson and Inger Mewburn, 'Why Do Academics Blog? It's Not for Public Outreach, Research Shows', 2 December 2013, <https://www.theguardian.com/higher-education-network/blog/2013/dec/02/why-do-academics-blog-research>, accessed 21 August 2019; Liliana Fonseca, 'Third Mission Accomplished? Why are Universities Bad at Engaging With Local and Regional Government and What We Can Do About It', 13 March 2019, <https://blogs.lse.ac.uk/impactofsocialsciences/2019/03/13/third-mission-accomplished-why-are-universities-bad-at-engaging-with-local-and-regional-government-and-what-we-can-do-about-it/>, accessed 21 August 2019; *Hansard*, 'UK's Nuclear Deterrent', Columns 612, 626.

deeper problem could stem from the gap between the political and academic communities. Policymakers place less importance on policy reflecting academic study, meaning contingencies widely debated in academic circles are often not mirrored in policy creation.

However, it is most likely that a lack of political understanding is facilitated by the nature of civil service employment, with expertise being systematically lost by civil servants' brief postings. If this expertise is to be regained, regular communication with academics and think tanks is necessary to strengthen the internal intellectual/policy nexus. The former Permanent Under-Secretary of State at the MoD, the late Sir Michael Quinlan, actively contributed to academic scholarship during his time in office – it is this proactive, internal relationship with academia that should be aimed for. Reinitiating internal Cold War-era crisis-management exercises could also be beneficial. Increasing 'in-house' deep understanding of nuclear issues, with individuals who contribute to academic study, would serve to increase political understanding and so strengthen UK nuclear policy creation.

Third, emotive historical associations and conflated terms, such as 'nuclear deterrence' and 'the nuclear deterrent', undermine political analysis. Both serve as impediments to discussion, meaning politicians' understanding fails to go beyond comments such as Trident 'does what it says on the tin; it deters'.[20] This means key nuclear decision-makers do not understand how deterrence can work today and in the future, nor are they debating how these limitations can be overcome.

Recommendations

This paper offers three key recommendations. First, the creation of formal political platforms. For example, a nuclear select committee would create a platform for ministers, their advisers and MPs to engage in nuclear debate with the academic community, ultimately aiding political understanding. It would reserve time in politicians' diaries to debate nuclear issues, directly address the separation of political and academic spheres, and increase 'in-house' political expertise. Alternatively, a subset of standing MPs focused on nuclear policy within the Commons Defence Committee could be another means of achieving the desired progress. The Global Security and Non-Proliferation All-Party Parliamentary Group goes some way to achieving this, but a select committee would raise the status of such a platform. By their nature, APPGs are not official bodies of Parliament and so attendance is often marginal. Wider political engagement is necessary for notable change to be made. Moreover, the new platform should focus more on facilitating political discussion and analysis of nuclear policies and issues, rather than purely being an information-providing forum.

Second, from the academic perspective, using less technical, jargon-fuelled language to communicate findings with politicians would likely improve political understanding. This does not mean over-simplifying messages, but instead delivering messages with clarity, which have been tailored for a political audience. Nuclear issues are complex even for experts, so for

20. *Hansard*, 'UK's Nuclear Deterrent', Column 588.

politicians without a deep understanding, academic language can appear foreign. The resultant gap between academic and political communities seems to be a primary block to political understanding, on which the success of formal platforms is conditional.

Third, a more general point is that addressing a lack of accepted nuclear definitions would aid political understanding. Although these terms are contested, adding concepts such as ‘nuclear deterrence’ to the UN Permanent 5 glossary would serve to underpin an effort to enhance political understanding. Presenting this as a technical rather than a political step could help to increase political buy-in, particularly if linked to a means of combating contemporary concerns, such as global risk reduction and non-proliferation.

In conclusion, political understanding in MPs and their staff of nuclear issues is lacking. Political debate and analysis that does not reflect contemporary security realities and instead assumes that UK nuclear policy status quo safeguards the UK from threats nuclear weapons are presumed to deter leaves UK defence vulnerable. Short civil service employment postings undermining the government’s nuclear expertise further deepen this deficiency, which requires addressing.

This paper has outlined a range of contributing factors to insufficient political understanding, as well as means to overcome them. Given that politicians, specifically the prime minister, have ultimate control over UK nuclear policy direction, remedying a lack of political analysis is central to the future of UK security.

XI. More than a Mission: Simulating a Support Solution to Achieve Submarine Availability, Cost and Safety

Thomas Roberts

THIS YEAR MARKS the 50th anniversary of Continuous At Sea Deterrence (CASD). Since 1969, there has always been a ballistic missile submarine (SSBN) at sea, providing the UK's nuclear deterrent.[1]

In 2016, Parliament voted overwhelmingly in favour of retaining the UK's nuclear deterrent, replacing the current *Vanguard*-class submarines with four new ballistic missile submarines. The new class of submarines will ensure that the UK has a credible, independent and capable nuclear deterrent out to the 2060s and beyond.[2]

This paper describes how an effective support solution can influence the design of this future class and how risk identification early in the concept phase can supplement lessons learned from previous platforms to de-risk CASD. In seeking to better quantify the impact of inherent design characteristics and wider supportability factors on availability, a modelling and simulation approach is recommended to enable operators to predict operational capability of the platform.

Operating Profile

Through-life performance is assessed against availability, cost and safety requirements. Defence acquisition programmes are increasingly focused on assuring and demonstrating that the through-life requirements relating to these core objectives can be achieved. Modelling and simulation early in the design phase allow operators to forecast the ability of a product to meet these requirements when operated in a defined usage and upkeep cycle.

Figure 1 portrays readiness states that Royal Navy submarines endeavour to achieve.[3] Performance modelling aims to predict the maintenance requirement for maintenance periods. This requires knowledge of how the platform will be maintained and operated during each of the readiness states to begin to build a coherent picture of the operational life of the vessel.

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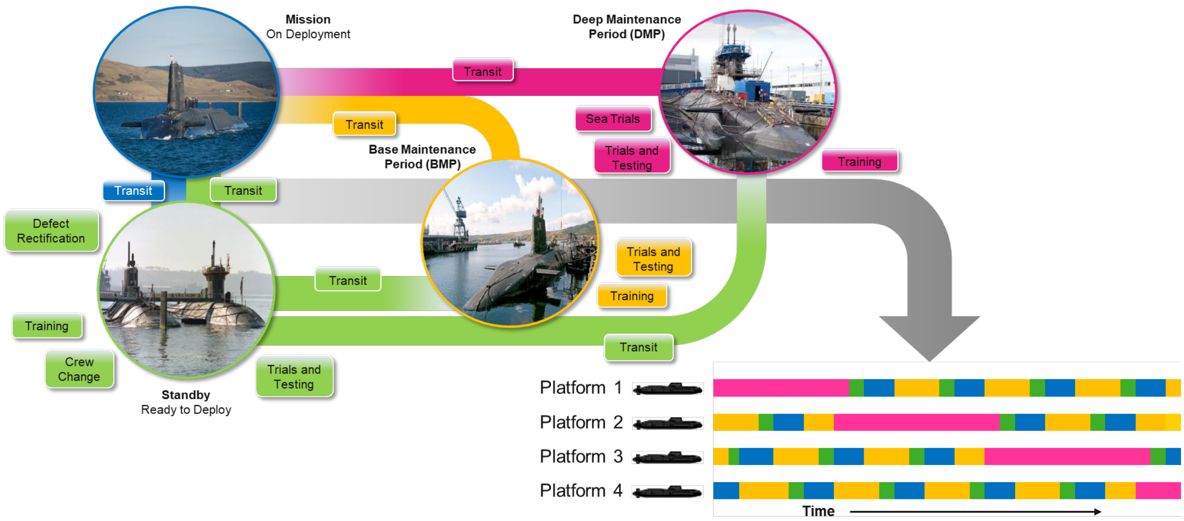
1. *Hansard*, 'The United Kingdom's Future Nuclear Deterrent: 2018 Update to Parliament', HCWS 1229, written statement, 20 December 2018.
2. *Ibid*.
3. National Audit Office and Ministry of Defence (MoD), 'Assessing and Reporting Military Readiness', Report by the Comptroller and Auditor General, HC 72, Session 2005–2006, 15 June 2005.

The bottom right of Figure 1 shows a maintenance upkeep and operating cycle (MUOC), which demonstrates the location and readiness level of each platform during a specified time period. The MUOC identifies decisions that can be made to maintain mission capability in line with operational doctrine through redeployment of capable platforms in other standby states.

The operating profile is built around system maintenance requirements and resource constraints, to enable the required submarine capability to be available when required. The main objective is to ensure the support solution is capable of maintaining this operating profile to sustain CASD.

Figure 1: Submarine Operating Profile.



Source: Babcock International Group.

Support Enterprise Challenges

Supportability is often a 'bolt-on' to the design happening later in the lifecycle post-manufacture that results in a sub-optimal support product. This is commonly caused by near-term financial pressure to minimise the initial procurement cost. Long-term programme implications – such as maintaining suitably qualified and experienced personnel, infrastructure and materials costs, and equipment obsolescence – are also key considerations of a support solution.

Submarines comprise some of the most complex systems in the world, built within a confined space and required to operate in a hostile environment. As-built platform specifications will differ between the first and last of class due to the lengthy build programme time, technical refreshes and the application of lessons learned. Four platform configurations will demand a tailored support solution that considers these differences.

There is a persistent challenge to achieve an acceptable quantity and quality of data for modelling given the low volume of products and therefore limited historical evidence from which to predict trends. To put this in context, there are 142 operational Eurofighter Typhoons in the Royal Air Force.[4] In comparison to the four *Vanguard*-class SSBNs, there is much more data on which to base supportability analysis.

Most of the cost of the product is realised during its service life. The concept and design phase provides the best opportunity to influence in-service cost – however, the cost of initial investment in the development of a support programme should be balanced against the likely cost and political implications of a failure of the product to meet its availability requirements (in this case, a failure to provide the UK's continuous at-sea deterrent).

Platform Life Extensions – Predicting Impact on Support

More is being demanded of the *Vanguard* class due to policy and budgetary processes surrounding defence procurement. As shown in Figure 2, the current class of SSBNs is expected to be in service for an additional 15 years after its original design life. This trend demands a more robust support solution that can predict availability and prioritise maintenance in such events.

Figure 2: *Vanguard*-Class Life Extension as a Result of Political Action.

Sources: Hansard, *'The United Kingdom's Future Nuclear Deterrent: 2018 Update to Parliament'; HM Government,* Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review *(SDSR), Cm 7948 (London: The Stationery Office, October 2010); MoD, 'The United Kingdom's Future Nuclear Deterrent: 2013 Update to Parliament', 2013.*

Some of the most significant UK political decisions relating to the replacement of the *Vanguard*-class and retention of the Trident deterrent have been illustrated in Figure 2, which have had a direct impact on the platform life of the current class. As a platform gets older, equipment will reach the end of its wear-out curve and the material state of the platform will decline. This results in a greater support resource requirement during the maintenance periods described earlier.

4. House of Commons Defence Committee, 'Formal Minutes 2017–19', 2019.

Given the historical evidence, support modelling should consider the likelihood of a life extension to future classes.

Design for Support

The single largest contributor to reducing through-life cost, while increasing availability and maintaining safety, is the delivery of a submarine that is designed to be supported. The ability to predict availability of the platform and constituent systems enables identification of risk for the operator which in turn can open channels to communicate the need for a particular design change to the designers.

An effective support solution delivers benefits such as:

- Training to maintain and operate the platform safely and effectively.
- Identifying a lean logistics support model to optimise cost and availability of spares.
- Influencing maintenance periodicity to fit the MUOC, such as identifying areas which may require specific or more frequent maintenance.
- Enabling lessons identified from in-service experience to be applied to future submarine design programmes.

Integrated Logistic Support Approach

Prevalent in the aerospace industry, Integrated Logistics Support (ILS) is in its infancy in the marine sector. However, it is recognised as an important strategic development, particularly with respect to maintaining CASD.

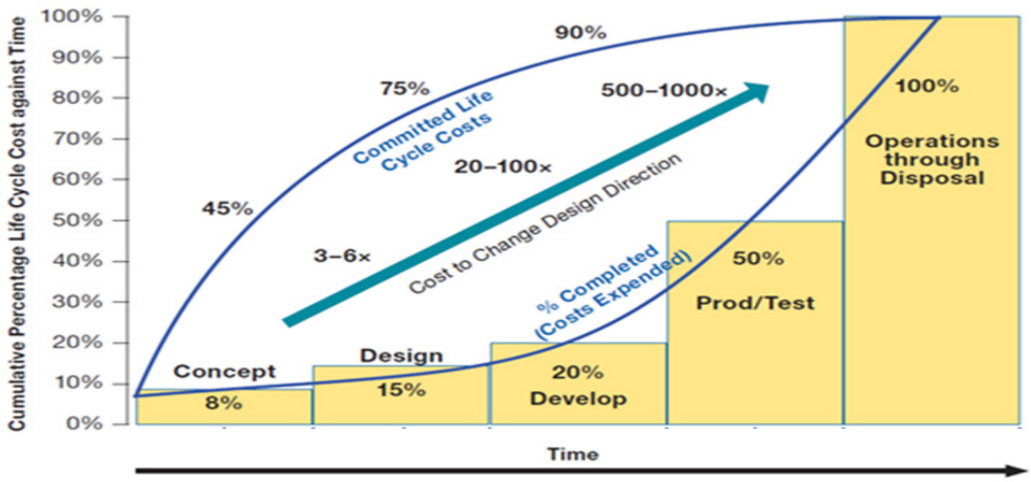
ILS was adopted by the MoD in 1993 and is compulsory for the procurement of complex MoD equipment. ILS is a disciplined approach to managing whole-life costs as described in the Defence Standard 00-600[5] and the archived Joint Services Programme (JSP) 886.[6]

Support as a Design Characteristic

Identifying cost and availability drivers enables ILS engineers to influence the design to ensure supportability is considered early in a product's life. The factors affecting whole-life costs are driven by decisions made during the early evolution of the product concept and design.

5. MoD, 'Defence Standard 00-600 Integrated Logistic Support', 2016.
6. MoD, 'JSP 886: The Defence Logistics Support Chain Manual', 20 December 2012.

Figure 3: Cost of Design Change.



Source: NASA, 'Systems Engineering Handbook', Vol. 2, December 2007.

As shown in Figure 3, the cost of design change dramatically increases as the process leaves the design phase. Committed cost is at its lowest during the concept and design phases, which makes this the best time to invest in and integrate a product's through-life support programme. Often, a platform is hindered by the decisions made during the design phase where a platform is designed for build but access for support activities is not considered.

Early design decisions determine the supportability of a platform, and given the cost implications for a bespoke and complex acquisition, it is advantageous to integrate supportability modelling into the early stages of design.

Supportability Analysis

Class-level modelling is used to forecast the ability of the submarine and support solution to maintain readiness over a defined duration and to identify and prioritise risks to optimise performance. The model is built up from component level. Millions of material items are assessed for impact on capability and candidate items are selected for further supportability analysis if they are defined as support significant. This means they are likely to be high cost, require a large amount of maintenance or are critical to fulfilling the mission.

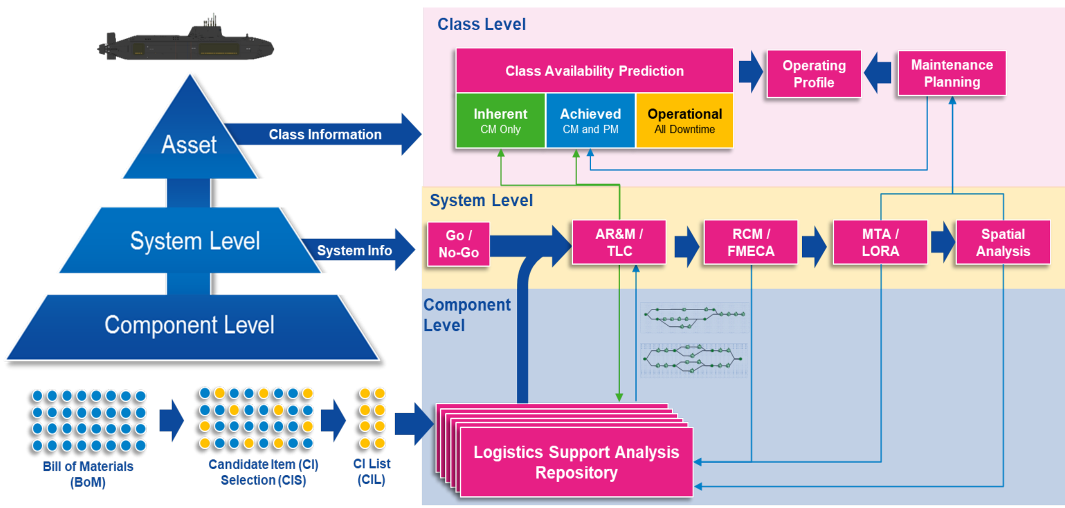
As shown in Figure 4, analysis is aggregated from component level to class level which enables the root cause of lower availability to be identified. The process identifies risk drivers that may impact the availability of the platform and class, and offers evidence for key decisions to be made to maximise capability and optimise cost.

Class-level modelling is at the top of this hierarchy, requiring prerequisite inputs from system- and component-level analysis. A tailored suite of tools is applied to perform supportability analysis and the fully integrated model combines the outputs from all supportability analyses.

Key processes at system level are as follows:

- Availability, Reliability and Maintainability (AR&M) and Through-Life Cost (TLC): A key area for influencing the design early is by using AR&M and TLC analysis. An overall system reliability prediction model is used to forecast the ability of a system to carry out its function by reconstructing the system's functional architecture, operation and component configuration to determine its AR&M characteristics.
- Reliability-Centred Maintenance and Failure Modes, Effects and Criticality Analysis: A method of defining failure modes, how equipment fails and the effects of these. This process is used to determine what must be done to ensure that equipment can continue to meet the system requirements and develops unique maintenance schedules for equipment.
- Maintenance Task Analysis (MTA) and Level of Repair Analysis (LoRA): MTA identifies how equipment will be maintained and includes details required for resource planning. LoRA then determines the best option for where and how an item will be repaired, replaced or discarded.
- Spatial Analysis: Spatial analysis uses 3D modelling produced by the designers to assess access/egress to equipment and potential difficulties resulting from equipment arrangements and space constraints. This is critical to the assessment of the maintenance burden.
- Logistics Support Analysis Repository (LSAR): The LSAR is configured and controlled to hold all supportability data and acts as a single point of truth for the analysis process. The tools feed a class availability prediction and maintenance planning capability, which enable the support authority to predict whether the platform and class can maintain the operating profile.

Figure 4: Supportability Modelling Methodology.



Source: Babcock International Group.

Conclusions

In conclusion, in-service sustainment costs dominate whole-life cost. The early lifecycle phases provide the greatest opportunity to influence in-service cost, yet it is challenging to quantify future capability demand and thus cost to support the platform. To address this, performance modelling is the most accurate and cost-effective way of predicting submarine availability, cost and safety prior to entering service which enables the operator to influence the design with a view to maximising availability and capability at an optimised cost.

Platform- and class-modelling can be used at every stage of a submarine's lifecycle to provide assurance that requirements are met and engineering risk is managed effectively through life. Future platforms will be the first Defence Acquisition Programmes to attempt this level of support engagement in the design phase. The foundations have been laid for the future class of submarines to be the most supportable ever delivered by the UK.

XII. Betwixt and Between Transformation? India and Nuclear South Asia

Shounak Set

SOUTH ASIA PRESENTS a unique template to examine issues of deterrence, nuclear proliferation and regional nuclear dynamics simultaneously. Integral to the process of South Asian security is India – a rising power that has been partially accommodated in the non-proliferation order, adheres to a malleable nuclear doctrine and demonstrates steady nuclear and conventional modernisation. South Asia as a region spawned the Second Nuclear Age in 1998 with the successive Indian and Pakistani nuclear tests that year. Since the advent of the Second Nuclear Age, the conventional understanding of South Asian security has largely been informed by the Stability–Instability Paradox – stability at a strategic (that is, nuclear) level coexists with instability at tactical (that is, conventional) levels in South Asia.[1] However, technological, political and structural developments of the recent past generate questions about the sustainability of prevailing assumptions. Discrepant trends, particularly in the past few years, have been steadily gaining ground and merit an appraisal in tandem with the evolving extra-regional dynamics.

India, South Asia and the Nuclear Order

An outlier in the global non-proliferation order, India has been seeking membership in the Nuclear Suppliers Group (NSG), although it has a waiver from the same thanks to the India–USA Civilian Nuclear Agreement signed in 2008.[2] Of no less significance, India has joined ancillary arrangements in the past few years, beginning with the Missile Technology Control Regime in 2016, followed by the Wassenaar Arrangement in 2017 and the Australia Group in 2018. These collectively facilitate greater Indian access to, and engagement with, strategic technologies. It is also often overlooked that the regional setting is permeated by global linkages in a cascading effect. Beyond India–Pakistan, South Asia is also subject to two interconnected bilateral groups – the US–China and the China–India dyads. Often, the outcomes are a function of this trinity, which is not always recognised in academic or policy engagement. These transforming variables raise the fundamental question – in contrast to existing understandings and assumptions, including the Stability–Instability Paradox – is the empirical reality on the ground changing due to technological advances and policy interventions?

1. Michael Krepon, 'The Stability-Instability Paradox, Misperception, and Escalation Control in South Asia', The Asia Dialogue, <https://theasiadialogue.com/wp-content/uploads/2017/10/stability-instability-paradox-south-asia.pdf>, accessed 29 November 2019.
2. Arms Control Association, 'The Nuclear Suppliers Group (NSG) at a Glance', August 2017, <https://www.armscontrol.org/factsheets/NSG>, accessed 29 November 2019.

It is instructive to note that concepts of nuclear issues, largely derived from Western settings, may remain similar in principle but differ in manifestation in South Asia. Deterrence in South Asia is distinguished by three key features – geography, doctrine and force posture. First, unlike the Soviet Union–US Cold War, with India and Pakistan being neighbours, the physical proximity obliterates the time window between attacks and potential nuclear fallout would proximately affect both countries. Second, unlike conventional understandings of the term, 'deterrence' here is characterised by the interlinkage between sub-conventional, conventional and strategic levels. The perpetuation of sub-conventional and asymmetric warfare by Pakistan is coupled with the introduction of tactical nuclear weapons on the one hand while the Indian response manifests through ballistic missile defence and limited warfare doctrines on the other. Finally, academic and policy literature is not unanimous about the doctrinal specificities. Indian doctrine covers chemical and biological weapons and there is an ongoing academic debate[3] about whether India is shifting from countervalue to counterforce targeting.[4] However, India's doctrine does not mention either of these terms and there is little tangible evidence of a shift on the ground.[5]

Indian Security: Trends and Trajectories

There are a few enduring trends in Indian security planning, including intense policy debates and an acute demonstration-induction gap. There are considerable debates among policymakers on doctrinal revisions and modernisation cycles, which are often shaped by exigencies and individuals. Counterintuitively, the lack of official declarations and the absence of a systematic declassification practice means that analysts must read between the lines. A characteristically pervasive trend, best evinced by the limited warfare doctrine – often referred to as 'Cold Start Doctrine' – involves swift and brief ingress through a combined-arms approach across the international border with Pakistan in response to asymmetric (such as terrorist) attacks.[6] Although acknowledged only in 2017,[7] military exercises and reorganisations at tactical levels have been evident since 2004[8] – and in 2018, after such an exercise, the Indian army declared that it was ready to fight in 'a battle space contaminated by nukes'.[9] Likewise, concerning acquisition of specific platforms, India demonstrates a significant lag between the triad of articulation of intent, demonstration of capability and the actual induction cycle. For example, although an indigenous nuclear submarine project was approved in the 1970s, the triad was

3. Rajesh Rajagopalan, 'India's Nuclear Strategy: A Shift to Counterforce?', Observer Research Foundation, 30 March 2017.
4. Christopher Clary and Vipin Narang, 'India's Counterforce Temptations: Strategic Dilemmas, Doctrine, and Capabilities', *International Security* (Vol. 43, No. 3, Winter 2018/19), pp. 7–52.
5. Indian Ministry of External Affairs, 'The Cabinet Committee on Security Reviews Perationalization of India's Nuclear Doctrine', 4 January 2003.
6. Walter C Ladwig III, 'A Cold Start for Hot Wars? The Indian Army's New Limited War Doctrine', *International Security* (Vol. 32, No. 3, Winter 2007/08), pp. 158–90.
7. Sandeep Unnithan, '"We Will Cross Again"', *India Today*, 4 January 2017.
8. Ladwig III, 'A Cold Start for Hot Wars?', pp. 158–90.
9. *Economic Times*, 'Vijay Prahar: Army Men Practise Fighting in "Nuclear Weapon Environment"', 7 May 2018.

completed only in 2018 when INS *Arihant* completed its first sea patrol.[10] Last but not least, Indian strategic consideration is driven primarily by China, but the response is bound to have an impact on Pakistan; under-balancing China and over-balancing Pakistan remain perennial features of Indian security policy.

Significantly, the domestic dimension in South Asia is marked by the emergence of new political constituencies and radical tendencies, the ramifications of which are still unfolding in both India and Pakistan. Salient transitions include the induction of the nuclear-powered ballistic missile submarine in 2018, anti-satellite tests in 2019 and cross-border punitive strikes in 2015, 2016 and 2019 by India under Prime Minister Narendra Modi – these crucial developments merit greater scrutiny. Commentators and scholars have debated the ongoing transition in a piecemeal fashion, but the point is to contextualise and evaluate it in a holistic manner that broadens the understanding of the region, but also widens the empirical and conceptual foundations of deterrence and proliferation. While these trends are still unfolding, and therefore cannot be forecast, it is crucial to take note of these and compare them with established practices. Some overlaps notwithstanding, the transitions can be generally classified for heuristic purposes into two categories – technological interventions and policy-political developments.

Tactics, Technology and Policy: Transitions Considered

The international media widely reported when India's first ballistic missile-carrying submarine (SSBN), INS *Arihant,* completed its debut deterrence patrol in 2018.[11] Four submarines are expected to be in the SSBN fleet, all to be commissioned by 2023. The second vessel, INS *Arighat,* was launched in 2017 and is expected to complete its deterrence patrol later this year.[12] Plans have been approved for production of six nuclear-powered attack SSNs (nuclear attack submarines)[13] and agreements were reached with Russia for leasing one *Akula*-class SSN,[14] in addition to the one already operational.

While currently the SSBNs carry 750-km range ballistic missiles, they are projected to be upgraded to carry ICBMs with a range of 3,000–3,500 km. These are part of the Indian navy's general expansion driven by the dynamics of the Indo-Pacific and the massive expansion of the Chinese navy. On 27 March 2019, India conducted Mission *Shakti* – a direct ascent, kinetic kill anti-satellite test.[15] This is directly related to the ballistic missile defence (BMD) calculus

10. *Indian Express*, 'INS *Arihant* is Now Operational: All About India's Nuclear Deterrent in the Sea', 6 November 2018.
11. *Economic Times*, 'INS *Arihant* Completes India's Nuclear Triad, PM Modi Felicitates Crew', 6 November 2018.
12. Rahul Bedi, 'India Quietly Launches Second SSBN', *Jane's Defence Weekly*, 11 December 2017.
13. Rajat Pandit, 'Govt Approves Construction of 7 Stealth Frigates, 6 Nuclear-Powered Submarines', *Times of India*, 18 February 2015.
14. Manu Pubby, 'India, Russia to Ink $3 Billion Nuclear Submarine Deal This Week', *Economic Times*, 4 May 2019.
15. Harsh V Pant and Shounak Set, 'India's Leap in the Space', *Business Standar*d, 3 April 2019.

and the anti-satellite missile was adapted from a BMD interceptor vehicle. The multi-layered Indian BMD architecture, which consists of land- and sea-based interceptor missiles, involves indigenous as well as foreign components, notably from the US (NASAMS-II), Israel and Russia.[16] Deliveries of Barak 8 (jointly produced by Israel and India) and the Russian S-400 system are expected from 2020.[17] This will have a significant effect on deterrence in South Asia.

In response to terrorist attacks, India carried out cross-border punitive strikes on terrorist camps inside Pakistan in 2016 and 2019.[18] The former was a special forces raid, a few kilometres across the Line of Control in Pakistan-occupied Kashmir; the latter were air strikes at Balakot inside Pakistan, which elicited a retaliatory aerial incursion by Pakistan. The 2019 conflict involved the first use of fixed-wing aircraft by both countries since 1971 – the first direct military confrontation using air assets between two nuclear-armed adversaries. A perusal of policy trajectory and official communications suggest growing appreciation of the role of force in international relations – without resorting to a full-fledged conventional conflict. This is reflective of a broader shift from the traditional pacifist stance of Indian foreign policy – which had been marked by a general agnosticism over the role of force in international relations – while operationally it is facilitated by relying on special forces and precision munitions through an undeclared posture of 'defensive offence', an enigmatic coinage which has gained currency among security policymakers in New Delhi.[19]

Would these doctrinal and policy revisions contribute to a broader shift in South Asia's security landscape? While it is too early for an emphatic affirmation, it is too late to assert that conventional ideas and structures remain unaffected by these transformations. New trends include a certain level of integration of various agencies under the role of the National Security Adviser and its elevation to cabinet rank.[20] Budgetary increases[21] and administrative reconfigurations[22] within the national security architecture, along with the creation of special agencies dealing with

16. Rajat Pandit, 'India to Buy US Missile System to Shield Delhi', *Times of India,* 10 June 2019.
17. *Times of India,* 'From Russia's S-400 to Israel's Barak-8 Missiles: How India is Fortifying its Defence', 25 October 2018.
18. Press Information Bureau, Government of India, Ministry of Defence, 'Press Statement by DGMO', 29 September 2016, <https://pib.gov.in/newsite/PrintRelease.aspx?relid=151242>, accessed 29 November 2019; Indian Ministry of External Affairs, 'Statement by Foreign Secretary on 26 February 2019 on the Strike on JeM Training Camp at Balakot', 26 February 2019, <https://www.mea.gov.in/press-releases.htm?dtl/31091/Statement_by_Foreign_Secretary_on_26_February_2019_on_the_Strike_on_JeM_training_camp_at_Balakot>, accessed 29 November 2019.
19. Shailaja Neelakantan, 'When NSA Ajit Doval Outlined India's New Pak Strategy – Defensive Offense – Perfectly', *Times of India*, 4 October 2016.
20. Elizabeth Roche, 'Ajit Doval to Stay as NSA, Gets Cabinet Rank with 5-Year Term', *livemint*, 4 June 2019.
21. Vijaita Singh, 'Security Council Secretariat Gets Rs.333 Crore, a Tenfold Hike', *The Hindu*, 3 February 2017.
22. Tara Kartha, 'The Rejig of India's National Security Architecture Has Been a Long Time Coming', *The Wire*, 17 October 2018.

special force operations, cyber and outer space,[23] are worth noting. Pointedly, these trends have been catalysed by Modi and the emergence of the new Indian Right, which have facilitated a shift in the public discourse on national security in both qualitative and quantitative terms. Modi's proactive foreign policy has been accompanied by interesting and irreversible changes in the national security architecture – and with an expanded mandate in his second-term win, the way these trends could unfold in the next few years warrants close attention.

Conclusion

What do these disparate strands mean for issues of regional nuclear dynamics and deterrence? The first step is to acknowledge the gap between conventional understanding and emerging reality as existing categories and concepts are rendered increasingly archaic due to political and technological developments. Variables include extra-regional dynamics such as US–China competition as well as technological and conceptual evolutions – hypersonic glide vehicles and tailored deterrence are illustrative. Most literature identifies the challenges to India arising from Pakistan and China individually or in combination, but a comprehensive assessment involving global, regional and domestic trends is conspicuously absent. Cumulatively, these political and technological developments could lead to a potentially cascading effect in South Asia, but are often overlooked. Comprehending nuclear issues in these times demands greater academic engagement with the growing interconnection between security, foreign policy and domestic politics.

The time is ripe to transcend the limitations of the traditional theories of international relations. In the case of South Asia, insights from the Strategic Triangle[24] and the Advocacy Coalition Framework[25] bear promise. The former leverages game theory among triadic relations whereas the latter studies policymaking through the configuration of individuals, organisations and worldviews; elements of both seem to be at play in the policy processes here. The imperative then is to revisit and re-examine the formulations of deterrence, nuclear proliferation and strategic stability in a holistic manner to deepen and widen the understanding not just of the region but also about the theory and praxis of deterrence and proliferation, in tandem with the realities of the 21st century.

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23. Rajat Pandit, 'Agencies Take Shape for Special Operations, Space, Cyber War', *Times of India*, 15 May 2019.
24. Lowell Dittmer, 'The Strategic Triangle: An Elementary Game-Theoretical Analysis', *World Politics* (Vol. 33, No. 4, July 1981), pp. 485–515.
25. Paul A Sabatier, 'An Advocacy Coalition Framework of Policy Change and the Role of Policy-Oriented Learning Therein', *Policy Sciences* (Vol. 21, No. 2/3, 1988), pp. 129–68.

XIII. The UK and the Ban Treaty

Jana Wattenberg

THE HUMANITARIAN INITIATIVE on nuclear weapons and the Treaty on the Prohibition of Nuclear Weapons (TPNW) aim to reframe the debate on nuclear weapons and disarmament to acknowledge the catastrophic humanitarian consequences of nuclear weapons use. Through the stigmatisation of nuclear weapons, and ideally their prohibition, this movement has been trying to advance the global abolition of nuclear weapons.[1]

None of the nuclear-armed states have supported this movement. In fact, states such as the US, Russia, France, China and the UK have driven a vigorous counter-stigmatisation campaign against the initiative and treaty.[2] The UK has been part of a group of nuclear-armed states opposing the ban treaty, but it has spoken from a unique position of an ontologically insecure nuclear power, which means that its possession of nuclear weapons has been publicly contested more than in other cases.[3] Specifically, five factors weaken the UK's nuclear status. First, political parties, such as parts of Labour and the Scottish National Party, have long contested the UK's status as a nuclear power.[4] Second, a strong civil society sector advocates nuclear disarmament in the UK. Organisations such as the Campaign for Nuclear Disarmament (CND), the Women's International League for Peace and Freedom (WILPF) and the International Campaign to Abolish Nuclear Weapons (ICAN) have campaigned for nuclear disarmament

1. Beatrice Fihn, 'The Logic of Banning Nuclear Weapons', *Survival* (Vol. 59, No. 1, 2017), pp. 43–50; Elizabeth Minor, 'Changing the Discourse on Nuclear Weapons: The Humanitarian Initiative', *International Review of the Red Cross* (No. 97, 2015), pp. 711–30; Nick Ritchie, 'A Hegemonic Nuclear Order: Understanding the Ban Treaty and the Power Politics of Nuclear Weapons', *Contemporary Security Policy* (Vol. 40, No. 4, 2019), p. 5; Rebecca Davis Gibbons, 'The Humanitarian Turn in Nuclear Disarmament and the Treaty on the Prohibition of Nuclear Weapons', *Nonproliferation Review* (Vol. 25, No. 1–2, 2018), pp. 34–35.
2. République française, 'Statement by Ms Alice Guitton, Permanent Representative of France to the Conference on Disarmament, Head of the French Delegation', Geneva, 25 April 2018; House of Lords International Relations Committee, 'The Structure and Future of the Nuclear Nonproliferation Treaty', speech by Christopher Ashley Ford, Assistant Secretary, Bureau of International Security and Nonproliferation, 12 December 2018; UK Foreign and Commonwealth Office, 'UK Statement on Treaty Prohibiting Nuclear Weapons', press release, 8 July 2017.
3. Paul D Beaumont, 'Trident and the Unilateralist Taboo: The Curious Case of British Nuclear Weapons Retention', International Law and Policy Institute, Policy Paper No. 6, 2014, p. 3; William Walker, 'Managing, Reconciling, and Manipulating the Deterrence and Disarmament Norms: The Case of the United Kingdom', *Contemporary Security Policy* (Vol. 39, No. 3, 2018), p. 425; Nick Ritchie, 'Relinquishing Nuclear Weapons: Identities, Networks and the British Bomb', *International Affairs* (Vol. 86, No. 2, 2010), p. 465.
4. Len Scott, 'Labour and the Bomb: The First 80 Years', *International Affairs* (Vol. 82, No. 4, 2006), pp. 685–700.

for decades.[5] ICAN campaigners have thereby recognised the UK as the 'most vulnerable' nuclear-armed state.[6] Third, the UK is officially committed to global nuclear disarmament which creates a (vaguely framed) expiration date for the legitimacy of remaining a nuclear power.[7] Fourth, the British strategic rationale for maintaining nuclear weapons has become weaker in a post-Cold War international system, particularly due to the absence of 'the Soviet threat'.[8] Fifth, the UK's possession of nuclear weapons has always been driven by the desire to maintain a strong strategic link with the US. While other nuclear-armed states, such as France, sought such weapons as a way to detach from US influence, British nuclear weapons have always served as a way to maintain a strong strategic link with the US.[9]

Despite its relative ontological insecurity, the UK still has strong support for the maintenance of its nuclear force.[10] Recently, this enduring support became apparent in the country's opposition to the nuclear ban treaty. The UK's response aligns with the collective P5 stigmatisation of the TPNW and draws on four main claims.[11]

First, the claim that the ban treaty is dangerous because it disregards the wider security context and international environment. Second, the argument that the ban treaty is destabilising because it undermines existing structures of the global nuclear order, particularly the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). Third, the assertion that the ban treaty hinders disarmament progress and will not bring the world closer to global nuclear zero. And fourth, the proposition that the ban treaty is unrealistic and/or premature because nuclear disarmament has to happen multilaterally.

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5. Walker, 'Managing, Reconciling, and Manipulating the Deterrence and Disarmament Norms', pp. 425–26.
6. International Campaign to Abolish Nuclear Weapons UK (ICAN UK), 'The Treaty on the Prohibition of Nuclear Weapons. What Was Agreed, & Why the UK Should Join', October 2017.
7. Remarks by Margaret Beckett, UK Secretary of State for Foreign and Commonwealth Affairs, at the Carnegie International Non-Proliferation Conference, Washington, DC, 25 June 2007; Des Browne, 'Laying the Foundations for Multilateral Disarmament'; Secretary of State for Defence, Des Browne, addresses Geneva's Conference on Disarmament, 5 February 2008.
8. Beaumont, 'Trident and the Unilateralist Taboo', p. 8; Nick Ritchie, 'Deterrence Dogma? Challenging the Relevance of British Nuclear Weapons', *International Affairs* (Vol. 85, No. 1, 2009), p. 98; Walker, 'Managing, Reconciling, and Manipulating the Deterrence and Disarmament Norms', p. 423.
9. Nick Ritchie, 'Replacing Trident: Britain, America and Nuclear Weapons', *Contemporary Security Policy* (Vol. 28, No. 2, 2007), pp. 392–94; Nick Ritchie, 'Trident and British Identity. Letting Go of Nuclear Weapons', Bradford Disarmament Research Centre Briefing Paper, September 2008, p. 8.
10. Ontological insecurity is a relative category: the UK is relatively ontologically insecure in its nuclear status in comparison to other nuclear powers, such as the US or France.
11. P5 refers to the five permanent members of the UN Security Council.

The UK has expressed its opposition to the TPNW on various occasions.[12] For instance, in June 2017, the FCO explained that:

> ... we will not sign the treaty which has been published today. As we have previously made very clear, we do not believe that this treaty will bring us closer to a world without nuclear weapons. This treaty fails to address the key issues that must first be overcome to achieve lasting global nuclear disarmament.[13]

During the 2019 NPT Preparatory Committee, the UK's delegation further highlighted that it believes:

> ... further progress towards a world without nuclear weapons can only be made through gradual multilateral disarmament within existing international frameworks, negotiated using a step-by-step approach which takes into account the wider global security context.[14]

The UK has aligned with other NPT nuclear-armed states in their responses to the TPNW and particularly followed the US's lead. Three diplomatic actions and discursive interventions exemplify this. First, the UK initially debated attending the Oslo Conference on the Humanitarian Impact of Nuclear Weapons but decided to join other NPT nuclear-armed states in their boycott.[15] Second, the UK sent a delegation to the Vienna conference shortly after Washington had announced their attendance and has since opposed the TPNW in affiliation with the US.[16] Third, the UK has declared its support for the US-led 'Creating an Environment for Nuclear Disarmament' initiative, which evolved as the US counter-disarmament project in response to the TPNW.[17] The UK's alignment with the US on the nuclear ban treaty movement was captured well by former Secretary of Defence, Des Browne, in 2014. Speaking about the possibility of the UK attending the Vienna conference on the humanitarian impact of nuclear weapons, Browne explained that:

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12. See, for instance, Matthew Rycroft, 'A Step-by-Step Approach to Global Nuclear Disarmament is What We Need to Build Trust and Confidence', statement given at the UN, New York, NY, 27 March 2017.
13. Foreign and Commonwealth Office, 'UK Statement on Treaty Prohibiting Nuclear Weapons', London, 8 July 2017.
14. UK Mission to the United Nations, 'NPT Preparatory Committee 2019: Disarmament Statement of Great Britain and Northern Ireland', New York, NY, 2 May 2019.
15. *Article 36*, 'Documents Suggest UK Boycott of Key Nuclear Weapons Meeting was Driven by P5 Partners', 4 June 2013.
16. Hans M Kristensen, 'FAS at Vienna Conference on Humanitarian Impact of Nuclear Weapons', *Federation of American Scientists Blog*, 4 December 2014.
17. UK Mission to the United Nations, 'NPT Preparatory Committee 2019'.

> I'll tell you, from the point of view of the United Kingdom, if the US agrees to go, we will go. I mean, it's no coincidence that we have not made up our mind for each of the last two conferences until immediately after the United States made its decision.[18]

The UK's strategy of following other nuclear-armed states, particularly the US, has implications for its status as an ontologically insecure nuclear power. There is little the UK government could do to lessen the critique against its nuclear status voiced by civil society and politicians with various party affiliations. Yet, the development of arguments for the necessity of maintaining a nuclear arsenal could strengthen the UK's nuclear status. In response to the humanitarian initiative and TPNW, the UK has failed to deliver such arguments. Instead, Whitehall has rehearsed arguments that have featured in its disarmament rhetoric for decades. Even more, rather than developing its own response to the ban treaty, the UK has followed the US lead.

This strategy perpetuates the UK's status as an ontologically insecure nuclear power. It further makes the UK a follower of the US and creates a dual dependency for London on its strategic relationship with Washington. First, the special relationship with the US forms the basis of the UK's justification for possessing nuclear weapons. Second, the country has, so far, failed to step out of the shadow of the US in defending its opposition towards the nuclear ban treaty. This diplomatic and discursive behaviour deepens critics' suspicion that prestige aspirations – particularly in the UK's relationship with the US – serve as the main motive to remaining a nuclear-armed state. Prestige and influence, however, fall short of forming a publicly persuasive basis for the UK's nuclear status. Moreover, they are precisely the type of justifications that the ban treaty movement wishes to undermine.

18. Des Browne, 'Keynote Address at the Arms Control Association's Annual Meeting', Washington, DC, 23 October 2014.

About the Authors

Stephen Beckett studied Physics at Bristol University, which led to a fascination with nuclear power and the engineering aspects of building nuclear reactors. As a result, although his work is now largely defence-focused, he still keeps a keen eye on the development of nuclear power in the UK and feels it is essential to help combat climate change in the near future.

Jack Bowler is a structural engineer working for Lockheed Martin since 2017. He has a BEng in Aerospace Engineering and is currently working towards an MSc in Advanced Mechanical Engineering from Cranfield University.

Syed Adnan Athar Bukhari is a Visiting PhD Candidate in South Asian Studies at St Anthony College, University of Oxford.

Geoffrey Chapman is a PhD student at King's College London and a Research Assistant at the Centre for Science and Security Studies.

Thomas P Davis is the Director and Nuclear Engineering Consultant at Davis & Musgrove Ltd and a final-year PhD Researcher and Clarendon Scholar at the University of Oxford. He is also a Midshipman/Officer Cadet in the Oxford University Royal Naval Unit, Royal Naval Reserves.

Jennifer Edwards has a Master's in Physics with Astronomy from the University of Southampton. She is currently on the Lockheed Martin graduate scheme, working as a systems engineering graduate since 2018.

Madison A Estes is an Analyst with the Center for Naval Analyses' Strategy and Policy Analysis programme. She is a member of the 2019 CSIS Project On Nuclear Issues Nuclear Scholar's Initiative.

Sam Guthrie is a practitioner in the strategic policy field and has recently completed a scholarship on nuclear policy with the Center for Strategic and International Studies.

James Johnson is a Postdoctoral Research Fellow at the James Martin Center for Nonproliferation Studies at the Middlebury Institute of International Studies, Monterey.

Jamie Kwong is a Marshall Scholar pursuing her PhD in War Studies at King's College London, where her research focuses on public knowledge levels of nuclear weapons issues.

Lewis Lancaster is a fourth-year student at the University of Birmingham studying mechanical engineering. He recently completed a 12-month placement at Lockheed Martin working in the civil space team.

Oscar Liddiard is a mechanical design engineering apprentice working for Lockheed Martin since 2016. He has a Higher National Diploma in Mechanical Engineering and is currently working towards a BSc in Mechanical Engineering.

Sophie McCormack is a Nuclear Policy Analyst at BASIC.

Thomas Roberts is currently working within the Whole Boat Support Integrator Performance Engineering team as a Senior Systems Engineer, within the Babcock Engineering Services.

Shounak Set is a Marie Curie Global India Fellow at King's College London, specialising in Strategic Studies and Foreign Policy Analysis.

Jana Wattenberg is a PhD candidate in the Department of International Politics at Aberystwyth University and the Deputy Director of the David Davies Memorial Institute of International Studies.