RUSI
www.rusi.org

**Royal United Services Institute**
for Defence and Security Studies

UK PONI
UK Project on Nuclear Issues

# The 2020 UK PONI Papers

Edited by Luba Zatsepina-McCreadie and Tom Plant

# The 2020 UK PONI Papers

Edited by Luba Zatsepina-McCreadie and Tom Plant

October 2020

Royal United Services Institute
for Defence and Security Studies

**189 years of independent thinking on defence and security**

The Royal United Services Institute (RUSI) is the world's oldest and the UK's leading defence and security think tank. Its mission is to inform, influence and enhance public debate on a safer and more stable world. RUSI is a research-led institute, producing independent, practical and innovative analysis to address today's complex challenges.

Since its foundation in 1831, RUSI has relied on its members to support its activities. Together with revenue from research, publications and conferences, RUSI has sustained its political independence for 189 years.



Published in 2020 by the Royal United Services Institute for Defence and Security Studies.

The figures on pp. 78–80 were updated on 11 November 2020.



**Royal United Services Institute**
for Defence and Security Studies
Whitehall
London SW1A 2ET
United Kingdom
+44 (0)20 7747 2600
www.rusi.org
RUSI is a registered charity (No. 210639)

# Contents

# Editors' Note

Luba Zatsepina-McCreadie and Tom Plant

THIS YEAR MARKS the 10th anniversary of the UK Project on Nuclear Issues (UK PONI). Over the last 10 years, the UK PONI Annual Conference has gathered the next generation of nuclear experts to discuss contemporary nuclear issues. It has become a unique national forum for emerging scholars and professionals, bringing various nuclear communities together.

At the 2020 UK PONI 10th Anniversary Annual Conference, held entirely online in June, established and emerging experts from the nuclear industry, academia, government and the military gave presentations on a range of salient civil and military nuclear issues. These presentations were then adapted by the emerging experts for this publication. These papers were accepted and the information therein was current at the time of writing in July 2020. All views expressed are the authors' own, and do not necessarily reflect those of the authors' institutions, UK PONI or RUSI.

# I. Euro-Atlantic Security and the UK's Nuclear Strategy in 2040: The Case for a Robust UK Missile Defence System

Ramesh Balakrishnan

THE DOCTRINE OF 'Credible Minimum Deterrence (CMD)' remains the cornerstone of the UK's long-standing nuclear strategy. The 2015 National Security Strategy and Strategic Defence and Security Review (SDSR) reiterates the UK's nuclear posture in the following terms: 'We judge that a minimum, credible, independent nuclear deterrent, based on Continuous At Sea Deterrence and assigned to the defence of NATO, remains vital to our national security'.[1] The review leaves open the possibility of reassessing the strategy based on shifts in the global security environment and capabilities of adversaries.[2] As a member of the UN Security Council (UNSC) P5 with a significant stake in nuclear nonproliferation and global nuclear security, and its long-term investment to the Dreadnought strategic nuclear submarine programme, the UK's security policy will be highly influenced by nuclear weapons to 2040 and beyond. The UK's independent nuclear deterrent anchors its role as a leading security actor in Europe through its NATO membership and thus its contribution to Europe's collective security.

This paper argues that the UK's nuclear deterrent would be strengthened by deploying a robust ballistic missile defence (BMD) capability, without undermining the core principles of the current nuclear doctrine. Such a strategy would not only strengthen the UK's nuclear security but address the challenge of burden-sharing within the NATO alliance, which is a strategic imperative to fortify and build a resilient NATO in the future. It would also enable the UK to confront the security challenges and the technological fait accompli facing the UK in 2040.

## Strategic Threat Environment (circa 2040)

The global strategic threat environment has never been more precarious than it is today. The demise of the Intermediate-Range Nuclear Forces Treaty (INF), the uncertainty surrounding the renewal of the New Strategic Arms Reduction Treaty of (New START) 2010, which expires in 2021, and the refusal of China to join trilateral arms control talks with the US and Russia, have dampened the prospects for any progress on arms control negotiations in the foreseeable future. Moreover, the collapse of the Joint Comprehensive Plan of Action (JCPOA) with Iran,

---

1. HM Government, *National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom*, Cm 9161 (London: The Stationery Office, 2015), p. 34.
2. *Ibid*.

Russian rearmament through investments in advanced missile delivery capabilities, China's missile and nuclear modernisation and North Korea's nuclear belligerence are disturbing regional trends that point to a global security environment fraught with the risk of great power conflict and regional flare-ups. The UK faces a more fluid threat environment comprising traditional conventional threats from the proliferation of ballistic missiles, advanced cruise missiles and hypersonic missiles.[3] The 2015 SDSR captures the UK's current assessment of missile threats. It notes that 'states outside the Euro-Atlantic area and non-state actors are now acquiring ballistic missile technology. The threat faced by the UK, our Overseas Territories, and our military bases has evolved'.[4]

Great power relations have deteriorated considerably over the past decade, with US–China and US–Russia relations currently in a freefall. The US has identified both Russia and China as its two principal adversaries in its most recent national security strategy.[5] Russia is developing hypersonic weapons and advanced cruise missiles, thus endangering strategic stability in Europe.[6] Although Russia claims that its Avangard hypersonic missile system has been operationalised, Western analysts are deeply sceptical of such pronouncements.[7] Countries such as Iran have developed precision-guided long-range missile systems as part of their coercive strategic repertoire.[8] NATO is already taking note of the potential introduction of hypersonic and advanced nuclear powered and nuclear-armed cruise missiles that are currently under development by the Russian military.[9] Emerging technologies such as artificial intelligence (AI) and cyber are expected to infiltrate the decision-making process in nuclear command and control systems, endangering deterrence stability.

Moreover, NATO's investment in BMD capabilities and Russian countermeasures will have a direct impact on long-term strategic stability in Europe. The advent of more capable and faster

3. Joe Murphy, 'Britain is Exposed to the Threat of Missile Attacks', *Evening Standard*, 14 February 2020.
4. HM Government, *National Security Strategy and Strategic Defence and Security Review 2015*, p. 25.
5. The White House, 'National Security Strategy of the United States of America', December 2017, p. 2, <https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf>, accessed 15 July 2020.
6. John Vandiver, 'Russia to Base Hypersonic Tracking Radar in Middle of NATO Turf', *Stars and Stripes*, 20 March 2020, <https://www.stripes.com/news/europe/russia-to-base-hypersonic-tracking-radar-in-middle-of-nato-turf-1.623126>, accessed 20 August 2020.
7. *BBC News*, 'Russia Deploys Avangard Hypersonic Missile System', 27 December 2019.
8. Jennifer Jacobs and Glen Carey, 'Iran's Precision Guided Missiles Struck Unpopulated Sandy Area at US Base: Source', *National Post,* 8 January 2020, <https://nationalpost.com/news/world/iran-missed-american-troops-on-purpose-with-missile-attack-u-s-sources-think>, accessed 20 August 2020.
9. NATO, 'Speech by NATO Secretary General Stoltenberg at the High-Level NATO Conference on Arms Control and Disarmament', 23 October 2019, <https://www.nato.int/cps/fr/natohq/opinions_169930.htm>, accessed 20 August 2020.

nuclear delivery systems, cyber and other emerging technologies, such as AI, will dramatically reorient the military kill chain, including C4ISR systems.[10] In the wake of these dramatic shifts in the UK's strategic environment, which are likely to manifest in their entirety by 2040, security managers will have to rethink the UK's BMD strategy. The UK's approach to strategic defence must take account of this emerging reality. The nuclear threat landscape in 2040 will look very different from today, posing new challenges to the UK's nuclear deterrent.

## UK Missile Defence Drivers

There are several external and internal drivers for building a robust UK missile defence. First, as outlined in the previous section, the international security environment is deteriorating, and the full spectrum of regional and extra-regional missile threats are widening. Second, population defence and the defence of UK Overseas Territories, which are currently missing in the UK's BMD planning scenarios, will become more salient in the coming decades. Third, enhanced cooperation with the US on future BMD planning would fortify the UK–US 'special relationship'. Another rationale for why the UK may need a more robust BMD system is because of undeterrable actors. Such actors would be willing to engage in a nuclear punishment strategy against cities despite the risk of retaliation in kind and the use of risk manipulation tactics, which could involve limited use of force against critical targets to cause pain to an adversary.[11] Finally, the UK's alliance commitments to NATO would necessitate deeper alignment and synchrony with NATO's integrated air and missile defence platform. NATO countries have integrated their air and missile defence under a centralised Air and Missile Defence Command and Control centre located in Ramstein, Germany.[12] NATO's missile defence protection universe now includes defending the population of the European mainland from regional missile threats in addition to theatre defence of NATO troops engaged in land combat.[13]

An enlarged UK missile defence programme would provide a boost to British defence industrial capability and complement the country's long-term strategic submarine programme, which has a life span of three or more decades. The UK's air defence and limited missile defence capabilities, which are profoundly fragmented, demand a long-term evolutionary architecture that would provide the foundation for an integrated air and missile defence platform along the lines of NATO's evolving approach to air and missile defence.[14]

10. Christian Brose, *The Kill Chain: Defending America in the Future of High-Tech Warfare* (New York, NY: Hachette Books, 2020).
11. Sidharth Kaushal, 'A Critical Enabler for Power Projection: Options for a UK Missile Defence Capability in an Age of Escalation Control', *RUSI Occasional Papers* (May 2019).
12. NATO, 'NATO Ballistic Missile Defence', fact sheet, July 2016, <https://www.nato.int/nato_static_fl2014/assets/pdf/pdf_2016_07/20160630_1607-factsheet-bmd-en.pdf>, accessed 20 August 2020.
13. Roberto Zadra, 'NATO, Russia and Missile Defence', *Survival* (Vol. 56, No. 4), 2014), pp. 51–61.
14. *Army Technology*, 'Sky Sabre: Inside the UK's Missile Defence System', 25 April 2018.

## UK Missile Defence Strategy

The political signals for a BMD requirement for the UK have been emerging for some time.[15] However, the UK's current position on BMD is best summed up in the 2006 white paper presented to parliament on the future of the UK's nuclear deterrent. It supports a circumscribed role for BMD in defending against a limited number of missile attacks. It states that missile defence does not provide complete protection, but 'should be regarded as complementary to other forms of defence or response, potentially reinforcing nuclear deterrence rather than superseding it'.[16] The 2015 SDSR goes a step further by stating that the UK would 'continue to commit significant funds to the NATO Ballistic Missile Defence (BMD) network' and support R&D through the UK Missile Defence Centre (MDC). It also recommends investing in a ground-based BMD radar in support of the NATO BMD network and to 'investigate further the potential of the Type 45 Destroyers to operate in a BMD role'.[17] The UK's primary operational role in missile defence stems from the Cold War-era intelligence-sharing agreement with the US, whereby the UK agreed to host radars at RAF Fylingdales.[18] The radar base has three main functions. First, the radar serves as a ballistic missile early-warning system. Through an intelligence-sharing arrangement, data gathered from the radar is shared by the US and the UK. Second, it performs the role of enabling space situational awareness through the detection and tracking of orbiting objects in space and is a part of the US space surveillance network. Third, it also provides a satellite warning service for the UK in tracking spy satellites.[19] This arrangement came into existence in the aftermath of the V2 missile attacks on the UK during the Second World War.[20] UK–US missile defence cooperation was further upgraded in 2003 through the Framework Memorandum of Understanding on Ballistic Missile Defense.[21] The partnership is a purely bilateral arrangement between the US and the UK, involving no integration with NATO BMD assets.

The UK deploys theatre-wide anti-ship missile defence capabilities in its Type 45 destroyers, which are used to shield the British fleet from aerial attacks. However, the interceptor missiles

---

15. Peter Roberts, 'UK Ballistic Missile Defence: Drivers and Options', RUSI Occasional Paper, August 2015.
16. HM Government, 'The Future of the United Kingdom's Nuclear Deterrent', Cm 6994, December 2006, p. 21, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/27378/DefenceWhitePaper2006_Cm6994.pdf>, accessed 14 July 2020.
17. HM Government, *National Security Strategy and Strategic Defence and Security Review 2015*, p. 25.
18. Neil Hatfield, 'Powering Up: How We Support the Radar at RAF Fylingdales', 17 February 2020, blog for Inside DIO (Defence Infrastructure Organisation), <https://insidedio.blog.gov.uk/2020/02/17/powering-up-how-we-support-the-radar-at-raf-fylingdales/>, accessed 9 July 2020.
19. Hatfield, 'Powering Up'.
20. Richard Hollingham, 'V2: The Nazi Rocket That Launched the Space Age', *BBC News*, 7 September 2014.
21. Missile Defense Advocacy Alliance (MDAA), 'United Kingdom's Ballistic Missile Defense Capabilities', 27 June 2018, <https://missiledefenseadvocacy.org/intl_cooperation/united-kingdom/>, accessed 15 July 2020.

on board (the Aster 15 and the Aster 30) have short ranges of only up to 20 and 75 miles, respectively.[22] Moreover, the UK funds the NATO BMD network without participating in it in an operational role. Still, it engages in R&D initiatives with the US Missile Defense Agency through the UK's Missile Defence Centre. The missile defence arrangement with the US is institutionalised under the umbrella of the UK being a framework partner and includes joint project activities for cooperative R&D projects.[23] If the UK were to implement the recommendations made in the 2015 SDSR by investing in a new ground-based BMD radar and investigating the potential of Type 45 Destroyers to operate in an enhanced BMD role, if retrofitted with US Aegis radars, it would be a significant departure from its current BMD posture.

## Strategic Options for UK Missile Defence

There are three main strategic options for the UK to consider in its forward-thinking missile defence strategy. First, assemble an independent UK-based consortium of defence contractors to develop an indigenous capability and build the technology architecture from the ground up using domestic technology resources and support from other European partners and taking into account the UK's unique and specific threat environment in 2040. This would be prohibitively expensive and time-consuming but would give a significant boost to the domestic defence industrial base. Second, expand the current partnership agreement with the US Missile Defense Agency and work more closely on its next-generation BMD architecture. Third, work with the UK's European partners as part of the US European Phased Adaptive Approach (EPAA).[24]

Before choosing an appropriate strategy, the UK would have to determine which targets need to be protected on a priority basis. Potential missile defence targets include the UK mainland, population defence, military assets, UK Overseas Territories, joint expeditionary troops, and protection of allies. If the UK needs to guard against wide-ranging missile threats in the future, it would have to consider building an independent missile defence system within the confines of NATO's EPAA framework or as part of the US global missile defence architecture. Population defence is the most challenging target to defend against in a crisis involving missile forces. In the European context, NATO's missile defence thinking has evolved over the past decade or so, and NATO has expanded its missile defence target set to move from theatre defence exclusively to include population defence.[25]

---

22. *Ibid*.
23. *Ibid*.
24. Jaganath Sankaran, 'The United States' European Phased Adaptive Approach Missile Defense System: Defending Against Iranian Missile Threats Without Diluting the Russian Deterrent', RAND Corporation, 2015.
25. Roberto Zadra, 'NATO, Russia and Missile Defence: Towards the Lisbon Summit', *RUSI Journal* (Vol. 155, No. 5, 2010), pp. 12–16.

## Conclusion

In conclusion, missile defence will become a strategic imperative in the coming decades as the UK's threat spectrum widens and continues to expand in scale and scope. A robust BMD will provide the UK with the ability to deter limited conventional coercive regional missile threats, which may not warrant full-scale nuclear retaliation. It would further strengthen the domestic defence industrial base, and the special relationship with the US. Finally, a fully integrated air and missile defence system would enhance the trans-Atlantic partnership and cement the UK's commitment to NATO.

The speed at which futuristic missiles can deliver WMD payloads will present a renewed challenge for designers of missile defence systems. Whether it is an improvement in precision guidance and accuracy, payload capacity, manoeuvrability or command and control of next-generation missiles, missile defence systems have their work cut out in dealing with these over the horizon threats. A radical reinvention of the concept of missile defence in terms of how to design, develop, test and operationalise next-generation missile defence systems would address today's inadequacies in existing BMD capabilities. Newly emerging threats present the UK with a unique opportunity to rethink future missile defence capabilities in fundamentally new ways.

# II. Russian Hypersonic Boost Glide Vehicles: 'Boosting' Putin's National Security Strategy

Julia Balm

RUSSIA IS THE first country to pioneer and deploy a hypersonic boost glide vehicle (HBGV), the Avangard. This presents a good window into understanding nuclear modernisation motives. Russia's defence posture, deterrence by punishment strategy and its strategic culture, linked to a historical cosmist culture, all factor into the construction of the Avangard. Nuclear modernisation motives are rarely transparent, therefore decoding the various elements that prompt budgetary allocations can inform a best-guess of which countries are most likely to acquire a capability similar to the Avangard. Given that HBGVs have now been officially incorporated into a national security strategy, this paper conducts an analysis of Russia as a case study to demonstrate the value of modernised nuclear delivery vehicles in national security strategies.

## The Avangard

The largest inventory of ballistic and cruise missiles in the world is housed in Russia and the efficiency of these weapons is central to President Vladimir Putin's defensive and deterrent security strategy.[1] With 18 operational missiles in the Russian stockpile and three missiles in development, Putin's weapons complex has a significant focus on missile technology.[2] These missile modernisations give Russia a unique strategic position in arms control negotiations, allow for a survivable land-based intercontinental ballistic missile system (ICBM) to supplement submarine-based capabilities which are increasingly vulnerable to anti-submarine warfare (ASW) technology, and substantiate the power of a prompt nuclear response. The demand for high-precision, high-velocity delivery systems has motivated Russia to develop the Avangard HBGV, previously known as Project 4202 or YU-71.[3]

With a range of over 6,000 km, the Avangard is claimed to have the ability to manoeuvre and maintain atmospheric speed of up to Mach 20 (≈6.86 kilometres per second, 20 times the

1. Missile Threat, Center for Strategic and International Studies (CSIS) Missile Defense Project, 'Missiles of Russia', 14 June 2018, <https://missilethreat.csis.org/country/russia/>, accessed 27 July 2020.
2. *Ibid*.
3. *Ibid*.

speed of sound).[4] Anything capable of moving beyond Mach 5 while conducting atmospheric manoeuvring is said to be able to evade all current defence systems. Glide vehicles launch atop a ballistic missile or rocket booster, then, as it depresses trajectory, glides to the target along the top of the atmosphere.[5] Swift manoeuvrability allows for an unpredictable trajectory, making it particularly difficult to intercept the weapon after its boost phase.[6] In this regard, hypersonics differ from other ballistic re-entry vehicles (RV) that have steeper trajectories, a more predictable ballistic route, and a high launch and re-entry friction that impacts speed.[7] New space sensor architecture and radars would therefore be necessary developments to properly sense, track and characterise the threat of an incoming hypersonic. A central feature of the Avangard is the ability to penetrate US air and missile defences with its speed and manoeuvrable trajectory compressing the timeline for response. Putin stated in his 2019 presidential address that 'the development of the Avangard strategic hypersonic glide vehicle is tantamount to … enhancing the country's defence capability and security … and the development of unique technological assets'.[8] Evidently, the value of Avangard's defence evasion is crucial to its construction.

According to the Russian Ministry of Defence, US officials were able to view Avangard on 24–26 November 2019 in order to comply with the potential renewal of New START and, on 27 December 2019, it entered into service in the Strategic Missile Force at the 13th Red Banner Rocket Division in Yasny, Orenburg Oblast.[9] The US and China are also pursuing hypersonic weapons, such as China's DF-ZF, but they are still unable to match a similar capability to this type of Avangard missile in their speeds and conventionally designed payloads.[10] John Hyten, US Strategic Command General, testified to the Senate Armed Services Committee about the threat of hypersonic glide weapons: 'We don't have any defense that could deny the employment of such a weapon against us.'[11] A second strike capability is therefore insufficient, furthering American investment and increased interest in hypersonic defences as opposed to HBGVs.

---

4. Missile Threat, CSIS Missile Defense Project, 'Avangard', 3 January 2019, <https://missilethreat.csis.org/missile/avangard/>, accessed 24 June 2020.
5. Matthew Bunn, 'Technology of Ballistic Missile Reentry Vehicles', Review of US Military Research & Development, 1984, p. 67.
6. *Ibid.*
7. *Ibid.*
8. Vladimir Putin, 'Presidential Address to Federal Assembly', 20 February 2019, <http://en.kremlin.ru/events/president/news/59863>, accessed 22 September 2020.
9. Missile Threat, CSIS Missile Defense Project, , 'Avangard'.
10. Kelley M Sayler, 'Hypersonic Weapons: Background and Issues for Congress', Congressional Research Service, 27 August 2020, <https://fas.org/sgp/crs/weapons/R45811.pdf>, accessed 28 September 2020.
11. Federico Pieraccini, 'How Russia and China Gained a Strategic Advantage in Hypersonic Technology,' Strategic Culture Foundation, 21 May 2018,<https://www.strategic-culture.org/news/2018/05/21/how-russia-china-gained-strategic-advantage-in-hypersonic-technology/>, accessed 22 September 2020.

The advance of Russian HBGV strategic nuclear weapons delivery means that, with the ability to attain extreme speeds in extremely hot conditions while maintaining high manoeuvrability, such delivery efficiency will enhance Russia's strike capability beyond the demonstrable necessity to counter current missile defences.

## Russian National Security

How the Avangard fits into Putin's vision rests on the interpretation of security documents and Russia's national security strategy. Russian national security at present is founded on the reliance on modernised defensive weapons capabilities to maintain the Kremlin's approach to deterrence.[12]

As Putin outlined in his 2019 address, Russia is improving its quality of defence capabilities as a response to tense US relations and to avoid the 'launching of an aggression' against Russia.[13] A magnified threat perception that the West threatens Russia and that Russia must assume a defensive posture, plays a big role in the language of Russia's national security policy.[14] Russia's defence is the first priority for its long-term national security, calling for 'improvement in the forms and methods of deploying armed forces and the procurement of modern weaponry across the military and other forces'.[15] By emphasising the necessity for defence against the West, Russia will continue to modernise nuclear stockpiles using the popular image of a 'besieged fortress' to carry out its national security strategy.[16]

## Defence Posture

Despite any magnified threat perceptions, there is legitimate concern about the power and capabilities of US missile defences to threaten Russia's national security. The development of modernised Russian missiles was a reaction to President George W Bush's withdrawal in

---

12. Putin, 'Presidential Address to Federal Assembly', 20 February 2019.
13. *Ibid*.
14. Anya Loukianova Fink, 'The Evolving Russian Concept of Strategic Deterrence: Risks and Responses,' *Arms Control Today*, July/August 2017, <https://www.armscontrol.org/act/2017-07/features/evolving-russian-concept-strategic-deterrence-risks-responses>, accessed 27 June 2020.
15. *Ibid*.
16. The 'besieged fortress' expression was first popularised by Vladimir Lenin to reflect Russia's atavistic fears towards Western capital and is currently used by the Kremlin to convey attitudes on globalisation, perceptions of contemporary international politics and an interests-based approach to a global multipolar order. See Bobo Lo, *Russia and the New World Disorder* (Washington, DC: Brookings Institution Press, 2015), pp. 38–39. For more information on the expression, see Vladimir Lenin, 'Letters to the Workers of Europe and America', *Pravda*, No. 16, 24 January 1919, <https://www.marxists.org/archive/lenin/works/1919/jan/21.htm>, accessed 27 June 2020; Mathieu Boulegue, 'Russia's Military Posture in the Arctic: Managing Hard Power in a "Low Tension" Environment', NATO Defense College, 2019, pp. 25–30.

2002 from the landmark 1972 Anti-Ballistic Missile (ABM) Treaty.[17] This Treaty limited the construction of strategic defences for both Russia and the US to reduce the infinite offensive/defensive arms race in missile defence. American motivations for the withdrawal from the Treaty came in the wake of the 9/11 terrorist attacks, with Bush stating that 'we no longer live in the Cold War world for which the ABM Treaty was designed'.[18] The withdrawal from the Treaty, though formally recognised as reacting directly to the heightened necessity to defend against rogue states and terrorists, undermined Russian–US trust in arms control agreements. According to Article 12 of Russia's National Security Strategy, 'the strengthening of Russia is taking place against a backdrop of new threats to national security that are multifarious and interconnected in nature'.[19]

However legitimate the threat of US withdrawal from the ABM Treaty proves to Russia, framing Russian national security around the necessity for defence in the face of offensive external forces allows for a degree of ambiguous intentions and flexible interpretations.

Using the image of a 'besieged fortress' benefits Russia's foreign policy as it represents Russia's action against security threats as being derived from defensive urgency.[20] A stronger missile capability would not only factor into this reactionary security strategy, it would also assert new levels of national pride in Russia's ability to protect and support its national interests when important arms control treaties fall through. Overcoming US missile defences with HBGVs demonstrates an offensive reach outward and one which, if aiming for a target, it can and will effectively reach. As Putin declared at his national address on 1 March 2018: 'You have failed to contain Russia!'.[21]

## Deterrence by Punishment

Aside from its function as a deterrent, Avangard also works as an offensive capability, potentially even operating as a first-strike system. Avangard repels against newly deployed strategic missile defence systems as it is designed to immediately respond to threats by operating as a first and second strike capability, ideally reaching a target before any adversary attack reaches Russia. The motive for this qualitative modernisation, according to Putin, is to 'neutralise any military threats to Russia's security'.[22]

17. Wade Boese, 'U.S. Withdraws from ABM Treaty; Global Response Muted', *Arms Control Today*, July/August 2002, <https://www.armscontrol.org/act/2002-07/news/us-withdraws-abm-treaty-global-response-muted>, accessed 27 June 2020.
18. George W Bush, 'Statement on Formal Withdrawal from the 1972 Anti-Ballistic Missile Treaty', The American Presidency Project, 13 June 2002.
19. Katri Pyonnöniemi, 'Russia's National Security Strategy: Analysis of Conceptual Evolution', *Journal of Slavic Military Studies* (Vol. 31, No. 2, 2018), p. 248.
20. *Ibid.*, p. 249.
21. Vladimir Putin, 'Presidential Address to Federal Assembly', 1 March 2018. Author's translation.
22. Vladimir Putin, 'Meeting on Developing New Types of Weapons', 18 November 2016, <http://en.kremlin.ru/events/president/news/53268>, accessed 27 June 2020.

Given that a hypersonic weapon can quickly retaliate, potentially even before an attacker's strike could touch Russian soil, the Avangard could be a 'launch under attack' or 'launch on warning' weapon to be used when a US launch is confirmed but impact has not yet occurred.

By targeting the minds of adversary decision-makers with the impressive capabilities of HBGVs, Russia aims to reconcile any perceived necessity for numerical parity.[23] The technological capacity to perform precision strikes means the ability to strike with dual-capable conventional and nuclear means through effective, less predictable, delivery. By removing the predictability from a high-yield missile, a more precise strike and decisive retaliation is secured.[24]

## The 'Culture' in Strategic Culture

Aside from the technological value of HBGV evading missile defences, the desire to assert power over the boundaries of the visible skies, known as cosmological dominance, is key to understanding the sociocultural motivations of modernised hypersonic vehicles.[25] Russia's historical development of an 'infinite arm' extends beyond its landed borders and materialises in the demonstration of sea power and space power. The embellishment of Russia's missile progamme visuallly bolsters patriotic messages at home while securing a demonstrable strategic position more globally.

Dating back to the origins of the cosmist movement in the early 19th century, the genesis of cosmist ideology had faith in the ability of future sciences to overcome the physical limitations of man's existence in nature.[26] The mastery of technology was thought to liberate man into a higher degree of humanity through spatial conquest.[27] This plays a valuable role in the visual culture of Russia's strategic culture, especially in military modernisations. Russia's religious faith in science folds itself into the mystic occult where technology can overcome the boundaries of the divine skies.[28] By informing Putin's approach to developing 'unique technological assets', visual culture cannot be ignored when attempting to understand the full value of missile modernisation programmes and the strategic motivations of hypersonic development.[29]

Because hypersonic weapons are launched into the upper atmosphere atop ballistic missiles, the imagery of this agile weapon steering through the heavens is incredibly relevant. The

23. Loukianova Fink, 'Evolving Russian Concept of Strategic Deterrence'.
24. For more information on precision strike weapons, see Barry D Watts, 'The Evolution of Precision Strike', Center for Strategic and Budgetary Assessments, 6 August 2013.
25. Marlene Laruelle, 'Totalitarian Utopia, the Occult, and Technological Modernity in Russia: The Intellectual Experience of Cosmism', in Michael Hagemeister, Birgit Menzel and Bernice Glatzer Rosenthal (eds), *The New Age of Russia: Occult and Esoteric Dimensions* (Munich: Kubon & Sagner, 2012), p. 238.
26. Laruelle, 'Totalitarian Utopia, the Occult, and Technological Modernity in Russia'.
27. *Ibid*.
28. *Ibid*.
29. Putin, 'Presidential Address to Federal Assembly', 20 February 2019.

militarisation of the atmosphere through HBGVs therefore provides a sturdy vehicle for the display of national strength and security. Space power is topically relevant as demonstrated by the 4 December 2019 NATO declaration of space as the fifth 'operational domain' alongside sea, land, cyber and air.[30] Putin's alarmed response demanded that he committed to 'strengthening the orbital group and the space rocket and missile industry in general'.[31] The pursuit of military and technological dominance, particularly in space and missile defence, is one that affirms an important and visible high ground.

## Conclusion

Russia's HBGVs factor into the grand vision of Putin's national security strategy because of the deterrent, cultural and precision value of modernised delivery vehicles. The development of the Avangard advances Russian national security in an insecure world of withdrawn treaties and conventions, allowing Putin to visibly demonstrate an impressive extension of power beyond the country's borders. Through the unique strategic challenges and opportunities they pose, HBGVs have garnered international interest but how they warrant a place in national military budgets rests largely on the value of these 'unique technological assets' and what they could contribute to both a national security strategy and a particular strategic culture.[32]

30. Holly Ellyatt, 'Putin Fears the US and NATO are Militarizing Space and Russia is Right to Worry, Experts Say', *CNBC*, 5 December 2019, <https://www.cnbc.com/2019/12/05/nato-in-space-putin-is-worried-about-the-militarization-of-space.html>, accessed 30 June 2020.
31. *Ibid*.
32. Putin, 'Presidential Address to Federal Assembly,' 20 February 2019.

# III. Back to the Future: Past Lessons on Sustaining the UK's Weapons Establishment

Geoffrey Chapman

IF THE UK is to remain a nuclear weapons state, retaining a skilled nuclear workforce is essential and requires continual commitment. This is acknowledged in the UK government's 2015 'Sustaining Our Nuclear Skills' report, which recognises that: 'There are substantial challenges to overcome. The nuclear workforce is ageing, and attrition rates are high and growing as a result'.[1] When it comes to the UK's Atomic Weapons Establishment (AWE or AWRE before 1987) such concerns have been perennial issues. Fears over the longevity of the nuclear programme through skill loss have often been at the centre of nuclear weapons policy debates.[2] The ongoing ability of AWE to effectively manage its human capital has contemporary relevance given that the establishment is seeking to expand its workforce from 5,500 to 6,000 as it undertakes a programme of Trident warhead modernisation.[3] This paper argues that AWE can improve its current recruitment and retention efforts by learning from its historical experience, as well as where it can improve on them, in attempting to provide a safe, diverse and appealing place of employment.

## 'Intrinsic Character'

Recruiting sufficient staff quickly enough into the nuclear weapons programme was among the most important issues that the UK's initial atomic weapons effort had to overcome.[4] William Penney, often hailed as the father of the British bomb, faced intense competition for skilled engineers, scientists and craftsmen in a post-Second World War economy where employment opportunities for such staff were plentiful.[5] Penney warned as early as 1952 that

1. HM Government, 'Sustaining Our Nuclear Skills', 2015, p. 4.
2. Matthew Jones, *The Official History of the UK Strategic Nuclear Deterrent Volume II: The Labour Government and the Polaris Programme, 1964–1970* (Abingdon: Routledge, 2017), p. xii; Lorna Arnold, *Britain and the H-Bomb* (Basingstoke: Palgrave Macmillan, 2001), pp. 75–77; Graham Spinardi, 'Aldermaston and British Nuclear Weapons Development: Testing the "Zuckerman Thesis"', *Social Studies of Science* (Vol. 27, No. 4, 1997), p. 569.
3. Atomic Weapons Establishment (AWE), 'Future Careers Programme', November 2019, <https://www.awe.co.uk/app/uploads/2019/11/Future-Careers-brochure.pdf>, accessed 1 July 2020; Jamie Doward, 'Pentagon Reveals Deal With Britain to Replace Trident', *The Guardian*, 22 February 2020.
4. Margaret Gowing, *Independence and Deterrence: Britain and Atomic Energy 1945–52 Volume 2: Policy Execution* (Basingstoke: Palgrave Macmillan, 1974), p. 61.
5. *Ibid*., p. 72.

the 'establishment could easily become sterile in five to ten years unless we both keep the best of our top men and get an adequate supply of youngsters'.[6] Disquiet from the atomic programme's senior leadership led to an investigation into how the effort had been potentially mishandled.[7] In trying to identify blocks on recruitment, in 1953 Lord Cherwell identified 'a genuine dislike of AWRE work on … account of its intrinsic character'.[8] The hazards of dealing with radioactive material and explosives were combined with poor pay, an inability to publish in academic journals and potential unemployment if disarmament efforts were successful.[9] For aspiring young professionals, this made universities, the private sector or other defence research establishments more appealing places of employment.[10]

It is apparent that the situation has improved since the 1950s; in 2019, the AWE was accredited as one of the 25 Sunday Times Best Big Companies to work for.[11] Nonetheless, overcoming some elements of the 'intrinsic character' of work at the AWE remain relevant; Aldermaston has had to recently contend with labour dissatisfaction over pensions, continues academic outreach programmes to 'facilitate staff retention', and has 'failed to adequately address [safety] shortfalls' in the eyes of the regulator.[12]

From the outset of the atomic programme, Penney realised that recruitment would be reliant on promoting all the other benefits that work at the establishment could offer. In the immediate post-war environment, this most prominently rested on offering access to government subsidised housing. Therefore, according to the official history of the period, constructing houses became 'a major, almost obsessive, anxiety' for the weapons programme.[13] Offering subsidised public housing continued to be noted as 'a valuable recruitment aid' as late as 1988.[14]

---

6. The National Archives, 'Dr. Penney to Mr. Wilkinson', File ES1/83, 25 August 1952.
7. Gowing, *Independence and Deterrence*, pp. 429–36.
8. The National Archives, 'Lord Cherwell to Duncan Sandys', File AB16/1230, 15 September 1953.
9. *Ibid.*
10. *Ibid*.
11. AWE, 'AWE in Top 25 Best Big Companies to Work for', 26 February 2019, <https://www.awe.co.uk/2019/02/awe-in-top-25-best-big-companies-to-work-for/>, accessed 30 September 2020.
12. Chris Langley, 'Atoms for Peace? The Atomic Weapons Establishment and UK Universities', Nuclear Information Service and Medact, p. 33, <https://www.medact.org/wp-content/uploads/2014/02/Atoms-For-Peace-Report.pdf>, accessed 1 July 2020; Katie Scott, 'Atomic Weapons Establishment Staff Strike in Pensions Dispute', *Employee Benefits*, 18 January 2017, <https://employeebenefits.co.uk/issues/january-online-2017/atomic-weapons-establishment-staff-strike-in-dispute-over-pension/>, accessed 1 July 2020; Office for Nuclear Regulation, 'Improvements Required at AWE', 19 July 2019, <http://news.onr.org.uk/2019/07/regulator-requires-improvements-at-awe/>, accessed 30 September 2020.
13. Gowing, *Independence and Deterrence*, p. 77.
14. The National Archives, 'AWE Manning', File DEFE72/456, 10 August 1988.

When atomic weapons work was centred on the Aldermaston site from 1950 onwards, attention was directed at creating an appealing community with schools, churches and shops.[15] Even the provision of a bus service to Aldermaston was both an additional benefit and an initiative aimed at increasing the catchment area for labour in the Thames Valley area.[16] At present, AWE's approach to recruitment strongly highlights the organisation's role in fostering a community and benefits such as a nine-day working cycle and extending home and flexible working arrangements.[17] AWE's current plan for a 'centre of excellence' proposes to construct a gym and library to create a 'campus like environment … to attract, develop and retain world class scientific staff'.[18] The effort to bolster AWE's general research credentials mirrors Aldermaston's initial forays into non-nuclear weapons research in the 1950s, which were explicitly linked with its intended 'morale effect on staff and to ease the switch from weapons if such a change is ever required' as a result of an arms control treaty.[19]

Although the obvious solution to recruitment and retention issues would seem to be to offer better salaries to Aldermaston's employees, this could prove intensely controversial if applied unevenly and challenging to negotiate with the Treasury. Despite applicants rejecting offers because of low wages, Penney had to fight a protracted campaign in the early 1950s for salary increases for atomic weapon workers against Whitehall's fears that there would be 'demands for comparability elsewhere … [and that] the fire would spread'.[20] Similarly, the Treasury objected to special pay awards for Aldermaston in the late 1970s as 'they tend to spread, both in scope and geographically', and favouritism could provoke industrial disputes at other conventional armament or civil nuclear establishments.[21] Provision of special pay awards at Aldermaston in the 1980s provoked rolling strikes at AWRE as managers were sequentially forced to provide bonuses to scientists and engineers, then labourers and then administrators.[22]

In cases where recruitment has been threatened, Whitehall has historically looked at new models of management.[23] The ability to pay wages flexibly, free from prescribed civil service bands acted as the justification for both the transition of the atomic weapons programme to the

15. The National Archives, 'Amenities and Facilities at Aldermaston – Report by Sir Donald Perrott and Sir William Penney', File AB16/1430, nd; The National Archives, 'Notes on Amenities', File AB16/1430, nd.
16. The National Archives, 'Atomic Energy Council Minutes', File ES1/347, 7 December 1950
17. AWE, 'Benefits', <https://www.awe.co.uk/careers/benefits/>, accessed 1 July 2020.
18. Ryan Evans, 'AWE Planning New "Centre Of Excellence" at Aldermaston Site', *Basingstoke Gazette*, 31 May 2020, <https://www.basingstokegazette.co.uk/news/18486411.awe-planning-new-centre-excellence-aldermaston-site/>, accessed 20 October 2020.
19. The National Archives, 'Diversification at Aldermaston', File ES1/525, nd.
20. The National Archives, '"M" Rate – M.O.S. Establishment, Aldermaston', File ES1/83, 25 January 1951; Gowing, *Independence and Deterrence*, p. 82.
21. The National Archives, 'Pay of Industrials at AWRE – Biffen to Secretary of State for Defence', File, DEFE19/155, 13 July 1979.
22. The National Archives, 'Draft Letter to HM Treasury – marked E20', File DEFE72/456, nd.
23. *Ibid*.

UK Atomic Energy Authority in the 1950s and from the civil service towards contractorisation in the 1990s.[24] In both cases it was argued that comparatively modest adjustments in salaries and mechanisms for their allocation had disproportionately affected the establishment's ability to recruit and retain staff; it was perceived that if issues were left unaddressed, the resulting lack of specialised skills could threaten the establishment's ability to deliver programmes on time.[25]

## Secrecy

Although a necessity, strict secrecy is often at odds with the need to share information within the weapons establishment. Skills and knowledge must be passed on to the next generation for the nuclear programme to continue.[26] According to the available archival material, weapons designers expressed this concern most clearly after the end of the Grapple nuclear tests in 1959.[27] Having designed and tested many of the UK's nuclear weapons concepts, senior scientists were concerned that the emerging generation was ignorant of nuclear weapons design principles compared to their American colleagues due to a strict enforcement of the 'need to know' principle.[28] As a senior British nuclear weapons scientist put it, the 'most valuable thing the "old hands" can do at the present stage is to make sure that the new generation can in fact stand on their shoulders'.[29] As a result, senior staff introduced a lecture series intended to comprehensively pass on their knowledge and educate the next generation of weaponeers.[30] This remains relevant given the long service careers of AWE's current staff: apprentices and graduate recruits serve on average 18 and 11 years respectively and this experience must be passed on.[31] It is, therefore, imperative for AWE to continuously invest in knowledge retention programmes and to educate incoming cohorts using the expertise of the staff with remaining testing experience.

Secrecy has been cited as a deterrent to recruitment at the weapons establishment. Even in 1950, when obtaining security clearance to work at the nuclear establishment took two weeks, managers were still complaining about the delays.[32] The atomic programme's senior management noted that 'by the time clearance had come through the staff concerned had

24. Hansard, House of Lords, 'Atomic Energy', Debate, 5 July 1951, Columns 670–79; Hansard, House of Lords, 'Atomic Weapons Establishment Bill', Debate, 14 June 1991, Column 1288.
25. The National Archives, 'Proposed Atomic Energy Corporation', File ES1/329, 23 November 1951; House of Lords, 'Atomic Weapons Establishment Bill', Debate, 14 June 1991, Column 1288.
26. 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.
27. The National Archives, 'Problem of the "Need to Know" Principle', File ES1/1323, 26 November 1959.
28. *Ibid*.
29. *Ibid*.
30. The National Archives, 'The Problem of Dissemination of Secret and Top Secret Information Amongst Junior Scientific Staff', File ES1/1323, 18 November 1959.
31. AWE, 'Future Careers Programme'.
32. The National Archives, 'A. E. Security Procedure', File ES1/354, nd.

usually found other work'.[33] Presently, as acquiring a Developed Vetting clearance typically takes six months, top graduates are likely to find alternative employment during that time.[34] To improve recruitment across the defence sector, further investment could be made in United Kingdom Security Vetting to ensure the timely processing of applicants. A 2018 National Audit Office report found that the organisation's performance had declined to only one in five non-priority Developed Vetting clearances being processed within the target of 95 days.[35] Although clearance levels cannot be lessened for work on the most sensitive projects, some level of provisional access, even if not directly on weapons work, was suggested in both the 1950s and 1980s when staffing issues were at their most acute.[36] Although it is unclear if it has been implemented, such a policy could be reinvestigated as a means of securing the best candidates for Aldermaston, ensuring its reputation 'as a centre for scientific and engineering excellence'.[37]

## Safety

The most crucial element that Aldermaston must maintain to ensure ongoing recruitment and retention is its safety record. Staffing levels will collapse if safety is not robustly upheld. This was demonstrated by a series of radiological incidents in 1978, when 12 workers became contaminated with plutonium.[38] As highlighted in the subsequent inquiry, these incidents partly occurred due to reductions in the numbers of safety staff employed during the 1970s.[39] Poor safety created a vicious cycle where staff left the establishment, in turn leaving it less able to make improvements. The situation received extensive prime ministerial attention, the introduction of whole-body monitoring, an extensive recruitment outreach campaign, and special pay awards to induce retention.[40] Nevertheless, safety imposed reductions to production led to a year's

---

33. The National Archives, 'CSAR Progress Meeting', File ES1/11, 2 May 1950.
34. Carbon60, 'Developed Vetting Security Clearances: How They Create Recruitment Challenges', 31 January 2018, <https://www.carbon60global.com/blog/developed-vetting-security-clearances-may-be-creating-a-recruitment-crisis>, accessed 1 July 2020.
35. National Audit Office, 'Investigation into National Security Vetting', HC1500, 7 September 2018, p. 26.
36. The National Archives, 'A. E. Security Procedure'; National Audit Office, 'Ministry of Defence and Property Services Agency: Control and Management of the Trident Programme', 1 July 1987, p. 19.
37. AWE, 'Supporting the Government', <https://www.awe.co.uk/what-we-do/national-security/advising-the-government/>, accessed 1 July 2020.
38. Hansard, House of Commons, 'Atomic Weapons Research Establishment, Aldermaston', Debate, 21 December 1979, Cols 1102–04.
39. The National Archives, 'An Investigation into Radiological Health and Safety at the MoD AWRE', File DEFE24/1346, 30 October 1978.
40. David Hawkings, *Keeping the Peace: The Aldermaston Story* (Bath: Bath Press, 2000), pp. 84–87; The National Archives, 'Background Information on AWRE for PS Civil Service Department', File DEFE19/155, September 1979.

delay to deploying the Chevaline system, reductions to the Thatcher government's nuclear weapons ambitions, and lingering difficulties in producing Trident into the 1980s.[41]

While no comparable incident has occurred in recent times, AWE's safety record is imperfect. In the last decade, AWE has been fined twice and is currently facing prosecution for alleged breaches of health and safety law relating to non-radiological incidents.[42] Due to the aged nature of some of the infrastructure, particularly at Burghfield, AWE has also been under enhanced regulatory attention by the Office of Nuclear Regulation since 2013 while facilities are being modernised.[43] In terms of regulatory attention, this places AWE on a par with Devonport Royal Dockyard and below the scrutiny afforded to several sites on the Sellafield estate.[44] While the present situation is certainly better than the late 1970s, precedent serves to demonstrate that AWE personnel and potential recruits must continue to feel that their personal safety is being upheld, otherwise they may leave the sector for other employment. Therefore, AWE must maintain a robust safety culture as being a fundamental prerequisite to continuing operations.

## Discontinuity and Diversity

One area where the nuclear establishment has made undoubted progress compared to its historical record is in diversity. Archival materials indicate that despite the often serious need to improve staffing, the weapons establishment often implicitly and sometimes explicitly sought only male candidates. For instance, when Penney talked of needing an 'adequate supply' of 'top men,' this was literal – when AWRE started its apprenticeship scheme in 1952, only boys were recruited.[45] In 1955, when faced with a severe recruitment shortage when undertaking the

41. The National Archives, 'Chevaline', File PREM19/159, 18 March 1980; The National Archives, 'Chevaline', File PREM19/14, 1 November 1979.
42. Nuclear Information Service, 'Nuclear Weapons Factory Operators Fined £200,000 for Safety Breaches', 28 May 2013, <https://www.nuclearinfo.org/article/awe-aldermaston/nuclear-weapons-factory-operators-fined-%C2%A3200000-safety-breaches>, accessed 1 July 2020; Tim Birkbeck, 'AWE Hit with £1m Fine After Employee Injury', *Basingstoke Gazette*, 30 November 2018; Office for Nuclear Regulation, 'Atomic Weapons Establishment to Face Prosecution', 15 September 2020, <http://news.onr.org.uk/2020/09/atomic-weapons-establishment-awe-to-face-prosecution/>, accessed 30 September.
43. Office for Nuclear Regulation, 'Chief Nuclear Inspector's Annual Report on Great Britain's Nuclear Industry', October 2019, p. 35, <http://www.onr.org.uk/documents/2019/cni-annual-report-1819.pdf>, accessed 30 September 2020; Nuclear Information Service, 'AWE Will Miss 2020 Date to Leave "Special Measures"', 20 November 2019, <https://www.nuclearinfo.org/article/aldermaston-burghfield-safety/awe-will-miss-2020-date-leave-%E2%80%98special-measures%E2%80%99>, accessed 30 September 2020.
44. Office for Nuclear Regulation, 'Chief Nuclear Inspector's Annual Report on Great Britain's Nuclear Industry', pp. 13–14; Nuclear Information Service, 'AWE Will Miss 2020 Date to Leave "Special Measures"'.
45. Hawkings, *Keeping the Peace*, p. 106.

thermonuclear programme, AWRE reluctantly recruited women but considered it a 'dilution' of the workforce.[46]

While gender diversity has gradually improved as societal attitudes towards gender roles changed, it is only relatively recently that AWE has undertaken active measures to promote inclusion and diversity. A strategy group composed of the establishment's senior leaders leads these efforts.[47] From a pragmatic perspective alone, this ensures that it can recruit from the widest talent pool possible. New initiatives to promote diversity include the provision of unconscious bias training, the foundation of grassroots employee networks to promote gender, BAME and LGBT inclusion and the annual production of a gender pay gap report.[48] For these efforts, AWE won two awards in 2019.[49] However, AWE's gender balance ratio in 2019 was still 78 men to 22 women across the organisation.[50] This matches the UK nuclear industry's gender balance in 2018, but compares unfavourably with the female STEM student intake, which was at 35% in 2017/18.[51]

## Conclusion

In conclusion, the weapons establishment has always struggled with the recruitment and retention necessary to deliver the UK's nuclear programme. The establishment's historical experience suggests that this challenge can be overcome by maintaining a rigorous safety culture, by offering the best working conditions and benefits to staff and reducing to whatever extent possible the pernicious effects of secrecy. These can often involve innovative and comparatively cheap programmes to improve the attraction of the establishment to prospective and current employees. While divorced from the technical aspects of nuclear weapons, the defence programme can only continue through ongoing investment in human capital. In this respect, current efforts to increase diversity and inclusion are crucial.

---

46. The National Archives, 'Recruitment of Unskilled Industrials at AWRE', File ES1/920, 18 February 1955.
47. Josie Coltman, Dominic Jones and Paula Rose, 'Diversity and Inclusivity at AWE', AIP Conference Proceedings (Proc. 2109, 130002, 2019), pp. 1–3.
48. *Ibid*.
49. AWE, 'Connect', November 2019, <https://www.awe.co.uk/app/uploads/2019/11/1976-AWE_connect_issue-22_12pp_November-2019-FINAL-spreads.pdf>, accessed 1 July 2020.
50. AWE, 'Gender Pay Gap Report', February 2019, <https://www.awe.co.uk/app/uploads/2019/03/AWE-GenderPayGapReport_Feb_2019.pdf>, accessed 1 July 2020.
51. STEM Women, 'Women in STEM: Percentages of Women in STEM Statistics', 26 September 2019, <https://www.stemwomen.co.uk/blog/2019/09/women-in-stem-percentages-of-women-in-stem-statistics>, accessed 30 September 2020; The Nuclear Institute, 'Gender Diversity Sits at the Top of the Nuclear Sector Deal', 28 June 2018, <https://www.nuclearinst.com/News/NI-News/gender-diversity-sits-at-the-top-of-the-nuclear-sector-deal>, accessed 30 September 2020.

# IV. National Security Implications of the UK Hualong One Nuclear Power Station

Thomas P Davis

THE NUCLEAR ENERGY director of the China Atomic Energy Authority (CAEA), Liu Baohua, emphasised in 2016 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’.[1] This principle provides insight into potential strategic advantages that a nuclear export programme provides, given the uniqueness of nuclear commerce.[2] This is due to the length of engagement, dependency on the nuclear relationship through its services, and apparent geopolitical influence of the supplier state on the host state. For example, nuclear commerce creates a potential dependence of host countries on the suppliers of reactors.[3] It further requires a multi-decade[4] relationship between the supplier and host state for fuel fabrication, spent-fuel management, and reactor maintenance.[5] Such uniqueness could enable this type of energy source to become a powerful tool in state-to-state negotiations.

The Chinese state-owned China General Nuclear Power Group (CGN) has provided a 33.5% financial stake in the around £24.5bn UK Hinkley Point C (HPC) nuclear power plant in Somerset, set to come online by 2025 and expected to provide 7% of the UK’s electrical power for 60 years.[6] In exchange for their investment in HPC, the UK’s government has allowed CGN to build their own nuclear reactor design (Hualong One, also known by HPR1000) at the UK Bradwell nuclear site. By 2021, the Office for Nuclear Regulation (ONR) is set to formally approve the

1. Lili Liu, ‘核电消纳管理办法即将发布’ [‘Administrative Measures for Nuclear Power’], *China5e*, 2016, <https://www.china5e.com/news/news-971094-1.html>, accessed 5 July 2020.
2. Ira Martina Drupady, ‘Emerging Nuclear Vendors in the Newcomer Export Market: Strategic Considerations,’ *Journal of World Energy Law and Business* (Vol. 12, No. 1, 2019), pp. 4–20.
3. Thomas Paul Davis, ‘Could Generation IV Nuclear Reactors Strengthen Russia’s Growing Sphere of Influence?’, in Sam Dudin and Chelsea Wiley (eds), ‘The 2019 UK PONI Papers’, Royal United Services Institute, December 2019.
4. Steve Thomas, ‘Russia’s Nuclear Export Programme’, *Energy Policy* (Vol. 121, June 2018), pp. 236–47.
5. Drupady, ‘Emerging Nuclear Vendors in the Newcomer Export Market’; Davis, ‘Could Generation IV Nuclear Reactors Strengthen Russia’s Growing Sphere of Influence?’.
6. Stephen Thomas, ‘The Hinkley Point Decision: An Analysis of the Policy Process,’ *Energy Policy* (Vol. 96, 2016), pp. 421–31.

Hualong One design.[7] The UK is set to become the first Western country to formally approve a Chinese nuclear reactor for construction.

This paper argues that cooperation with the Chinese state in civil nuclear energy endeavours has national security implications for the UK. Among these implications are that the ONR's formal approval could serve as a catalyst in compelling countries in the Middle East, South East Asia, Africa, South America and Europe to purchase, either independently or via Chinese state loans, Chinese nuclear power. A further implication is China's potential strategic leverage over the UK as well as the national security implications related to the financial and construction approval for the UK Hualong One nuclear power station on British soil. The paper provides policy suggestions that could mitigate these potential risks to the UK's national security.

## Chinese Nuclear Export Capability

Nuclear power stations have been operating in China since 1991 and have only in the last decade been pursued at a rapid rate, with 35 of China's 48 operating reactors commissioned between 2011 and 2020.[8] Since 2014, the Chinese state has sought to export nuclear reactors as part of its international cooperation diplomacy and the Belt and Road Initiative,[9] despite Russian dominance[10] and competition from France, Japan and South Korea.[11] The first Chinese exported reactor began operation during 2000 in Pakistan. The Hualong One design merges the ACP1000 and ACPR1000 reactor designs and is China's flagship pressure water reactor design.[12] There are five principal reasons why China is exporting nuclear energy:

7. Office for Nuclear Regulation, 'UK HPR1000 Progresses to Next Stage of Assessment,' 2020.
8. Bao-guo Shan et al., 'China's Energy Demand Scenario Analysis in 2030,' *Energy Procedia* (Vol. 14, 2012), pp. 1292–98; World Nuclear Association, 'Nuclear Power in China', updated April 2020, <https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx>, accessed 5 July 2020; Yan Xu, Junjie Kang and Jiahai Yuan, 'The Prospective of Nuclear Power in China', *Sustainability* (Vol. 10, No. 6, 2018).
9. Ravi Madhavan, Thomas G Rawski and Qingfeng Tian, 'Capability Upgrading and Catch-Up in Civil Nuclear Power: The Case of China', in Loren Brandt and Thomas G Rawski (eds), *Policy, Regulation and Innovation in China's Electricity and Telecom Industries* (Cambridge: Cambridge University Press, 2019), pp. 419–86.
10. Davis, 'Could Generation IV Nuclear Reactors Strengthen Russia's Growing Sphere of Influence?'.
11. Drupady, 'Emerging Nuclear Vendors in the Newcomer Export Market'; Boqiang Lin, Nuri Bae and François Bega, 'China's Belt & Road Initiative Nuclear Export: Implications for Energy Cooperation', *Energy Policy* (Vol. 142, 2020), pp. 1115–19.
12. Ming Zeng et al., 'Review of Nuclear Power Development in China: Environment Analysis, Historical Stages, Development Status, Problems and Countermeasures', *Renewable and Sustainable Energy Reviews* (Vol. 59, 2016), pp. 1369–83.

1. Domestic nuclear reactor construction provides economies of scale and a large skilled work force.[13]
2. The assumption is that China can reduce the costs of reactors for host countries.[14]
3. Nuclear marketplace competitors Westinghouse (US) and Areva/EDF (France) are facing serious financial difficulties,[15] and challenges arise for Rosatom (Russia) to provide the financial support promised due to reductions in the Russian economy.[16]
4. Large Chinese cash reserves enable the financing of nuclear exportation.[17]
5. Nuclear energy exportation is a state venture and receives strong domestic political support.[18]

## UK Nuclear Market

The UK Department of Energy & Climate Change's 2008 'Meeting the Energy Challenge: A White Paper on Nuclear Power' outlined the UK's future nuclear build programme.[19] In 2015, then Prime Minister David Cameron and President Xi Jinping signed the Strategic Investment Agreement, enabling CGN to hold a 33.5% financial stake in HPC, a 20% financial stake in Sizewell C, and allowing China to construct their Hualong One nuclear reactor at the UK Bradwell site (around 60 miles east of London).[20] This launched the Sino–British civil nuclear power partnership.

The formal approval by ONR for the Hualong One design will likely be in 2021 through the Generic Design Assessment (GDA), indicating that the reactor meets UK safety and security expectations (a 'gold standard' in the nuclear industry[21]), and is suitable for construction and operation on British soil. The UK will become the first Western country to accept a Chinese nuclear reactor.

13. *Ibid*.
14. Steve Thomas, 'China's Nuclear Export Drive: Trojan Horse or Marshall Plan?', *Energy Policy* (Vol. 101, 2017), pp. 683–91.
15. Drupady, 'Emerging Nuclear Vendors in the Newcomer Export Market'.
16. Thomas, 'Russia's Nuclear Export Programme'.
17. Nadira Barkatullah and Ali Ahmad, 'Current Status and Emerging Trends in Financing Nuclear Power Projects', *Energy Strategy Reviews* (Vol. 18, 2017), pp. 127–40.
18. Zeng et al., 'Review of Nuclear Power Development in China'.
19. HM Government, *Meeting the Energy Challenge: A White Paper on Nuclear Power* (London: The Stationery Office, 2008).
20. HM Government, 'Hinkley Point C to Power Six Million UK Homes', 21 October 2015.
21. Jane Nakano, 'The Changing Geopolitics of Nuclear Energy: A Look at the United States, Russia, and China', Center for Stragetic and International Relations, 12 March 2020; T Hurel, 'Chinese Nuclear Industry in Search of Internationalisation', *Revue Générale Nucléaire* (No. 5, 2017), pp. 34–35.

## National Security Implications of the UK Hualong One Nuclear Reactor

At the core of national security is freedom from military threat and political coercion, including freedom from foreign dictation.[22] The national and international security implications of the Sino–British relationship raise specific concerns. The CCP has enabled President Xi Jinping to rule for life, suppressed the Uyghur population (meeting the UN's definition of genocide[23]) and illegally expanded into the South China Sea,[24] as well as, according to extensive evidence, stolen intellectual property.[25] Furthermore, the recent Hong Kong national security law[26] reneges on the Sino–British joint declaration of Hong Kong in 1984. In 2015, CGN committed an espionage act against the US government by stealing nuclear secrets from Westinghouse.[27] The US Department of Commerce has now blacklisted CGN, China Nuclear Power Technology Research Institute Co Ltd and Suzhou Nuclear Power Research Institute Co Ltd.[28] These facts have wide-ranging international security implications which in turn present possible challenges to UK national security.

As discussed in the previous section detailing the upcoming UK approval of Chinese nuclear technology, this paper assesses that China may employ the UK nuclear regulatory stamp of approval as a catalyst to accelerate China's nuclear export programme. The acceptance of this new reactor by a Western country will send strong signals globally that CGN is a capable, responsible and trustworthy nuclear vendor, irrespective of the evidence of espionage by CGN. Orders for Chinese nuclear power will likely come from the Middle East, South East Asia, Africa, South America and Europe, given their interest in Chinese nuclear power, and could be

---

22. Joseph J Romm, *Defining National Security: The Nonmilitary Aspects* (New York, NY: Council on Foreign Relations Press, 1993); HM Goverment, *National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom* (London: The Stationery Office, 2015).
23. Adrian Zenz, 'Sterilizations, Forced Abortions, and Mandatory Birth Control: The CCP's Campaign to Suppress Uyghur Birthrates in Xinjiang', *China Brief* (Vol. 20, No. 12, 2020).
24. Dong Manh Nguyen, 'Settlement of Disputes Under the 1982 United Nations Convention on the Law of the Sea: The Case of the South China Sea Dispute', *University of Queensland Law Journal* (Vol. 25, No. 1, 2006), pp. 145–80.
25. National Bureau of Asian Research, 'IP Commission Report: The Theft of American Intellectual Property: Reassessments of the Challenege of United States Policy', 2017.
26. Hong Kong Government, 'Promulgation of National Law 2020', 2020, <https://www.gld.gov.hk/egazette/pdf/20202444e/es220202444136.pdf>, accessed 10 July 2020.
27. *Justice News*, 'U.S. Nuclear Engineer Sentenced to 24 Months in Prison for Violating the Atomic Energy Act', 31 August 2017.
28. National Archives Federal Register, 'Addition of Certain Entities to the Entity List, Revision of Entries on the Entity List, and Removal of Entities From the Entity List', 14 August 2019, <https://www.federalregister.gov/documents/2019/08/14/2019-17409/addition-of-certain-entities-to-the-entity-list-revision-of-entries-on-the-entity-list-and-removal>, accessed 5 July 2020.

underpinned with Chinese state loans, as stated by Ira Martina Drupady.[29] This renders the financial return of the Chinese investment in HPC insignificant (around £8 billion) compared to the more than £400 billion of potential nuclear export orders over the next few decades.[30] Furthermore, this would position China to become a leading competitor against Russia's nuclear export omnipresence.[31]

In addition, and specifically for the UK Hualong One nuclear power station, the reactor will operate for 60 years, implying Chinese involvement for this time period. Beijing has demonstrated it uses economic levers as political tools to advance China's interests[32] and will hold a significant investment of around 21%[33] in the UK power grid by 2030. Baohua[34] has also stated that civil nuclear power is part of a military–civil fusion strategy – the development of floating nuclear power plants to be deployed in the South China Sea for military purposes using civil nuclear technology.[35] These factors are likely to have four primary implications for the UK's national security:

1. The Sino–British civil nuclear partnership will further deepen economic entanglement between the UK and China because Beijing considers nuclear power to be a tool for 'international cooperation diplomacy'.[36] This is evidenced in the 28 January 2020 UK government decision[37] to allow Huawei to be part of the UK 5G network until a review was commissioned on 24 May 2020 after major security concerns were raised.[38] On 7 June 2020, the *Sunday Times* reported[39] that the Chinese Ambassador to the UK, Liu Xiaoming, warned that if the UK government abandoned the Huawei 5G deal, China

29. Drupady, 'Emerging Nuclear Vendors in the Newcomer Export Market'.
30. *Ibid.*; Rolls-Royce, 'UK SMR: A National Endeavour', <https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/nuclear/a-national-endeavour.pdf>, accessed 6 October 2020.
31. Davis, 'Could Generation IV Nuclear Reactors Strengthen Russia's Growing Sphere of Influence?'.
32. Charles Clover and Michael Peel, 'China Tries Chequebook Diplomacy in Southeast Asia', *Financial Times*, 7 November 2016.
33. HPC, Sizewell C and Bradwell B are each set to produce around 7% of UK power (based on a 30 gigawatt consumption on 6 July 2020 at 1300), see <www.gridwatch.co.uk>. See Suzanna Hinson, 'New Nuclear Power', House of Commons Library, Briefing Paper, CBP 8176, 29 July 2020.
34. Liu, '核电消纳管理办法即将发布' ['Administrative Measures for Nuclear Power'].
35. Viet Phuong Nguyen, 'China's Planned Floating Nuclear Power Facilities in South China Sea: Technical and Political Challenges', Maritime Issues, 21 November 2018, <http://www.maritimeissues.com/environment/china39s-planned-floating-nuclear-power-facilities-in-southchina-sea-technical-and-political-challenges.html>, accessed 5 July 2020.
36. Mary-Ann Russon, 'Fresh UK Review into Huawei Role in 5G Networks', *BBC News*, 24 May 2020.
37. HM Government, 'Foreign Secretary's Statement on Huawei', 28 January 2020, <https://www.gov.uk/government/speeches/foreign-secretary-statement-on-huawei>, accessed 5 July 2020.
38. Russon, 'Fresh UK Review into Huawei Role in 5G Networks'.
39. Tim Shipman, 'China Threatens to Pull Plug on New British Nuclear Plants', *Sunday Times*, 7 June 2020.

would suspend all Sino–British nuclear projects. If China's interpretation of 'international cooperation diplomacy' involves coercing the UK to accept the Huawei 5G deal or risk losing the UK Hualong One nuclear reactor and financial investments in HPC and Sizewell C, it aligns with the very definition of a national security challenge through political coercion. On 14 July 2020, the UK government announced the removal and banning of Huawei 5G equipment.[40]

2. Hualong One may render a reduction of British agency when challenged abroad by China's strategic assertions, including the South China Sea expansion. Dependence on Chinese involvement in the Hualong One nuclear power station incentivises military and political hesitance by the UK to counter this expansion and risks losing Chinese investment in the UK.
3. The outsourcing of nuclear expertise for Hualong One could jeopardise the British defence nuclear industry due to the lack of sustainable suitably qualified and experienced personnel (SQEP) available.
4. Hualong One creates and deepens the UK's economic and geopolitical dependency on China.

Fusing the Hualong One nuclear power station with other elements of the Sino–British international relationship characterises the 'China Card' proposed by the Chinese government in 2016 that nuclear power 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'.[41] By definition, Chinese involvement in UK civil nuclear power is a national security issue that should be tackled by foreign and domestic policy solutions.

This assessment supports a UK policy-based solution which suspends all Sino–British nuclear projects. This is to reduce the national security implications and/or remove them entirely. For the replacement of the cancelled nuclear projects, the UK is conversely in a unique position to become self-sufficient in the design, supply chain, engineering, SQEP, and industrial support for construction of Rolls-Royce's Small Modular Reactor (SMR).[42] This type of governmental support would rejuvenate the UK's domestic nuclear industry and build support for the eventual goal of exporting Rolls-Royce's SMR, as outlined by the House of Lord's Science and Technology Select Committee report on UK nuclear development.[43] The latter enables the UK to directly compete with China and Russia on the international nuclear market place, with projections of up to £400 billion nuclear exports occurring outside the EU.[44] Eliminating the UK's reliance on Chinese nuclear power technology whilst enabling British self-sufficiency in producing

40. HM Government, 'Huawei to Be Removed from UK 5G Networks by 2027', 14 July 2020.
41. Liu, '核电消纳管理办法即将发布' ['Administrative Measures for Nuclear Power'].
42. Simon de Haas et al., 'Integrated Design of a Reactor Core for the Rolls-Royce Small Modular Reactor Project', International Conference on Nuclear Engineering, 24 October 2018, <https://doi.org/10.1115/ICONE26-81311>, accessed 23 September 2020.
43. House of Lords Science and Technology Select Committee, 'Nuclear Research and Technology: Breaking the Cycle of Indecision', HL Paper 160, 2 May 2017.
44. Rolls-Royce, 'UK SMR'.

nuclear power stations together reduce the national security risk posed by the Hualong One nuclear power station.

## Conclusion

This paper has identified two findings pertinent to the UK's national security interests which are related to the UK Hualong One nuclear power station:

1. The Chinese government is using the UK nuclear regulatory stamp of approval (GDA) as a catalyst to launch China's nuclear export programme. This could entail the beginning of the Chinese nuclear power export industry.
2. China is taking advantage of the Sino–British civil nuclear partnership to coerce the UK into accepting Huawei 5G hardware; this exemplifies the degree of strategic power provided by exporting nuclear reactors.

Nuclear commerce and the associated geopolitical factors can span decades and multiple levels, all of which have been further complicated by the coronavirus pandemic.[45] In the current global environment, the type and degree of influence that the supplier state is able to exercise on the host state could prove that civil nuclear energy cooperation is a powerful tool in state-to-state negotiations. Recognising and acting on this reality would position the UK in a more strategically advantageous position than it is in currently; rather than becoming dependent on foreign imports for nuclear energy, the UK would have the potential to become self-sufficient in domestic nuclear energy supply and position itself as a nuclear energy exporter once again.

*All text, opinions, and conclusions do not represent the views of the University of Oxford, Davis & Musgrove Limited or any other affiliations. These are Thomas P Davis's personal views alone.*

45. Steven Erlanger, 'Global Backlash Builds Against China Over Coronavirus', *New York Times*, 4 May 2020.

# V. Setting the Perception: How Do Media and Policy Affect the UK Nuclear Skills Pipeline?

Lorne Dryer

THE CIVIL AND defence nuclear industry within the UK is currently preparing to expand. This places additional strain on an already challenged nuclear skills pipeline.[1] While a range of industry bodies from the Nuclear Skills Strategy Group (NSSG) to the Nuclear Industry Council (NIC) have arisen to support the skills pipeline,[2] there are less visible direct and indirect impacts on the pipeline from departmental policy, media and public perception. While defence and apprenticeship policy directly impact mechanisms of the pipeline, education policy, in conjunction with the media and resulting public perception, influences the number of potential entrants into the pipeline.

## The Problem

The Department of Business, Energy and Industry Strategy (BEIS) predicts the nuclear skills pipeline will need 8,600 full-time equivalent employees (FTEs) each year.[3] Whilst 3,900 of these FTEs make up for employees leaving the pipeline, 4,700 new FTEs will need to enter the sector to enable the industry to expand to 98,000 FTEs by 2021.[4] The BEIS breaks the pipeline down into three tiers of decreasing size:

1. Engineers/project managers with transferable skills that need minimal nuclear specific training. They are heavily in demand across all science, technology, engineering and maths (STEM) industries, not just nuclear.
2. Nuclear engineers/technical managers/physicists that take at least five years of nuclear specific training.
3. Subject matter experts (SMEs) who have 20 years of nuclear specific experience.

---

1. HM Government, 'Sustaining Our Nuclear Skills', 2015, p. 4, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/415427/Sustaining_Our_Nuclear_Skills_FINAL.PDF>, accessed 12 July 2020.
2. HM Government, 'Nuclear Industry Council', 2020, <https://www.gov.uk/government/groups/nuclear-industry-council>, accessed 13 July 2020.
3. HM Government, 'Sustaining Our Nuclear Skills', p. 11.
4. *Ibid.*, pp. 9–11.

## Apprenticeship Policy

Apprenticeships make up 63% of trainees in the pipeline, according to the 2019 NSSG Nuclear Workforce Assessment.[5] Therefore, government apprenticeship policy as summarised by the skills policy parliamentary briefing notes is highly relevant to the pipeline.[6]

Apprenticeship policy is intended to make apprenticeships a viable alternative to university education for future skilled FTEs. It does this partly through standardisation, making the qualifications more transferable,[7] and partly through the introduction of a levy that places a burden on large organisations which is then refunded as part of apprentice training subsidies.[8] The NSSG 2019 Nuclear Apprenticeship survey found 44% of organisations increased their number of apprentices as a result of the levy.[9] Additionally, 56% used the levy to assist retention by upskilling or retraining their workforce.[10]

However, the levy has attracted criticism not just within the nuclear industry.[11] The use of only 61% of the levy points to a need for flexibility in its usage.[12] Although the government responded to feedback and enabled the transfer of 25% of the levy between organisations, employers within the nuclear industry have called for more regulatory flexibility;[13] they point to the 80:20 on-job, off-job training structure as being too limiting given many nuclear jobs benefit from additional on-the-job training[14] and the transfer of tacit knowledge that apprenticeships provide.[15]

---

5. Nuclear Skills Strategy Group (NSSG), 'Nuclear Workforce Assessment 2019', p. 27, <https://www.nssguk.com/media/2018/nuclear-workforce-assessment-2019-full-report-final.pdf>, accessed 12 July 2020.
6. Andrew Powell, 'Apprenticeships and Skills Policy in England', House of Commons Library, Briefing Paper, CBP 03052, 7 September 2020.
7. Doug Richard, 'The Richard Review of Apprenticeships', November 2012.
8. Powell, 'Apprenticeships and Skills Policy in England'.
9. NSSG, 'Nuclear Apprenticeship Survey 2019', p. 16, <https://www.nssguk.com/media/2020/nuclear-apprenticship-survey-2019-final.pdf>, accessed 12 July 2020.
10. *Ibid*., p. 6.
11. Elizabeth Howlett, 'Employers Lose £133M From Levy Accounts as Funds Expire', *People Management*, 10 September 2019, <https://www.peoplemanagement.co.uk/news/articles/employers-lose-133m-from-levy-accounts-as-funds-expire>, accessed 13 July 2020.
12. NSSG, 'Nuclear Apprenticeship Survey 2019', p. 16.
13. *Ibid*., p. 14.
14. Ronald L Jacobs and Mohammad Jaseem Bu-Rahmah, 'Developing Employee Expertise Through Structured On-The-Job Training (S-OJT): An Introduction to This Training Approach and the KNPC Experience', *Industrial and Commercial Training* (Vol. 44 No. 2, 2012), pp. 75–84.
15. Niina Rintala and Tanja Kuronen, 'How to Share Tacit Nuclear Knowledge?', *International Journal of Nuclear Knowledge Management* (Vol. 2, No. 2, 2006), pp. 121–33.

Regardless of changes, apprentices are considered to be in full-time education and training can start at the age of 16 rather than 18. Given their exceptionally high retention rate,[16] it is reasonable to suggest this will increase the availability of SMEs who will gain the requisite experience earlier in their careers.

## Defence Policy

Defence policy, on the other hand, influences what skills are needed and provided by the pipeline. A literature review conducted by the University of Sussex Science Policy Research Unit (SSPRU) found that nuclear new build policy is partially influenced by the need to maintain a UK-based defence applicable nuclear skillset,[17] giving examples such as Hinkley Point C's UK-based supply chain and workforce that is maintained through the project, which in turn retains potential defence capability.[18]

Additionally, defence programmes such as the Royal Navy Nuclear Undergraduate Apprenticeship Scheme act as a subsidised training ground for the civil and defence nuclear industry:[19]

> Many former nuclear submariners already occupy positions at all levels in the civil nuclear power and contracting industry and this is likely to continue. Thus, the Royal Navy can be seen as a training ground for supporting the future UK nuclear power sector.[20]

However, this relationship works both ways; the Office for Nuclear Regulation (ONR) identified three workstreams to address pipeline issues, one of which focused on defence:

---

16. NSSG, 'Nuclear Apprenticeship Survey 2019', p. 6.
17. Emily Cox, Phil Johnstone and Andy Stirling, 'Understanding the Intensity of UK Policy Commitments to Nuclear Power: The Role of Perceived Imperatives to Maintain Military Nuclear Submarine Capabilities', Science Policy Research Unit Working Paper Series, 28 November 2016, pp. 27–98, <https://www.sussex.ac.uk/webteam/gateway/file.php?name=2016-16-swps-cox-et-al.pdf&site=25>, accessed 12 July 2020.
18. Andy Stirling, Phil Johnstone and Science Policy Research Unit, University of Sussex, 'Some Queries Over Neglected Strategic Factors in Public Accounting for UK Nuclear Power: Evidence to the House of Commons Public Accounts Committee Inquiry on Hinkley Point C', House of Commons Public Accounts Committee, 2017, <http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/public-accounts-committee/hinkley-point-c/written/70983.pdf>, accessed 12 July 2020.
19. Cox, Johnstone and Stirling, 'Understanding the Intensity of UK Policy Commitments to Nuclear Power'; House of Commons Innovation, Universities, Science and Skills Committee, *Engineering: Turning Ideas Into Reality*, Volume III Oral and Written Evidence (London: The Stationery Office, 2019), p. 88; Philip Dunne, 'Growing the Contribution of Defence to UK Prosperity', Ministry of Defence, July 2018, pp. 29–33, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/723679/20180709_MOD_Philip_Dunne_Review_FOR_WEB_PUB.pdf>, accessed 12 July 2020.
20. Dunne, 'Growing the Contribution of Defence to UK Prosperity'.

> Workstream 1 (Skills Coherence) will integrate the needs of the defence programme into existing cross-government and Industry work to maximise the scope and value of skills training across the civil nuclear sector. Action will be taken to refocus and introduce greater collaboration in development of nuclear skills.[21]

Conveniently, the impacts of the ONR workstream and defence steerage of civil new build are visible in Rolls Royce's Small Modular Reactor (SMR) marketing material:

> The expansion of a nuclear-capable skilled workforce through a civil nuclear UK SMR programme would relieve the Ministry of Defence of the burden of developing and retaining skills and capability.[22]

This concisely evidences the SSPRU's review and parliamentary inquiries' findings as well as showing the ONR workstream in action, therefore suggesting defence nuclear policy has an impact on the nuclear skills pipeline and vice versa.

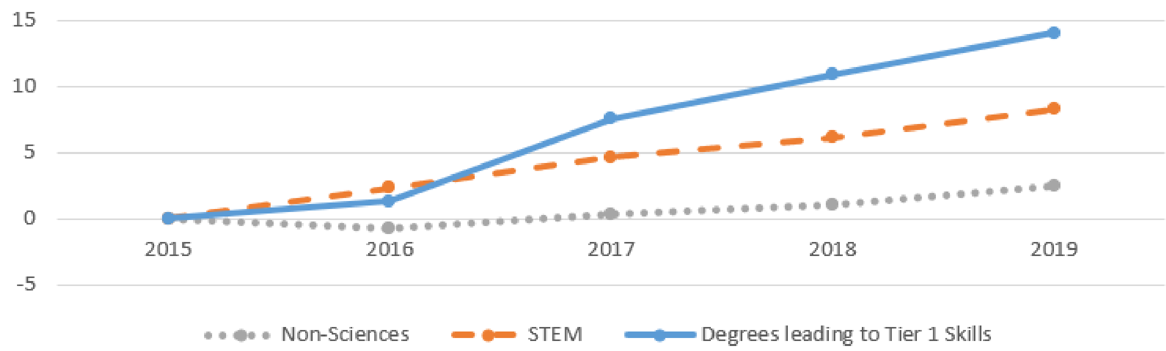
## Education Policy

Education policy develops the STEM skills needed to enter the pipeline and helps to set perceptions through its curriculum. In 2015, the Department of Education outlined its policy to encourage STEM in schools and improve public awareness in the hope of reducing skills shortages.[23] This has resulted in an improvement in university STEM course enrolments,[24] particularly courses that are relevant to Tier 1 professions within the nuclear industry, such as mechanical engineering and physics (see Figure 1).[25]

---

21. Amanda Harrison, 'ONR's Contribution to the Public Sector Nuclear Skills Challenge', ONR Board Meeting Paper No: ONR/15/03/06, Office for Nuclear Regulation, p. 6, <http://www.onr.org.uk/meetings/2015/onr-15-03-06.pdf>, accessed 12 July 2020.
22. Rolls-Royce, 'UK SMR:A National Endeavour', p. 22, <https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/nuclear/a-national-endeavour.pdf>, accessed 12 July 2020.
23. HM Government, '2010 to 2015 Government Policy: Public Understanding of Science and Engineering', <https://www.gov.uk/government/publications/2010-to-2015-government-policy-public-understanding-of-science-and-engineering/2010-to-2015-government-policy-public-understanding-of-science-and-engineering>, accessed 12 July 2020.
24. HESA, 'What Do HE Students Study?', 2020, <https://www.hesa.ac.uk/data-and-analysis/students/what-study>, accessed 12 July 2020.
25. HM Government, 'Sustaining Our Nuclear Skills'; NSSG, 'Nuclear Career Pathways', 2020, <https://www.nssguk.com/nuclear-career-pathways/>, accessed 13 July 2020; UCAS, 'Nuclear Engineer Job Profile', 2020, <https://www.ucas.com/ucas/after-gcses/find-careerideas/ explore-jobs/job-profile/nuclear-engineer>, accessed 13 July 2020.

**Figure 1:** Percentage Change in Degree Enrolments from 2015



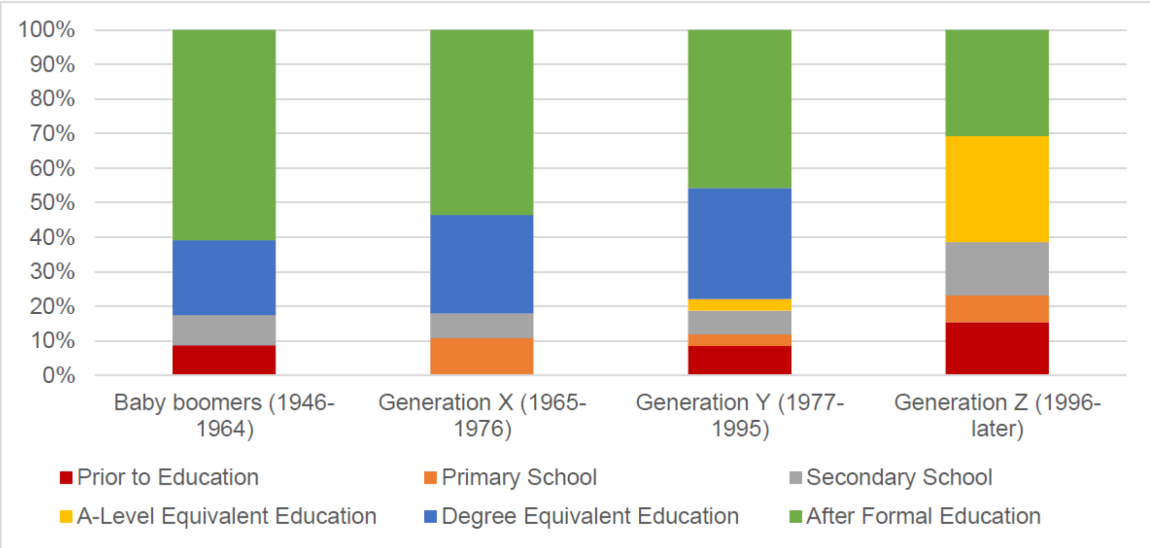

*Source: HESA, 'What Do HE Students Study?', <https://www.hesa.ac.uk/data-and-analysis/students/what-study>, accessed 12 July 2020.*

While this growth in engineering-related STEM courses could be the result of engineering career engagement programmes similar to the Smallpeice trust,[26] it suggests education policy is increasingly providing the skills needed by the pipeline.

Additionally, research by the Young Nuclear Industry Safety Professionals Forum (YNSPF) suggests that education policy is increasingly responsible for current nuclear employees to the nuclear industry, as seen in Figure 2.[27]

26. The Smallpeice Trust, 'About Us', <https://www.smallpeicetrust.org.uk/about-us>, accessed 13 July 2020.
27. Ben Percy et al., 'Generational Analysis for the Recruitment and Retention of Talent Within the Nuclear Industry', Young Nuclear Safety Professionals' Forum, 4 March 2018, p. 6, <https://www.nuclearinst.com/write/MediaUploads/SDF%20documents/YNSPF/NGSReport_Final_v1.0.pdf>, accessed 12 July 2020.

**Figure 2:** Stage in Life When the Respondents Were First Exposed to the Nuclear Industry, by Generation




*Source: Ben Percy et al., 'Generational Analysis for the Recruitment and Retention of Talent Within the Nuclear Industry', Young Nuclear Safety Professionals' Forum, p. 6, <https://www.nuclearinst.com/write/MediaUploads/SDF%20documents/YNSPF/NGSReport_Final_v1.0.pdf>, accessed 12 July 2020.*

While they highlight generation Z had not yet graduated university and therefore those respondents were predominantly apprentices in the nuclear field,[28] the research suggests GCSE and A-Level education is where the next generation of the pipeline has its perceptions set. There is, however, a disparity between the inclusion of nuclear subject matter in GCSE and A-level mandatory content. This is an issue for the industry since A-level courses are optional and have a considerably smaller audience than GCSE courses.[29]

The 2016 education reforms have helped to increase the visibility of the nuclear industry within the curriculum by including the basics of nuclear reactions and radiation in GCSE mandatory content.[30] Despite this it has the potential to reinforce misconceptions about nuclear safety (connecting nuclear reactions to the dangers of radiation but making little mention of safety

28. Percy et al., 'Generational Analysis for the Recruitment and Retention of Talent Within the Nuclear Industry'.
29. Ofqual, 'Provisional Entries for GCSE, AS and A Level: Summer 2020 Exam Series', 2020, <https://www.gov.uk/government/publications/provisional-entries-for-gcse-as-and-a-level-summer-2020-exam-series/provisional-entries-for-gcse-as-and-a-level-summer-2020-exam-series>, accessed 13 July 2020.
30. Department for Education, 'Combined Science GCSE Subject Content', 2015, pp. 29, 36, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/800339/Combined_science_GCSE_updated_May_2019.pdf>, accessed 13 July 2020.

measures). In contrast, A-level courses such as Environmental Sciences and Physics include a detailed analysis of the impact of the UK nuclear industry. Whilst students are encouraged to formulate their perceptions at this level,[31] they are required to show an understanding of the impacts of the industry.[32] Some Physics A-level exam boards even require students to compare the safety features of different reactor designs.[33]

## The Perception

There has been convincing research conducted linking public perception of an industry and recruitment. A Wellcome Trust-commissioned literature review conducted by the University of London's Evidence for Policy and Practice Information and Co-ordinating Centre looked at what influences young people in their job choices. The authors found that how useful students thought a subject was in terms of getting a job dictated what they studied, and these perceptions were shaped by the curriculum.[34]

In contrast, the *Journal of Vocational Behaviour* looked at job applicants and found that perception of industry was one of the most influential factors among graduates seeking employment.[35] This is important since the NSSG 2019 Nuclear Workforce Assessment showed 36% of trainees are direct graduates.[36]

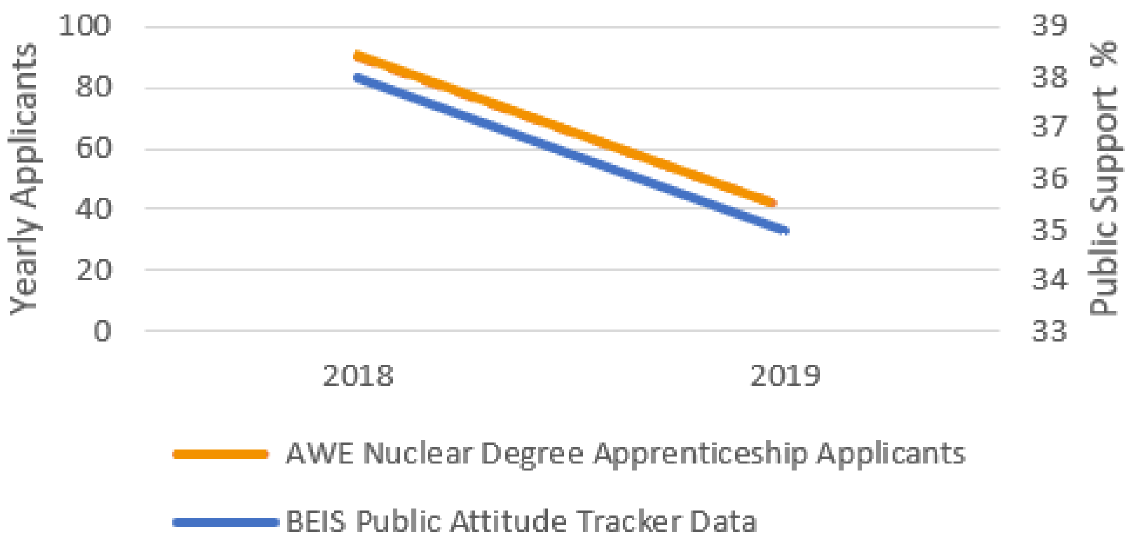
Comparably, in the US, a Cornell University survey demonstrated that engineering students' preconceptions of industries influenced their career decisions even though these were swayed by wider public perception.[37] This is highly relevant since engineers are a key component of all three skill tiers and in demand across many STEM industries.[38] Additionally, since nearly 60%

31. Ofqual, 'GCE Subject Level Conditions and Requirements for Environmental Science', 2016, pp. 3–4, 12, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/504231/gce-subject-level-conditions-and-requirements-for-environmental-science.pdf>, accessed 13 July 2020.
32. Ofqual, 'GCE Subject Level Conditions and Requirements for Environmental Science', p. 24.
33. AQA, 'AS And A-Level Physics Specification', 2015, pp. 41–46, <https://filestore.aqa.org.uk/resources/physics/specifications/AQA-7407-7408-SP-2015.PDF>, accessed 13 July 2020.
34. Janice Tripney et al., 'Factors Influencing Young People (Aged 14-19) in Education About STEM Subject Choices: A Systematic Review of the UK Literature', <https://discovery.ucl.ac.uk/id/eprint/1472699/7/Tripney_wtx063082.pdf>, accessed 12 July 2020.
35. Daniel B Turban, Organizational Attractiveness as an Employer on College Campuses: An Examination of the Applicant Population', *Journal of Vocational Behavior* (Vol. 58, No. 2, 2001), pp. 293–312.
36. NSSG, 'Nuclear Workforce Assessment', 2019, p. 27, <https://www.nssguk.com/media/2018/nuclear-workforce-assessment-2019-full-report-final.pdf>, accessed 12 July 2020.
37. Christopher J Collins and Cynthia Kay Stevens, 'The Relationship Between Early Recruitment-Related Activities and the Application Decisions of New Labor-Market Entrants: A Brand Equity Approach to Recruitment', *Journal of Applied Psychology* (Vol. 87, No. 6, 2002), p. 1121.
38. HM Government, 'Sustaining Our Nuclear Skills', pp. 9–11.

of staff recruited (excluding trainees) came from outside the industry[39] it is important to note that the *International Journal of Selection and Assessment* found that general recruitment into organisations is influenced by public opinion.[40]

Furthermore, even though records of applications to the Atomic Weapons Establishment are only kept for two years, when compared with BEIS public opinion data[41] they suggest public perception influences the number of applicants to Nuclear Degree Apprenticeships, as seen in Figure 3.[42]

**Figure 3:** Comparison of Applicants to Public Opinion




*Source: Department for Business, Energy and Industrial Strategy, 'Wave 33-Excel Dataset. BEIS Public Attitudes Tracker, 2020, <https://www.gov.uk/government/statistics/beis-public-attitudes-tracker-wave-33>, accessed 12 July 2020; Defence Nuclear Organisation Secretariat, Ministry of Defence, Ref: FOI2020/05747, 16 June 2020, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/897529/FOI202005747.pdf>, accessed 12 July 2020.*

39. NSSG, 'Nuclear Workforce Assessment', p. 27.
40. Greet Van Hoye and Filip Lievens, 'Recruitment-Related Information Sources and Organizational Attractiveness: Can Something Be Done About Negative Publicity?', *International Journal of Selection and Assessment* (Vol. 13, No. 3, 2005), pp. 179–87.
41. Department for Business, Energy and Industrial Strategy, 'Wave 33-Excel Dataset', BEIS Public Attitudes Tracker, 2020, <https://www.gov.uk/government/statistics/beis-public-attitudes-tracker-wave-33>, accessed 12 July 2020.
42. Defence Nuclear Organisation Secretariat, Ministry of Defence, Ref: FOI2020/05747, 16 June 2020, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/897529/FOI202005747.pdf>, accessed 12 July 2020..

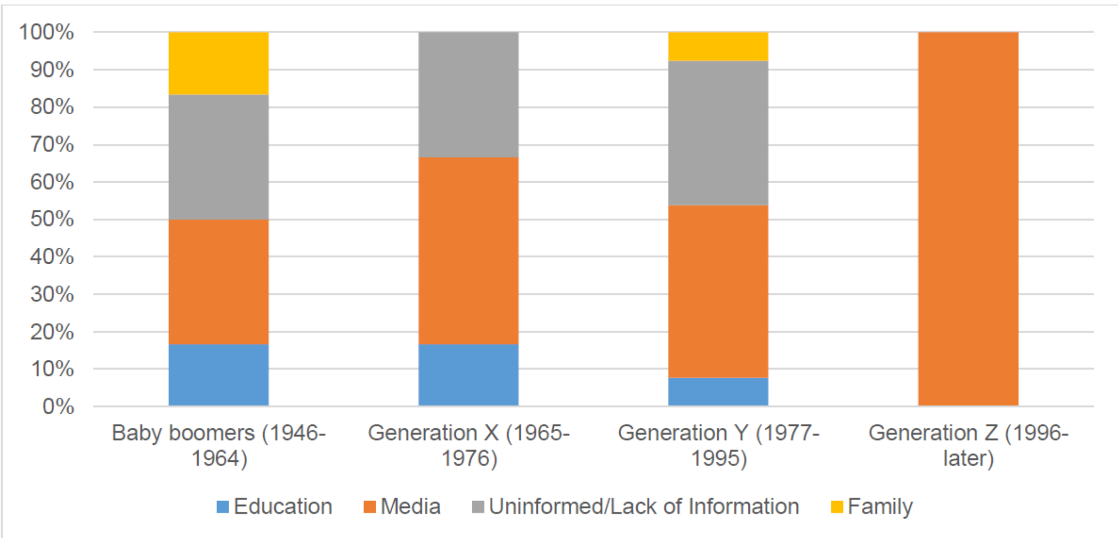
Finally, the YNSPF surveyed seven companies and showed that 'a near majority (47.8%) of all respondents had a positive perception of the nuclear industry prior to joining', while only 12% held a negative perception.[43] When combined with public perception at the time (showing 38% of the population supporting the nuclear industry and 22% opposing the industry[44]), it is clear that positive public perception has an impact on recruitment.

It should also be noted that since the July 2014 NIC publication, 'In the Public Eye: Nuclear Energy and Society' (which outlined a strategy to improve public perception of the industry in part through the media),[45] public perception has fallen slightly from 42% supporting the industry in September 201 to 32% in March 2020.[46]

## The Media

Accordingly, the YNSPF survey on sources of perceptions about the nuclear industry suggests the media has an increasing impact, as seen in Figure 4.[47]

**Figure 4:** Perceived Source of Negative Opinions of the Nuclear Industry, by Generation

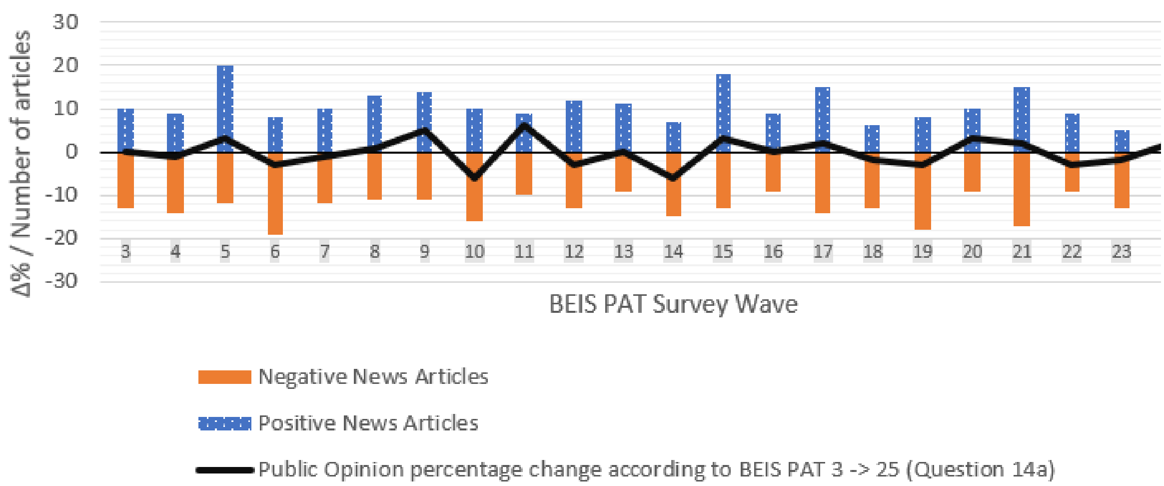



*Source: Percy et al., 'Generational Analysis for the Recruitment and Retention of Talent Within the Nuclear Industry'.*

43. Percy et al., 'Generational Analysis for the Recruitment and Retention of Talent Within the Nuclear Industry'.
44. Department for Business, Energy and Industrial Strategy, 'Wave 33-Excel Dataset'.
45. Nuclear Industry Council, 'In the Public Eye: Nuclear Energy And Society', Issue 1, July 2014.
46. Department for Business, Energy and Industrial Strategy, 'Wave 33-Excel Dataset'.
47. Percy et al., 'Generational Analysis for the Recruitment and Retention of Talent Within the Nuclear Industry'.

This data highlighted the need for a more detailed assessment of the impact media coverage has on public perception of the nuclear industry. This led to a comparison of BEIS Public Attitude Tracker (PAT) data[48] (part of which aimed to assess public opinion of the UK nuclear industry) and sentiment analysis of 545 online news articles from the *BBC*, *Daily Mail* and *The Guardian* that relate to UK civil or military nuclear issues between September 2012 and March 2018. The articles were located using the Guardian API and Google Advanced Search Tools while the media sources were selected because of their varied political leanings[49] and consistently high readership.[50] The analysis was conducted manually but verified with the Python Natural Language Toolkit[51] to maintain consistency while the time set was chosen because it was the longest continuous set of accessible polling on public opinion of the nuclear industry. The BEIS PAT data consists of 48,302 survey responses over 22 quarterly survey waves averaging 2,100 responses per wave plotted for Q14a: 'From what you know, or have heard about using nuclear energy for generating electricity in the UK, do you support or oppose its use?'.[52] The results in Figure 5 suggest a correlation between the media and public perception.

**Figure 5:** Percentage Change in Public Support Overlayed on all Online News Articles About UK Civil/Military Nuclear Between September 2012 and March 2018




*Source: Department for Business, Energy and Industrial Strategy, 'Wave 33-Excel Dataset'.*

48. Department for Business, Energy and Industrial Strategy, 'Wave 33-Excel Dataset'.
49. Matthew Smith, 'How Left or Right-Wing are the UK's Newspapers?', YouGov, 7 March 2017, <https://yougov.co.uk/topics/politics/articles-reports/2017/03/07/how-left-or-right-wing-are-uks-newspapers>, accessed 13 July 2020.
50. YouGov, 'The Most Popular Newspapers in the UK', 2020, <https://yougov.co.uk/ratings/media/popularity/newspaper/all>, accessed 13 July 2020.
51. Steven Bird, Ewan Klein and Edward Loper, *Natural Language Processing With Python: Analyzing Text With the Natural Language Toolkit* (Sebastopol, CA: O'Reilly Media Inc, 2009).
52. Department for Business, Energy and Industrial Strategy, 'Wave 33-Excel Dataset'.

There are limitations to the survey as no distinction was made between a small article and front-page coverage. Additionally, the survey examines three major online media sources and excludes other media, such as television. This may serve to explain abnormalities such as wave eleven, which saw an uptick in public perception of the nuclear industry despite net negative coverage at the time due to highly visible coverage that Hinkley Point C had gained approval[53] while multiple negative articles about EDF reactors remaining offline were less visible.[54]

Despite this, the results of the survey suggest that media coverage is shaping public perception and, by extension, recruitment into the pipeline. In addition to a visible correlation, it shows that of the articles surveyed, 55% left the reader with a negative impression of the nuclear industry. However, in terms of impact, positive articles were more effective, requiring an average of 4.5 articles to gain a percentage point, but 6.56 negative articles to lose a percentage point. While negative articles have a smaller impact, their greater number means that on balance the media appears to have a negative impact on public perception.

## Conclusion

In conclusion, while apprenticeship policy supports training via the levy, defence policy subsidises training in addition to steering new build to ensure defence and civil skillsets are interoperable. Both of these policy solutions benefit from the STEM skills developed by education policy which works with the media to shape public perception that has a clear effect on recruitment.

53. Arthur Neslen, ‘Hinkley Nuclear Reactor Project Gains EU Approval, Leak Reveals’, *The Guardian*, 22 September 2014.
54. *BBC News*, ‘Nuclear Reactors May Stay Offline Until End of Year, EDF Says’, 4 September 2014; Hugo Duncan, ‘Fears of Winter Blackouts as Repairs to Mend Boiler Cracks Shut EDF Nuclear Plants for Two Years’, *Daily Mail*, 18 October 2014.

# VI. Addressing the 'Leaky Pipeline': Taking the Temperature of the UK's Early Career Nuclear Weapons Policy Cohort

Emily Enright

THIS RESEARCH PROJECT interrogates the idea of a 'leaky pipeline' in the nuclear weapons policy community which, according to the call for proposals for the UK PONI's 2020 Annual Conference (to which this paper responded), is a 'key challenge … (where) early to mid-career professionals leave the field for various reasons after a promising start in it'.[1] This may well be an accurate assessment, but surprisingly little supporting evidence is available – much of the knowledge in this area, specifically pertaining to the UK experience, is tacit and often anecdotal.

Whether there are challenges presented to the UK's nuclear weapons policy community by a 'leaky pipeline' is contestable on at least two fronts. First, for this premise to be credible, there must be a demonstrable career pipeline operating in the space from which early to mid-career staff are 'leaking'. Second, if there is a pipeline, and if it is indeed leaking, this only presents a challenge if the leak is unsustainable, or if it is being driven by negative workplace or sector conditions that are adversely impacting the nuclear weapons policy community. Attrition of early-career professionals from any field is presumably to be expected, as younger employees discover new interests or change location, for example.[2] The real issues at stake then are how much attrition is the 'right' amount, and whether attrition is being driven by the 'right' forces. This paper takes the first steps in addressing these questions. It attempts to gauge whether a career 'pipeline' is applicable and/or observable in this field, and what the key drivers of attrition from the field are among junior cohorts (what could be causing a 'leak'?), and furthermore provides recommendations for addressing the issues uncovered during data collection and analysis.

## Aims and Methodology

The core aims of the project for this paper were to examine the current and projected career 'pathways' of young professionals in the nuclear policy field (probing the concept of the 'pipeline'), and to assess factors that are driving the attrition of this cohort.

1. RUSI, 'The 10th UK PONI Annual Conference: Call for Presentations', 11 June 2020, p. 1.
2. Amy Adkins, 'Millennials: The Job-Hopping Generation', Gallup, <https://www.gallup.com/workplace/231587/millennials-job-hopping-generation.aspx>, accessed 7 July 2020.

This qualitative research project employed two steps for sampling and data collection. The sample was fairly expansive – any person aged 30 or under working on nuclear issues in the UK. The 'target cohort' within the sample comprised individuals working on nuclear policy in research institutes (think tanks and academic institutes), but the wider sample included, for example, members of the defence nuclear and nuclear energy industry cohorts – providing valuable comparisons between sectors.[3]

The first and primary data-collection method was an online survey posted on Google Forms.[4] Composed of 13 questions (five demographic, six exploratory short-answer, and two multiple-choice questions), the survey was designed to elicit respondents' insights on their experiences of attrition risks and retention opportunities in the UK nuclear community.[5]

The second data-collection method was 10 short, semi-structured interviews with volunteers drawn from the survey sample, as well as with representatives of various nuclear sectors (policy experts, government officials, academics and industry professionals) from across the UK. The interviewees drawn from the survey were exclusively employees in nuclear policy, facilitating an in-depth look at the challenges and opportunities for this small cohort.

The data analysis categorised survey respondents by age, gender, sector, type of employment, time since entering the field, and predicted time remaining in the field. This step was useful in generating a workforce profile.[6] Short-answer responses were coded by the types of interventions respondents noted that their workplaces offer, interventions not offered but desired, and interventions neither offered nor desired. Where possible, they were also coded for respondents' identification of specific attrition risks, as well as their magnitude (rated significant or insignificant) and emotional or professional impact (rated high, medium or low). The key findings, which informed the policy recommendations detailed in this paper, are presented in the next section.

---

3. Pamela Baxter and Susan Jack, 'Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers', *Qualitative Report* (Vol. 13, No. 4, December 2008), pp. 544–59.
4. The survey can be found at <https://docs.google.com/forms/d/e/1FAIpQLSejv4jFQF4ULv-UNpOabeJ-b-yDHYzYdcHi8JnEt38ZVvf6eQ/closedform>, accessed 23 September 2020. The value of staff surveying to assess retention intervention needs is outlined in Jack Phillips and Adele Connell, *Managing Employee Retention: A Strategic Accountability Approach* (London: Taylor & Francis Group, 2011), p. 27.
5. The value of insights on current staff is outlined in Jeremy Wilson et al., *Recruiting and Retaining America's Finest: Evidence-Based Lessons for Police Workforce Planning* (Cambridge: RAND Corporation, 2010), p. 32.
6. The value of demographic analysis is noted in Phillips and Connell, *Managing Employee Retention,* p. 27.

## Data/Results

Of the 55 survey respondents, 21 (37.5%) self-identified as working in either policy and research institutes (11) or academia (10). Of those, 19 described their work as related to defence and security issues within the nuclear research and policy field. The author's 'target cohort' was thus 19 (34.5%) of the respondents. Of these, 13 (68.4%) identified as women (including transgender women), 12 (63.1%) were aged 23–26, 11 (57.9%) were employed full time, and the average length of time elapsed since they entered the field was just over two years. Asked to estimate how long they intended to remain in the nuclear weapons policy field, 14 (73.7%) answered 'unsure or don't want to say' (57.9%) or 'less than five years' (15.8%), while only 3 (15.8%) answered '10 years or more'.

The target cohort reported a variety of positive factors in their workplace and wider nuclear weapons policy community experience that were actively facilitating their retention in the field. These included opportunities to attend conferences and other professional events (10 [52.6%]), flexible working policies (9 [47.4%]), professional development and education opportunities (8 [42.1%]) and networking opportunities provided or facilitated by their employer (6 [31.6%]).

When asked to specify the attrition drivers that might precipitate a decision to leave the nuclear policy field, the target cohort gave a wide array of responses. Table 1 compares the percentage of respondents in the target cohort to those overall reporting five key drivers as likely to significantly impact any future decision to leave the field: need or desire to diversify careers beyond nuclear, insufficient jobs or advancement opportunities, suboptimal remuneration (noting that exact salary figures were not discussed), negative workplace culture (examples included harassment), and suboptimal working conditions (limited flexible working policies, job-share opportunities, inflexible paid leave policies, etc.)

**Table 1:** Respondents Confirming Key Drivers of Attrition from Nuclear Industry

| Attrition Driver | Target Cohort | Overall |
|---|---|---|
| Need to expand into a broader field (for example, security) or otherwise diversify experience | 57.9% | 32.7% |
| Insufficient jobs and/or vertical progression opportunities | 42.1% | 30.9% |
| Suboptimal remuneration | 31.6% | 29.1% |
| Negative workplace culture | 26.3% | >10% |
| Suboptimal working conditions | 26.3% | >10% |

*Source: Author generated.*

Finally, when asked to specify whether any particular interventions could be implemented to increase their retention in the nuclear weapons policy field, respondents in the target cohort pointed to both business practices and changes to and within the wider nuclear weapons policy community. Of the respondents, 16 (84.2%) suggested that assistance and support with career planning would be a very significant intervention for their retention; 11 (57.9%) called for formalised mentoring; eight (42.1%) for higher salaries; and seven (36.8%) for improved workplace culture (particularly greater emphasis on healthy work/life balance). Other interventions included more funded opportunities for professional and academic development, greater inclusion and diversity in the workforce, more scope for interdisciplinary work and learning.

# Discussion and Recommendations

Generated data presents several findings significant to the objectives of this research. To recap, the core aims of the project were to assess what factors might be driving attrition of early career researchers from the nuclear weapons policy field and to examine the conception of a 'pipeline' in this space. With this in mind, key results from the dataset are that at least some attrition is being driven by negative features of the field (and that these attrition risks are reported more frequently than in other nuclear sectors such as the nuclear energy industry). Additionally, there might not be a clear 'pipeline' for researchers to move up through the field in the traditional sense – despite there being significant appetite among early career staff for clearer career pathways.

This paper considers three areas for potential interventions to manage these issues.

### Business Practices

In the category of business practices, survey respondents noted several interventions that might facilitate their retention in the nuclear weapons policy field (see previous section). Interventions of this type facilitate greater job satisfaction and, therefore, staff retention, and perhaps more importantly, their implementation would respond directly to the concerns of today's early career researchers.[7] Their implementation should thus be seen as a baseline expectation for the organisations comprising the UK's nuclear weapons policy community.

The very small number of early career research positions at policy and research institutes or in academia is another significant issue. Increasing the number of paid early-career positions in nuclear weapons policy will contribute to generating a much greater pool of skilled and experienced candidates at the mid-career level and will also contribute to the overall strength and quality of the UK's nuclear weapons policy community.

### Field Configuration: Size and Silos

In terms of the configuration of the nuclear weapons policy field, several interventions could make a difference to retention. First, study participants did not feel that diversity and inclusion measures are being met by employing organisations. Interviewees noted an increasing emphasis on promoting gender equality in the nuclear weapons policy (and broader security) space, facilitated by the efforts of bodies such as Women in International Security UK and Women in Nuclear UK.[8] Other diversity metrics, such as the inclusion of BAME, those who identify as LGBTIQ+, and people who are not neurotypical or able-bodied, do not seem to have been met. Diversity and inclusion are widely recognised as essential ingredients for innovation and success in all fields,[9] and organisations in the nuclear weapons policy have work to do to meet the expectations of early career staff.

Fostering diversity in terms of the skillsets of those involved in policymaking could also address some of the attrition risks outlined by survey respondents. Of the target cohort, 57.9%, and of the overall sample, 32.7%, cited the need to gain experience and skills outside the nuclear

7. Harold Goldstein et al., *The Wiley Blackwell Handbook of the Psychology of Recruitment, Selection and Employee Retention* (Chichester: John Wiley and Sons, 2017), pp. 44–72, 494–512.
8. See, for example, Kate Hewitt et al., 'Breaking Barriers: Best Practices for the Advancement and Inclusion of Women in STEMM and National Security', CRDF Global, 2019, <https://www.crdfglobal.org/what-we-do/women-science-and-security>, 2019; Heather Hurlburt et al., 'The "Consensual Straitjacket": Four Decades of Women in Nuclear Security', *New America*, 2019; Sylvia Mishra, 'The Importance of Creating Gender-Equitable Space in the Field of Nuclear Policy', *Atomic Pulse,* 2018; N Square Collaborative, 'Greater Than: Nuclear Threat Professionals Reimagine Their Field', 2019.
9. There is a significant literature on this topic, see, for example, Ankita Saxena, 'Workforce Diversity: A Key to Improve Productivity', *Procedia Economics and Finance* (Vol. 11, 2014), pp. 76–85, <https://www.sciencedirect.com/science/article/pii/S2212567114001786>, accessed 8 July 2020.

field to facilitate career advancement as a significant attrition risk. Breaking down the silos between policy, academia, industry and the military, and promoting transdisciplinary exchanges and collective learning could both reduce the impact of this attrition risk and bolster the quality and innovativeness of the UK's nuclear weapons policy community.

### Support for Early Career Researchers

The survey and interview results reinforced scepticism of a career 'pipeline' in the UK's nuclear weapons policy field. Of the target cohort, 84.2% called for increased career planning assistance and support, suggesting that pathways for advancement in the field are not evident to early career staff. Indeed, several interviewees flatly refuted that any pipeline exists, and lamented that a lack of guidance in this area diminishes their ability to plan for the future or take career risks. Clearly, there is appetite for interventions in this space.

Education for early career staff on the complex reality of career progression in nuclear weapons policy is a key step. If the community and/or the employment market cannot support certainty and structure in the careers of today's early career cohort, this information needs to be effectively disseminated, and expectations managed from the point of entry into the field. Career planning support is deeply valuable for employees and employers,[10] and senior leaders and employers in nuclear weapons policy, given their wealth of experience, should take responsibility for educating and guiding their younger colleagues. Challenges to the UK's economy and employment market due to the coronavirus pandemic could provide impetus for the nuclear weapons policy community to reconceptualise and co-design contemporary career pathways that have high tolerances for uncertainty, and which encourage early career researchers to seek diverse experiences and skills from the outset.

## The Way Ahead

Collecting and analysing more data should be the first step in moving forward from this research. More research is needed to map today's workforce, to better assess retention needs and attrition risks, and answer the question 'how much attrition is the right amount?'. In the long term, centralisation and oversight of reform of the nuclear weapons policy community could be achieved through the development of an advocacy body, but this idea requires time and dedication to scope. In the meantime, improving business practices, addressing field configuration issues and helping the next generation of leaders come to terms with the changed career landscape are vital steps that will yield positive results for the workforce of today and tomorrow.

10. William Rothwell et al., *Career Planning and Succession Management: Developing Your Organisation's Talent – for Today and Tomorrow*, 2nd Edition (Santa Barbara, CA: Praeger, 2015), pp. 3–22.

# VII. Cyber- and Space-Based Capabilities and Their Impact on Strategic Stability

Marina Favaro

THERE IS LITTLE scholarship dedicated to understanding how new capabilities in the space and cyber domains – or indeed, how existing capabilities in the hands of new actors – might impact strategic stability. Without a systematic assessment of these technologies, both the anxiety and opportunities associated with so-called 'emerging technologies' (although some have been around for a while) go unchecked. Thus, evaluating and comparing these technologies is in the interests of the nuclear policy community, because it will facilitate more effective prioritisation and policymaking.

## Method

In order to assess the possible future impact of cyber- and space-based capabilities on strategic stability and propose policy responses, this paper uses the STREAM (Systematic Technology Reconnaissance, Evaluation and Adoption Methodology) approach, developed by Steven Popper and his RAND colleagues.[1] STREAM provides a structured process for assessing the potential application and disruptiveness of capabilities against the same criteria. This is done through a questionnaire, which asks experts to evaluate technologies against technological maturity, impact and implementation criteria. Experts are also asked to make any qualitative remarks in the STREAM questionnaire itself and in an exercise debrief. This method helps to overcome the challenges associated with comparing technologies – especially across two domains – while cutting through hype and/or misinformation.

## Defining Strategic Stability

In designing this study, this paper acknowledges that there are multiple definitions for strategic stability.[2] Rather than narrow it down to one definition, instead the focus is on defining metrics that amount to a model for strategic stability. The model for analysing strategic stability has five aspects:

1. National Academies of Sciences, Engineering, and Medicine, 'Strategic Issues Facing Transportation, Volume 3: Expediting Future Technologies for Enhancing Transportation System Performance', 2013.
2. Institute of World Economy and International Relation Russian Academy of Sciences, 'Strategic Stability After the Cold War', 2010.

1. Technological maturity.
2. Rate of development.
3. Capability increase.
4. Ease of countering.
5. Crisis instability.

Together, these metrics produce a model for strategic stability that is somewhat definition-agnostic and modular.

Crucially, these metrics amount to only one definition of strategic stability, and there are many other metrics which do not feature here, such as the ability to attribute the use of the technology to a specific actor and whether the technology is likely to be developed in the private sector. The benefit of using the STREAM method is that the analysis that is presented in subsequent sections is only one of many possible ways of 'cutting' the data.[3]

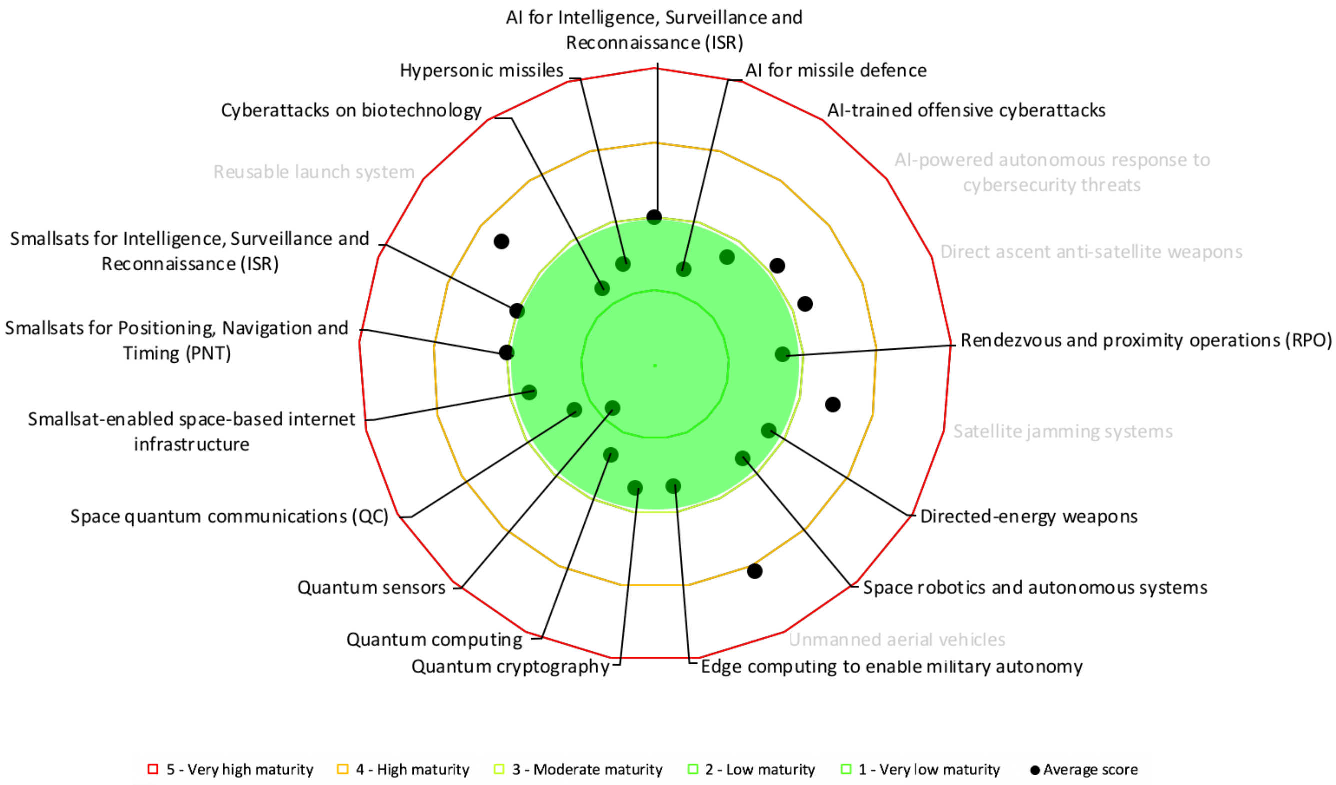
## Technological Maturity

The rationale for including technological maturity as a metric for strategic stability is that only technologies that will mature within the next 10 years constitute a threat to strategic stability within the scope of study. For this to be the case, technologies need to be of a reasonable maturity now.

Most technologies were gauged by experts[4] (n=10) to be low to moderate in their technological maturity for the UK and its allies, as shown in Figure 1. However, Figure 2 illustrates that a few technologies have already reached technological maturity, meaning that they have the potential to cause an imminent threat to strategic stability.

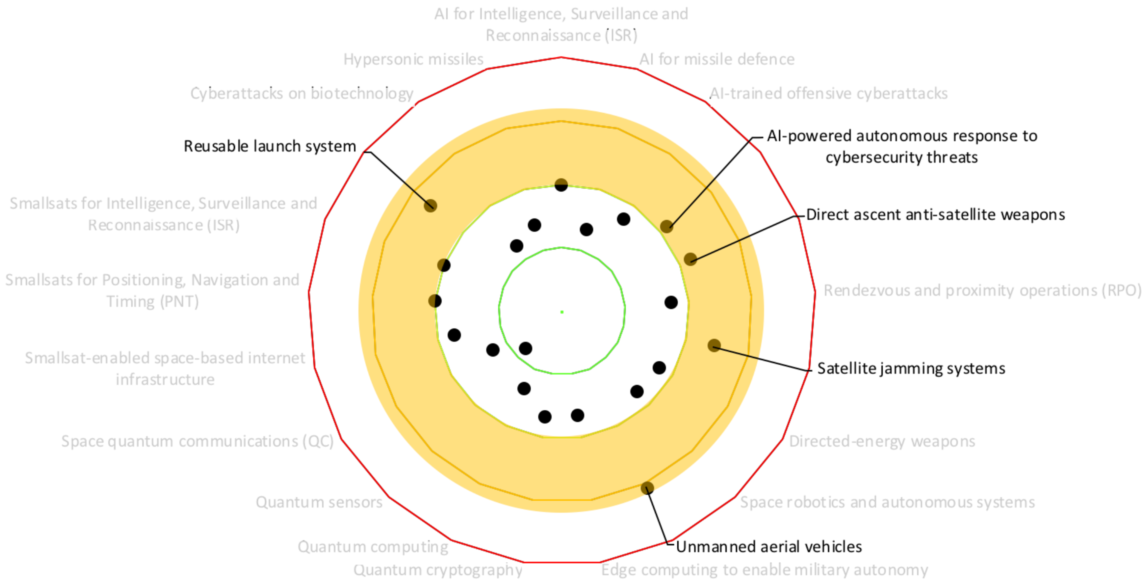
3. All figures in this conference paper use scores from the STREAM questionnaire.
4. Experts were primarily drawn from academia and think tanks, but one expert represented private sector/industry. These experts were chosen on the basis of their familiarity with the method and/or cyber/space domains and/or emerging technologies. As this is a proof-of-concept study, the author does not allege that these research participants are representative of the sector as a whole.

**Figure 1:** Most Technologies are Considered Low-to-Moderate Maturity




*Source: Author generated.*

**Figure 2:** Some Technologies are Reasonably Mature and Pose an Imminent Threat to Strategic Stability




*Source: Author generated.*

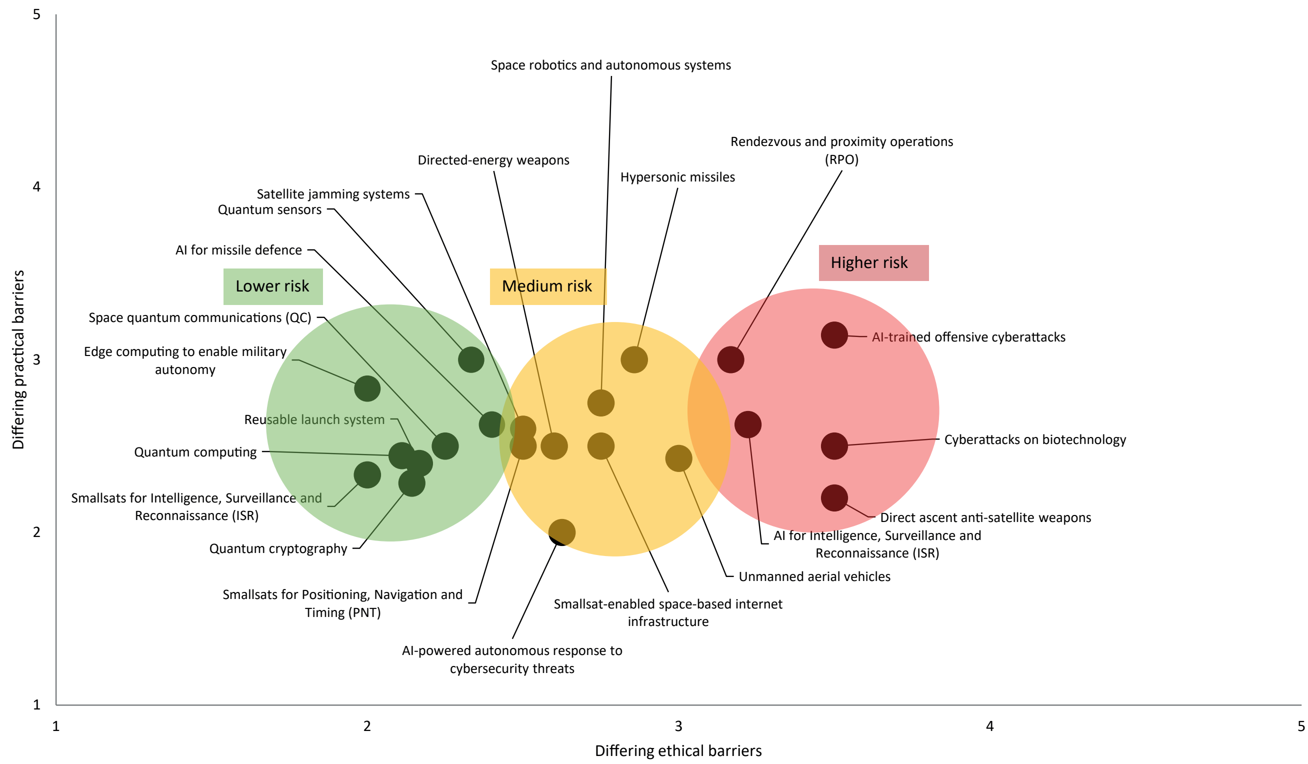
# Rate of Development

If technologies develop at different rates between adversaries, the rate of development may lead to asymmetries in capability, which may in turn compromise strategic stability.[5] On the other hand, technologies that develop at similar rates for the UK and its allies and the UK's adversaries may pose a lower threat to strategic stability. The assumption here is that these technologies affect each party equally.

The graph in Figure 3 shows how barriers to implementation – both ethical and practical – differ for the UK and its allies versus the UK's adversaries. In the bottom left corner, both the UK and its allies and the UK's adversaries have similar barriers to implementation, whereas in the top right corner, the UK's adversaries have lower barriers to implementation. Although there is variation in ethical barriers along the x-axis, the practical barriers are roughly the same for both parties.

5. Lawrence Freedman and Jeffrey Michaels, *The Evolution of Nuclear Strategy: New, Updated and Completely Revised*, 4th Edition (London: Palgrave Macmillan, 2019), pp. 233–35.

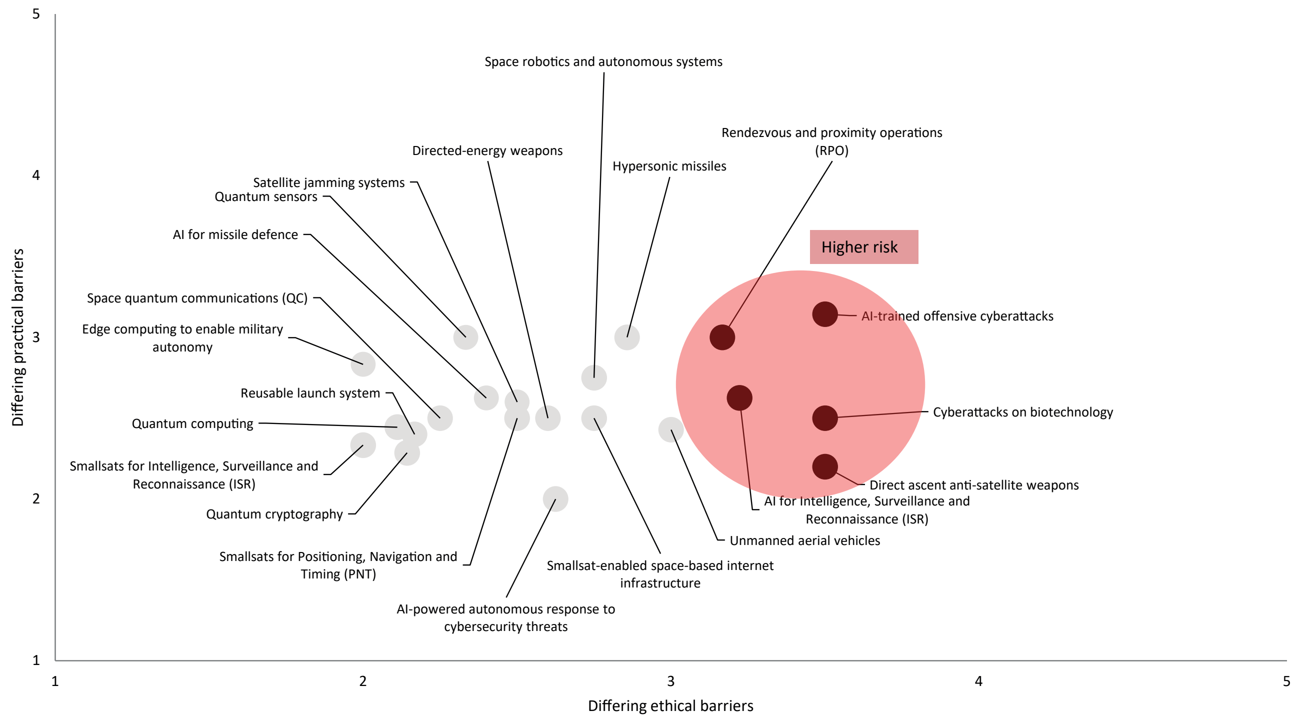
**Figure 3:** Evaluating the Degree to Which Ethical and Practical Barriers Differ for the UK and its Allies Versus for the UK's Adversaries




*Source: Author generated.*

The technologies highlighted in red in Figure 4 can be understood as being a more imminent threat to strategic stability, because the ethical barriers to development and/or deployment are lower for the UK's adversaries than they are for the UK and its allies and practical barriers are about the same. Given that barriers to implementation are relatively low, a quicker rate of development for the UK's adversaries relative to the UK and its allies can be expected, which has the potential to upset strategic stability.

**Figure 4:** Technologies With the Highest Risk of Asymmetrical Development

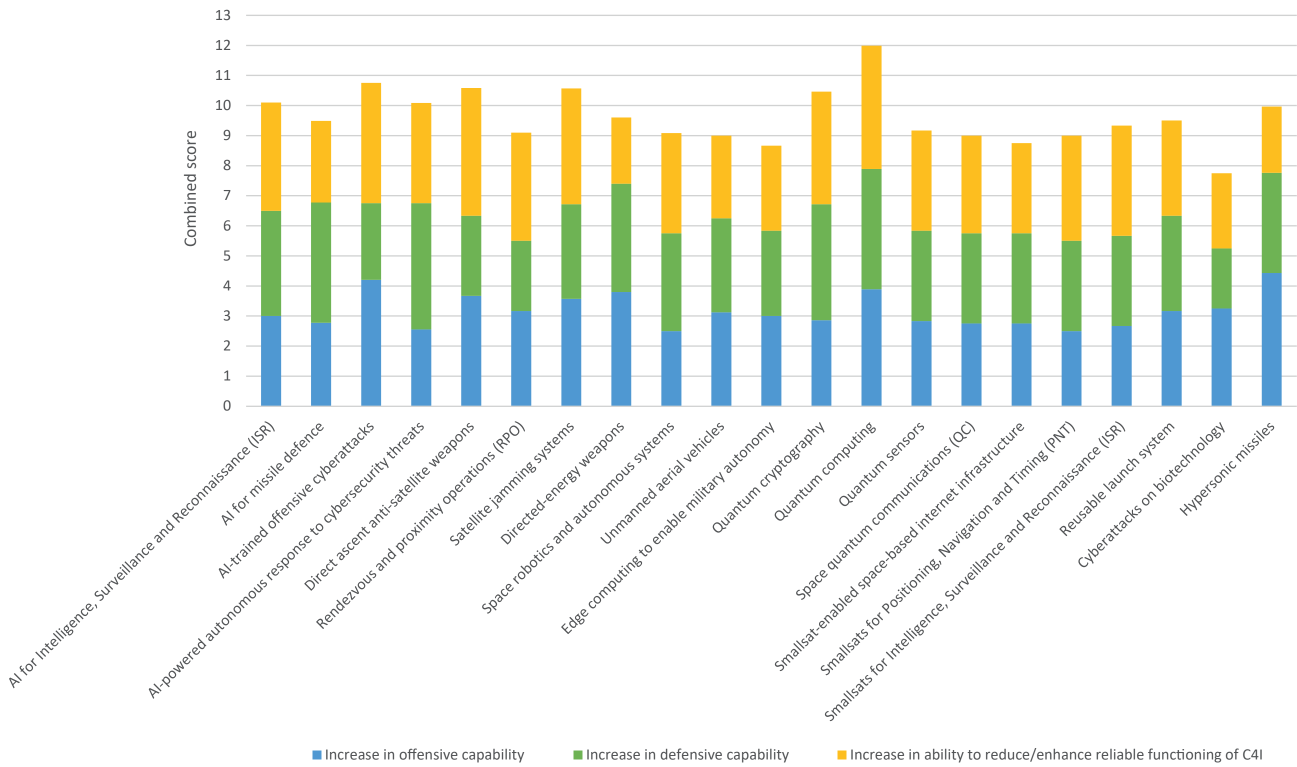



*Source: Author generated.*

# Capability Increase

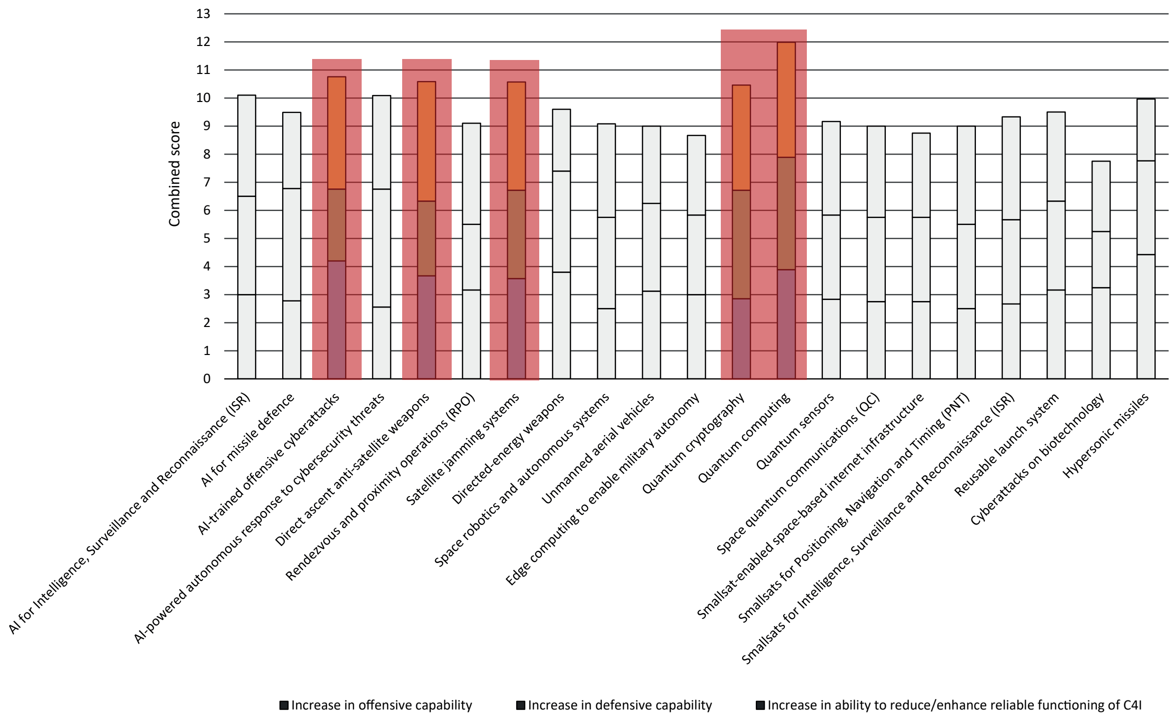
Figure 5 illustrates the landscape of capability increase across all technologies, accounting for: an increase in offensive capability in blue; an increase in defensive capability in green; and an increase in the ability to reduce or enhance the reliable functioning of command, control, communications, computers, and intelligence (C4I) in yellow. Figure 6 highlights the technologies with the greatest total capability increases. Technologies that significantly impact all three of these capabilities are well positioned to impact strategic stability.

**Figure 5:** Evaluating Which Technologies Would Create the Biggest Capability Increase if Developed




*Source: Author generated.*

**Figure 6:** Technologies With the Greatest Capability Increase if Developed




*Source: Author generated.*

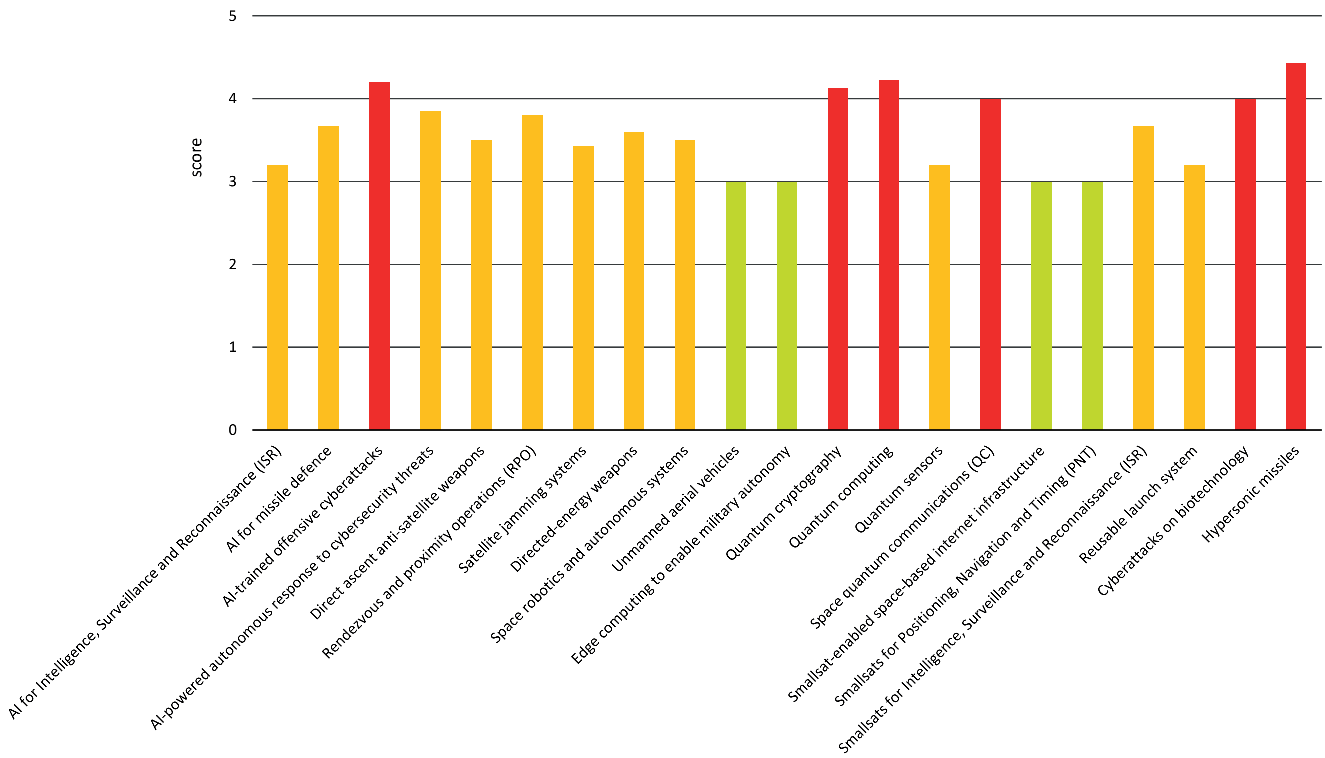
# Ease of Countering

Technologies that are more difficult to counter are potentially destabilising because a central tenet of strategic stability is that a potential attacker could be dissuaded from attacking if they perceive a countermeasure to their measure.[6] A technology that is potentially very impactful but is also easy to counter might be neutralised as a threat to strategic stability. By disaggregating 'potential impact' from 'ease of countering', the paper endeavours to eliminate game theoretic dynamics from the scoring exercise.

Figure 7 features a bar graph which surveys the ease or difficulty of countering each technology, whereas Figure 8 highlights the technologies that have the most potential to upset strategic stability because they are the most difficult to counter.

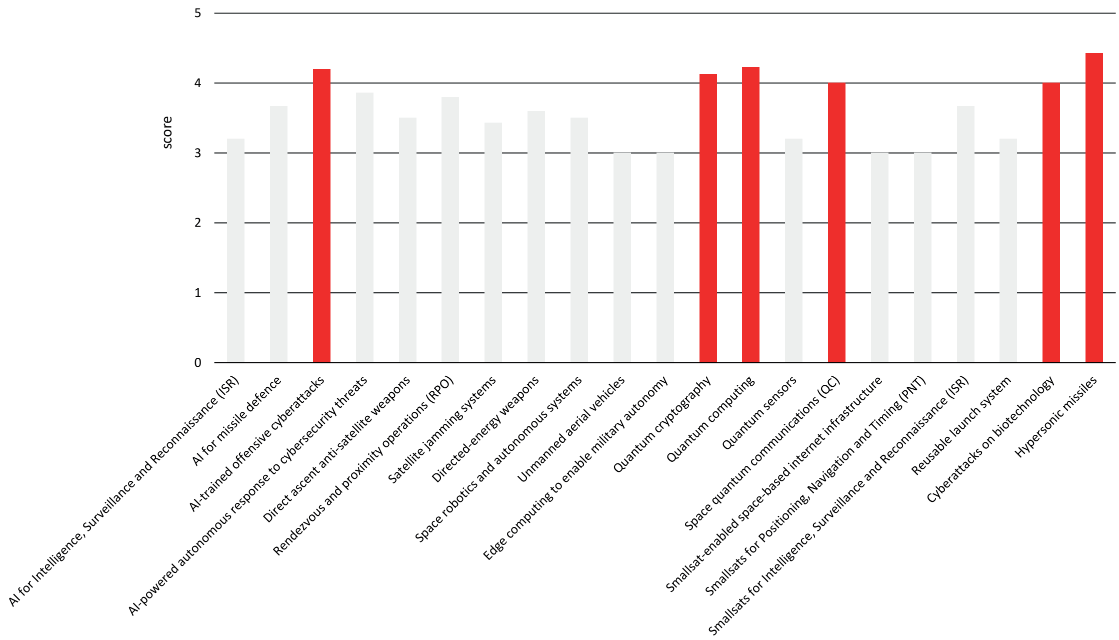
6. Christopher A Bidwell, J D and Bruce W MacDonald, 'Emerging Disruptive Technologies and Their Potential Threat to Strategic Stability and National Security', Special Report, Federation of American Scientists, September 2018.

**Figure 7:** Assessing Which Technologies Would Be the Most Difficult to Counter




*Source: Author generated.*

**Figure 8:** The Technologies That Would Be Most Difficult to Counter



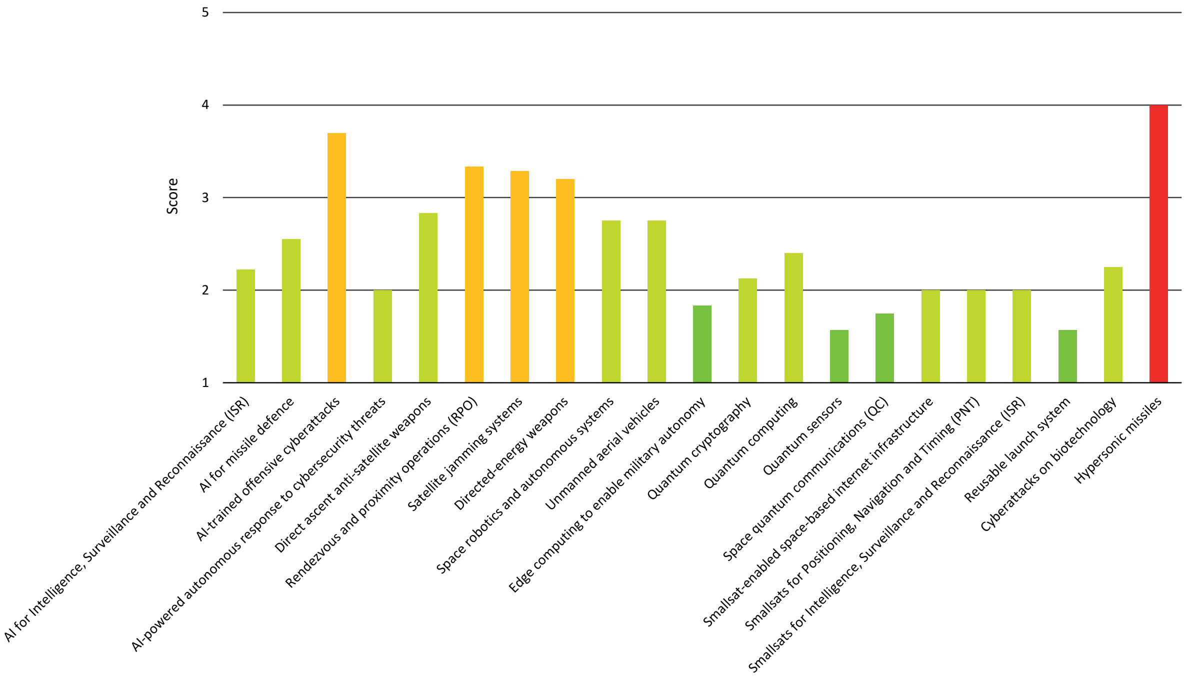

*Source: Author generated.*

# Crisis Instability

Technologies with the potential to trigger an escalatory response during a crisis might escalate a crisis past the nuclear threshold. Any technology that might incentivise the use of nuclear weapons first in a crisis would clearly be antithetical to strategic stability.

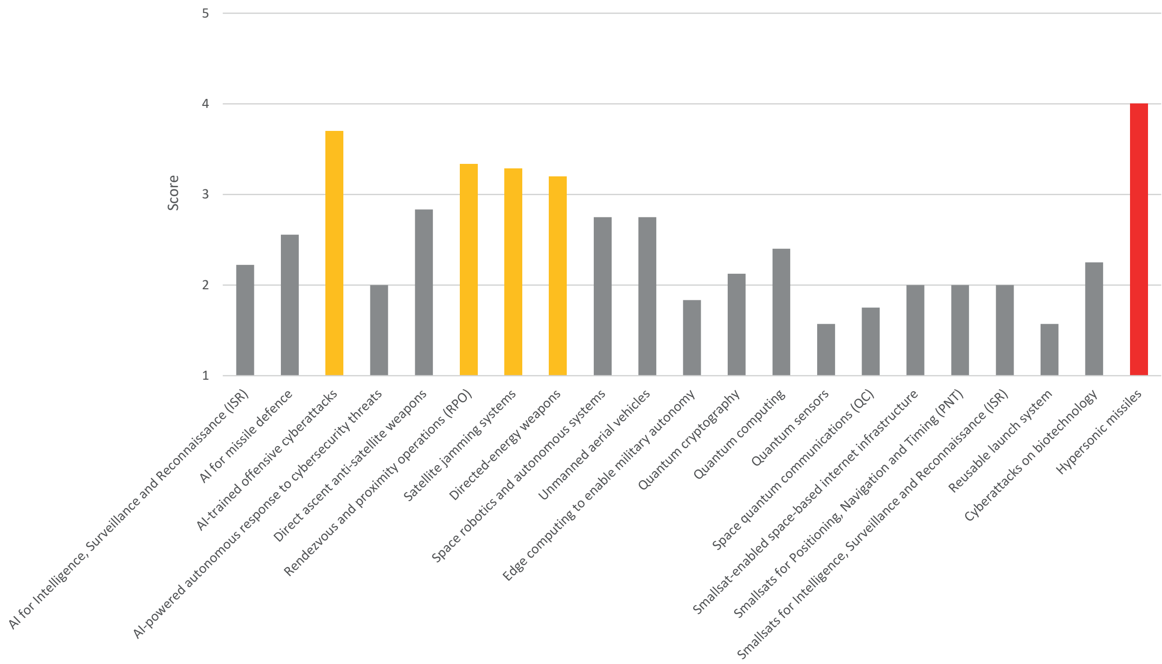
Figure 9 shows the extent to which each of the technologies, if deployed, would be likely to accelerate crisis instability, whereas Figure 10 highlights the top five technologies that would be most likely to accelerate an ongoing crisis.

**Figure 9:** Surveying Which Technologies – If Deployed – are Most Likely to Accelerate Crisis Instability




*Source: Author generated.*

**Figure 10:** Which Technologies – If Deployed – are Most Likely to Accelerate Crisis Instability




*Source: Author generated.*

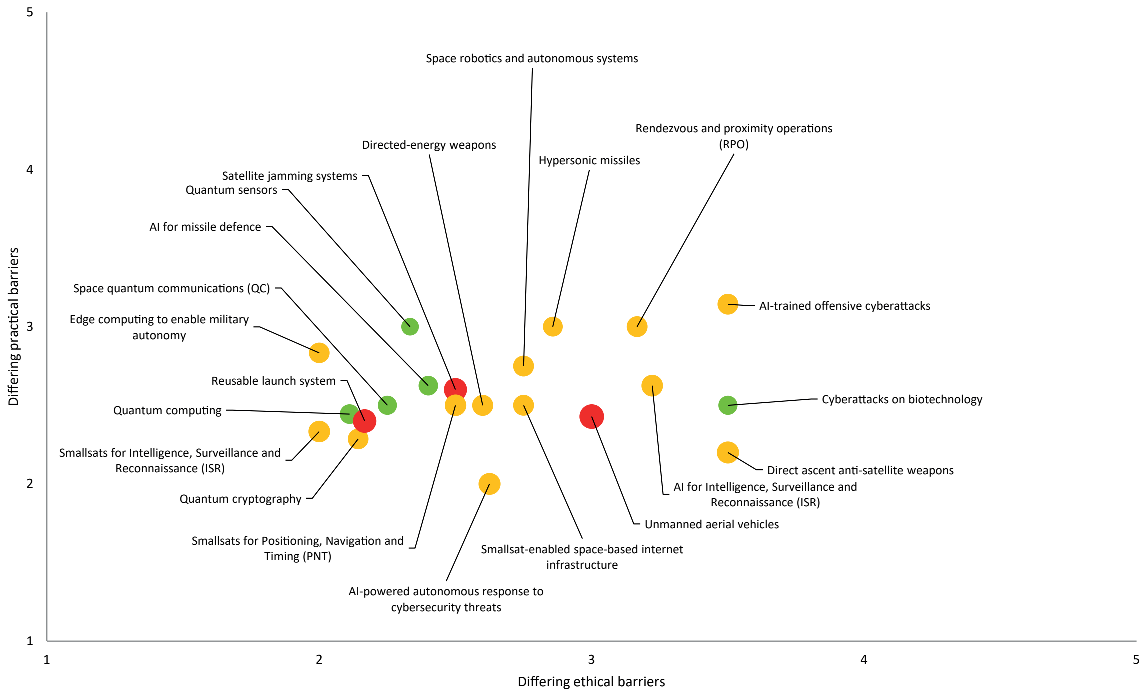
## Combining These Metrics

It is possible to combine these five metrics – technological maturity, rate of development, capability increase, ease of countering and crisis instability – in order to glean more nuanced interpretations of the impact of these technologies upon strategic stability.

### Combining Technological Maturity and Rate of Development

Combining current technological maturity with the rate of development yields a clearer picture of how mature technologies are right now and how quickly they might reach maturity. As before, the rate of development for each technology is deduced from the existence of barriers to implementation for a given technology.

**Figure 11:** Combining Technological Maturity With the Rate of Development




*Source: Author generated.*

The technologies highlighted in red in Figure 12 are at a moderate maturity level, with lower ethical barriers for the UK's adversaries relative to the UK and its allies and have about the same practical barriers for both parties.

The technologies highlighted in amber in Figure 12 paint two distinct pictures. On the one hand, 'cyber-attacks on biotechnology' are technologically immature, but it has the greatest disparity in ethical barriers between the UK and its allies versus the UK's adversaries, meaning that its development could happen quite quickly, making it potentially disruptive to an established order. On the other hand, UAVs are very mature technologically, but the lower ethical barriers for the UK's adversaries relative to the UK and its allies might mean that the UK's adversaries are less constrained in their deployment of this technology. By combining technological maturity and rate of development, these technologies constitute different types of threats to strategic stability.

**Figure 12:** Prioritising Technologies Using Technological Maturity and Rate of Development Metrics

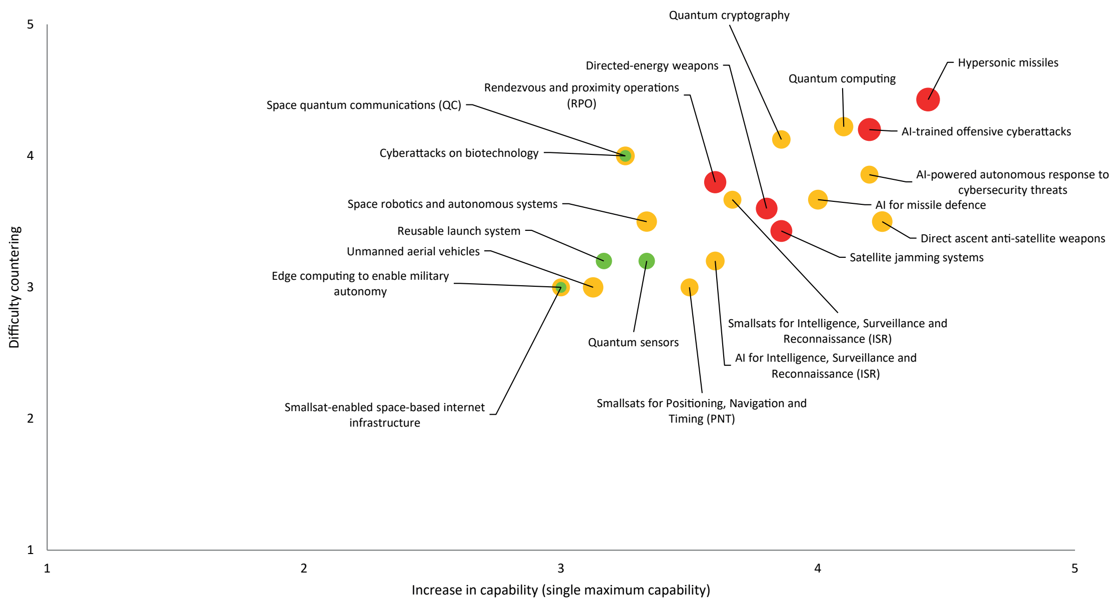

*Source: Author generated.*

## Combining Capability Increase, Ease of Countering and Crisis Instability

The second combination that this model lends itself to comprises capability increase, ease of countering and crisis instability.

Figure 13 shows the increase in capability on the x-axis and the difficulty in countering that technology on the y-axis. Increase in capability is expressed as the single maximum capability increase for each technology (capability increase for offensive or defensive forces or reducing/ enhancing the reliable functioning of C4I).

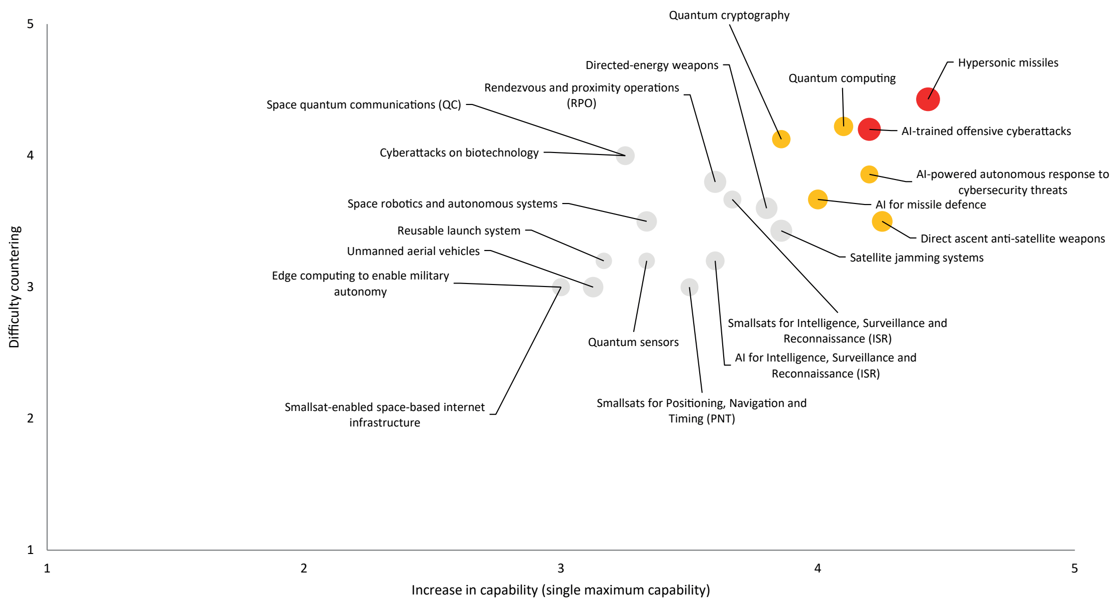
**Figure 13:** Combining Capability Increase, Ease of Countering and Crisis Instability




*Source: Author generated.*

The technologies highlighted in red in Figure 14 have the potential to significantly increase capabilities, are difficult to counter and are highly likely to accelerate crisis instability. On the other hand, the technologies highlighted in amber will have a similar impact on capabilities and are similarly difficult to counter but are slightly less likely to accelerate crisis instability. In conclusion, all the technologies highlighted in red or amber in Figure 14 have the potential to significantly impact strategic stability for different reasons.

**Figure 14:** Prioritising Technologies Using Increase in Capability, Difficulty in Countering and Acceleration of Crisis Instability Metrics




*Source: Author generated.*

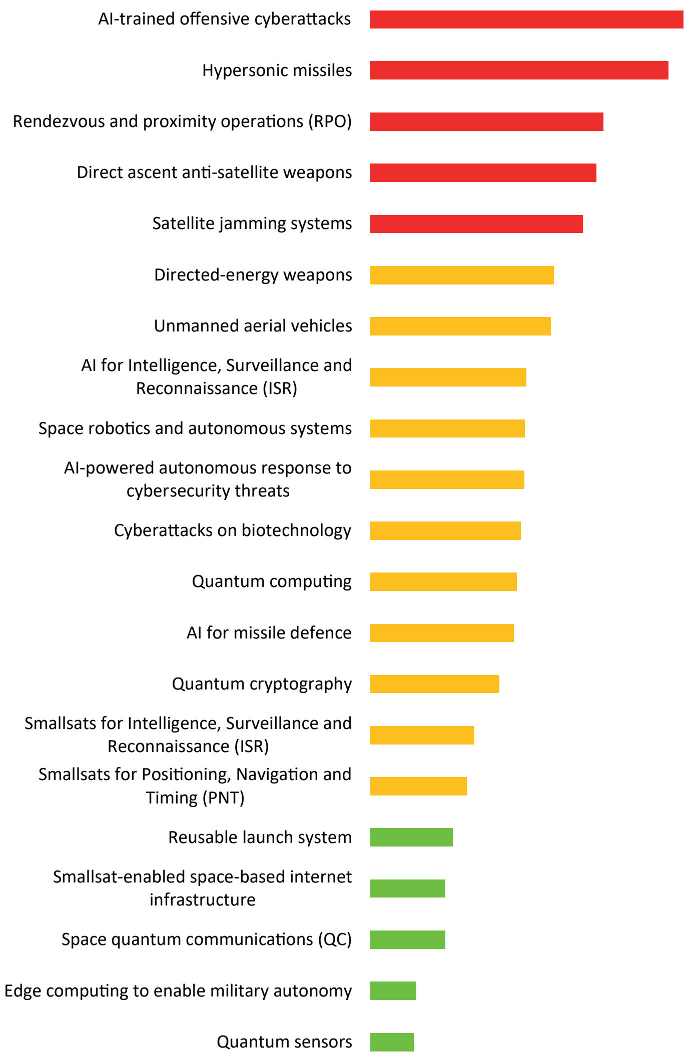
# Prioritisation

The ultimate objective for this study was to prioritise the technologies as a basis for appropriate policy responses.

# Quantitative Findings

In order to combine the quantitative results, a simple addition method was used. This gives the top five technologies with the highest potential to disrupt strategic stability, as shown in Figure 15. These are: AI-trained offensive cyber attacks; hypersonic missiles; rendezvous and proximity operations; direct ascent anti-satellite weapons; and satellite jamming systems. This prioritisation demands the caveat that together, these metrics produce a specific definition of strategic stability, so different conceptualisations of strategic stability – using the same data set but different metrics – could return entirely different results.

**Figure 15:** Ranking the Technologies




*Source: Author generated.*

## Qualitative Findings

In addition to the quantitative scoring exercise, STREAM participants were encouraged to leave qualitative remarks and were invited to participate in an exercise debrief. The list below provides a brief overview of some of the recurring points:

- Who is considered an ally or an adversary of the UK can differ depending on the technology/domain. For example, India has successfully demonstrated anti-satellite capabilities, but it is unclear whether this makes them an adversary of the UK and whether India's status as an ally or adversary applies uniformly to all technology areas.

- What we think of as ethically 'right' or 'wrong' is not universal. Subject matter experts pointed out that in the UK, certain security measures have citizens' tacit approval but are not universally 'right'. These include targeted killing via drones, the Metropolitan Police's use of facial recognition, and algorithmic bias.
- Ethical issues for the UK and its allies primarily arise when a human is no longer in the loop of when the technology infringes on international humanitarian law.
- There is a sense of an arms race in quantum capabilities. One expert noted that the prestige that would come from this breakthrough is analogous to the race for nuclear weapons in past decades.
- Involvement from the private sector in developing these technologies will shift the future of diplomacy and arms control. This will necessarily include who gets a seat at the table.
- AI research and development is driven by the private sector in the UK. This could create issues when it comes to optimising this technology for defence applications. Furthermore, commercial technology companies have expressed misgivings about partnering with ministries of defence in the past, as this creates a PR issue for them (for example, Project Maven).
- Even experts are susceptible to hype in their assessments. Experts were given the opportunity to abstain from scoring any technology if they were not familiar with it. However, all experts (n=10) felt that they were in a position to assess hypersonic missiles, thereby indicating some knowledge of the technology. It is possible that a cohort of experts in missile technologies specifically might be more sceptical of whether hypersonic missiles really are a game-changer.

## Conclusion

This study had three objectives: to provide an overview of 15–30 technologies in the cyber and space domains; to assess the possible future impacts of these technologies on strategic stability across a 10-year horizon; and to propose policy responses.

The benefit of using a foresight method such as STREAM is that it allows the nuclear policy community to better account for the uncertainties inherent in new technologies and better understand the strategic dynamics of tomorrow's technologies. Of the 21 technologies that were shortlisted, five were determined by subject-matter experts to have the highest potential to disrupt strategic stability. These are: AI-trained offensive cyber attacks; hypersonic missiles; rendezvous and proximity operations; direct ascent anti-satellite weapons; and satellite jamming systems. However, this prioritisation reflects only one definition of strategic stability. This paper is intended as a foundational study in the nuclear policy field, which can hopefully generate the foundation for a body of future research.

# VIII. Deployment of the W76-2: Strengthening Deterrence or Lowering the Threshold?

Artúr Hőnich

THE NUCLEAR POSTURE Review (NPR) of President Donald Trump's administration, published in February 2018, stated the intention of modifying 'a small number of existing SLBM [submarine-launched ballistic missile] warheads to provide a low-yield option'.[1] In February 2019, the National Nuclear Security Administration announced the completion of the first W76-2 warhead, a low-yield modification of the W76-1 warhead.[2] On 4 February 2020, Under Secretary of Defense for Policy John Rood confirmed in a statement that the W76-2 low-yield SLBM warhead has been fielded.[3]

While there is no official confirmation regarding its explosive power, estimates by the Union of Concerned Scientists and the Federation of the American Scientists put the warhead's yield at around 5–7 kilotons, which is less than half of the yield of 'Little Boy' that was dropped on Hiroshima.[4]

This new capability has been debated in the nuclear policy community ever since the 2018 NPR called for its development. In fact, there are two parallel debates that are often conflated.[5] One

1. US Department of Defense, 'Nuclear Posture Review 2018', February 2018, p. 55, <https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF>, accessed 15 July 2020.
2. National Nuclear Security Administration, 'NNSA Completes First Production Unit of Modified Warhead', 25 February 2019, <https://www.energy.gov/nnsa/articles/nnsa-completes-first-production-unit-modified-warhead>, accessed 15 July 2020.
3. US Department of Defense, 'Statement on the Fielding of the W76-2 Low-Yield Submarine Launched Ballistic Missile Warhead', 4 February 2020, <https://www.defense.gov/Newsroom/Releases/Release/Article/2073532/statement-on-the-fielding-of-the-w76-2-low-yield-submarine-launched-ballistic-m>, accessed 15 July 2020.
4. Lisbeth Gronlund, 'Memo to Congress: America Already has Low-Yield Nuclear Warheads', *All Things Nuclear*, 8 January 2019, <https://allthingsnuclear.org/lgronlund/us-already-has-low-yield-nuclear-warheads>, accessed 15 July 2020; Hans M Kristensen and William M Arkin, 'US Deploys New Low-Yield Nuclear Submarine Warhead', *Federation of American Scientists*, 29 January 2019, <https://fas.org/blogs/security/2020/01/w76-2deployed>, accessed 15 July 2020.
5. Vipin Narang, 'A Big Debate About a Little Nuke', *War on the Rocks,* podcast, 14 March 2018, <https://podtail.com/en/podcast/war-on-the-rocks/a-big-debate-about-a-little-nuke>, accessed 15 July 2020.

concerns lower-yield nuclear weapons per se, whether they are dangerous or necessary, and in the broader sense, whether the US should possess such weapons or not. By continuing to retain over-air-delivered non-strategic nuclear weapons and developing the W76-2, the Trump administration has a clear position in this debate.

Therefore, this paper focuses on the second, narrower debate, which is not about low-yield nuclear weapons on the whole, only about the W76-2. To critically examine the logic the Trump administration put forward, this paper first discusses the American perception of the Russian threat that admittedly prompted the development of this warhead. The paper argues that the declared US deterrence goal with the W76-2 is an insufficient characterisation of reality, particularly in light of recent scholarship on escalation management in Russian military thought. Second, this paper examines the strengths and shortcomings of the W76-2 warhead. Finally, it is noted that this deployment could have an impact on the future of NATO nuclear sharing as well as on non-strategic nuclear arms control.

## Threat Perception and the Implications of Uncertainty

In June 2015, US officials asserted that Russia secretly has a so-called 'escalate to de-escalate' nuclear doctrine.[6] This allegation was reiterated in the 2018 NPR, which accused Moscow of threatening and exercising 'limited nuclear first use' with the objective of ending a conflict 'on terms favorable to Russia'.[7]

However, examining Russian declaratory policy, capabilities and posture, the evidence is inconclusive. First, official documents and the military doctrine do not explicitly reference nuclear de-escalation and top Russian officials, including President Vladimir Putin, have repeatedly denied such allegations.[8] The expert community remains divided over the matter,

6. Then Deputy Secretary of Defense Robert Work and then Vice Chairman of the Joint Chiefs of Staff Admiral James Winnefeld discussed in their testimony that Russia 'purportedly seeks to deescalate a conventional conflict through coercive threats, including limited nuclear use'. Robert Work and James Winnefeld, 'Testimony Before the Committee on Armed Services, U.S. House of Representatives', 25 June 2015, p. 4, <https://docs.house.gov/meetings/AS/AS00/20150625/103669/HHRG-114-AS00-Wstate-WorkR-20150625.pdf>, accessed 15 July 2020.
7. US Department of Defense, 'Nuclear Posture Review 2018', p. 30.
8. It is only the 2012 and 2017 naval doctrines that hint at the possibility of limited nuclear use for managing a conflict. Katarzyna Zysk, 'Escalation and Nuclear Weapons in Russia's Military Strategy', *RUSI Journal* (Vol. 163, No. 2, 2018), pp. 3–4. In contrast, current Russian military doctrine states: 'The Russian Federation shall reserve the right to use nuclear weapons in response to the use of nuclear and other types of weapons of mass destruction against it and/or its allies, as well as in the event of aggression against the Russian Federation with the use of conventional weapons when the very existence of the state is in jeopardy'. See Embassy of the Russian Federation to the United Kingdom of Great Britain and Northern Ireland, 'The Military Doctrine of the Russian Federation', Article 27, 29 June 2015, <https://www.rusemb.org.uk/press/2029>, accessed 15 July 2020. In the plenary session of the 15th anniversary meeting of the Valdai International Discussion

and the recently published 'Basic Principles of State Policy of the Russian Federation on Nuclear Deterrence' does not definitively provide clarification either.[9]

Second, turning to capabilities, the Russian non-strategic nuclear arsenal consists of around 1,900 warheads according to the estimates of the Federation of American Scientists.[10] It should be noted that 'non-strategic' does not necessarily mean 'low-yield', as it refers to a diverse set of weapons not included in the New START Treaty.[11] However, many of the Russian non-strategic nuclear weapons have lower-yield warheads and their continued modernisation suggests that Moscow sees a role for them.[12]

Third, Russian posturing and exercising patterns send mixed signals. Although Moscow maintains that non-strategic nuclear weapons are held in central storage, alarming signs include the involvement of dual-capable forces and simulated nuclear strikes in Russian military exercises as well as nuclear signalling during the crisis in Ukraine.[13]

In sum, it cannot be claimed with complete certainty that Russia has an 'escalate to de-escalate' doctrine. This prompts worst-case scenario thinking, because the capability clearly exists. In theory, the Russian non-strategic nuclear arsenal could be used for a limited nuclear strike in a

Club, Putin said 'there is no provision for a pre-emptive strike in our nuclear weapons doctrine. Our concept is based on a reciprocal counter strike'. See President of Russia, 'Meeting of the Valdai International Discussion Club', Valdai International Discussion Club, Sochi, 18 October 2018, <http://en.kremlin.ru/events/president/news/58848>, accessed 15 July 2020. Russian Ambassador to the US Anatoly Antonov also publicly claimed that 'escalation for de-escalation' is inconsistent with Russian military doctrine. See Anatoly Antonov, 'US Claims on Russia's "Escalation for De-Escalation" Doctrine Are Wrong – Envoy', *TASS*, 9 April 2019, <https://tass.com/politics/1052755>, accessed 15 July 2020.

9. Amy F Woolf, 'Russia's Nuclear Weapons: Doctrine, Forces, and Modernization', *Congressional Research Service Report*, 2 January 2020, pp. 3–7, 34–35, <https://fas.org/sgp/crs/nuke/R45861.pdf>, accessed 15 July 2020; Maxim Starchak, 'Russia's New Nuclear Strategy: Unanswered Questions', *RUSI Commentary*, 26 June 2020.
10. Hans M Kristensen and Matt Korda, 'Russian Nuclear Forces, 2020', *Bulletin of the Atomic Scientists* (Vol. 76, No. 2, 2020), p. 111.
11. Amy F Woolf, 'Nonstrategic Nuclear Weapons', Congressional Research Service Report, 4 May 2020, p. 9, <https:// https://fas.org/sgp/crs/nuke/RL32572.pdf>, accessed 15 July 2020.
12. Hans M Kristensen and Matt Korda, 'Russian Nuclear Forces, 2020', *Bulletin of the Atomic Scientists* (Vol. 76, No. 2, 2020), p. 104.
13. NATO Secretary General, 'The Secretary General's Annual Report 2015', 2015, p. 15, <https://www.nato.int/nato_static_fl2014/assets/pdf/pdf_2016_01/20160128_SG_AnnualReport_2015_en.pdf>, accessed 15 July 2020; Olga Oliker, 'Russia's Nuclear Doctrine: What We Know, What We Don't, and What That Means', Center for Strategic and International Studies, May 2016, pp. 5–8; Jacek Durkalec, 'Nuclear-Backed "Little Green Men": Nuclear Messaging in the Ukraine Crisis', Polish Institute of International Affairs, July 2015, <https://css.ethz.ch/en/services/digital-library/publications/publication.html/193514>, accessed 15 July 2020.

de-escalate mission even if this is not codified in doctrine since doctrines are not determinative but prescriptive.[14] Therefore, hedging against the Russian non-strategic nuclear arsenal is logical in line with key NATO objectives such as deterring armed attacks and nuclear coercion.

## The Real Complexity of the Threat: Scenarios of Russian Escalation Management

The Trump administration's reasoning is internally coherent when it intends to hedge against the Russian non-strategic nuclear arsenal and its potential coercive use. However, if US statements do not signal a realisation about the variety of possible Russian de-escalation missions that questions the range of the deterrent goals of the W76-2. Therefore, it is key to move beyond a simplistic understanding of nuclear de-escalation, which simply envisages a Russian-initiated aggression where Moscow creates a fait accompli, solidifying its gains through limited nuclear use.[15]

In reality, there is a multifaceted discussion in Russian military circles about the utility of lower-yield nuclear weapons in escalation management.[16] Generally, Russian military writing suggests that early nuclear use is neither a preferred choice, nor a precise description of how Russia would approach escalation management, especially in light of their improved conventional capabilities that provide more flexibility.[17]

Russian military scholarship also discusses that demonstrative limited nuclear use could achieve deterrence by fear-inducement, for instance, to deter NATO allies from further getting involved in the conflict or to split the US from its allies.[18] Progressive infliction of damage is also discussed

14. Alex Velez-Green, 'Why Moscow Might Not Reveal an "Escalate to De-Escalate" Strategy', CSIS Next Generation Nuclear Network, 8 May 2018, <https://nuclearnetwork.csis.org/why-moscow-might-not-reveal-an-escalate-to-de-escalate-strategy>, accessed 15 July 2020.
15. Commentary on 'escalate to de-escalate' often focuses only on such a scenario. See, for example, Paul Bernstein and Deborah Ball, 'Putin's Russia and U.S. Defense Strategy', National Defense University, August 2015, p. 3, <https://wmdcenter.ndu.edu/Portals/97/Documents/Publications/Articles/Putins-Russia-and-US-Defense-Strategy.pdf>, accessed 15 July 2020. The 2018 NPR also implies a similar scenario by defining de-escalation as 'Moscow's mistaken assumption of Western capitulation'. See US Department of Defense, 'Nuclear Posture Review 2018', p. 30.
16. In April 2020, a two-part comprehensive report was published overviewing the main debates and key concepts in Russian military thought on deterrence and escalation management in the post-Cold War period. See Michael Kofman, Anya Loukianova Fink and Jeffrey Edmonds, 'Russian Strategy for Escalation Management: Evolution of Key Concepts', Center for Naval Analyses, April 2020, <https://www.cna.org/CNA_files/PDF/DRM-2019-U-022455-1Rev.pdf>, accessed 15 July 2020; Anya Loukianova Fink and Michael Kofman, 'Russian Strategy for Escalation Management: Key Debates and Players in Military Thought', Center for Naval Analyses, April 2020, <https://www.cna.org/CNA_files/PDF/DIM-2020-U-026101-Final.pdf>, accessed 15 July 2020.
17. Kofman, Fink and Edmonds, 'Russian Strategy for Escalation Management', pp. 56–58.
18. *Ibid*., pp. 21–22.

as deterrence through limited use of force.[19] However, limited nuclear use could also serve warfighting objectives like containing the war geographically, generating an operational pause or defeating specific NATO operations.[20]

It is important to recognise that different scenarios could mean different thresholds for Russia depending on the stakes.[21] Consequently, the W76-2 will unlikely be an effective deterrent if the Russian leadership perceives such a dire threat to the regime that it would resort to using nuclear weapons.

Seeking to hedge against a hypothetical Russian military aggression against NATO requires a more credible response as strategic nuclear deterrence might not be sufficient.[22] A 2019 RAND wargame on the defence of the Baltics found that low-yield nukes are indeed useful in diminishing in-theatre asymmetries with Russia and to complicate Russian risk calculations.[23] However, the authors also found that deploying only low-yield nuclear weapons NATO could not credibly negate Russian advantages in both non-strategic nuclear weapons and conventional forces.[24] Although defence budgets across NATO are likely to be affected by the coronavirus pandemic and related economic hardships, the deployment of low-yield nuclear weapons per se will not substitute consistent investment into conventional capabilities.

## W76-2: Strengths and Issues

### Improvements in Assured Delivery and Survivability

Experts opposing the W76-2 pointed out that the US already had air-deliverable low-yield options.[25] So what was the need for this SLBM warhead? The State Department openly admitted that present forward-deployed air-delivered options are facing issues as they are vulnerable to advanced air defences and Russia could also pre-emptively target bases in Europe that host them.[26]

---

19. Michael Kofman and Anya Loukianova Fink, ‘Escalation Management and Nuclear Employment in Russian Military Strategy’, *War on the Rocks*, 23 June 2020.
20. Kofman, Fink and Edmonds, ‘Russian Strategy for Escalation Management’, pp. 7–18.
21. John K Warden, ‘Limited Nuclear War: The 21st Century Challenge for the United States’, SMA STRATCOM Speaker Series, 12 September 2018, p. 8, <https://nsiteam.com/social/wp-content/uploads/2018/09/Limited-Nuclear-War-brief-Warden.pdf>, accessed 15 July 2020.
22. Jack Watling, ‘By Parity and Presence: Deterring Russia with Conventional Land Forces’, *RUSI Occasional Papers* (July 2020), p. 55.
23. Paul K Davis et al., *Exploring the Role Nuclear Weapons Could Play in Deterring Russian Threats to the Baltic States* (Santa Monica, CA: RAND, 2019), p. 86.
24. Davis et al., ‘Exploring the Role Nuclear Weapons Could Play in Deterring Russian Threats to the Baltic States’, p. 85.
25. Kristensen and Arkin, ‘US Deploys New Low-Yield Nuclear Submarine Warhead’.
26. US Department of State, Bureau of Arms Control, Verification and Compliance, ‘Strengthening Deterrence and Reducing Nuclear Risks: The Supplemental Low-Yield U.S. Submarine-Launched

In contrast, the W76-2 warhead is attached to an SLBM, hence the State Department's claim that it is more survivable and its delivery is better assured.[27] Therefore, the W76-2 is a more credible capability for the role that the Trump administration wants for low-yield options. On another note, it also gives the US more flexibility in response to a hypothetical Russian limited first strike, because the warhead is not stored on the soil of a NATO ally, unlike the forward-deployed non-strategic nuclear weapons.

### The Discrimination Problem

One specific criticism of the W76-2 points out that the warhead is fielded on the Trident II missile, which serves as the delivery vehicle for other, much higher-yield warheads as well.[28] Consequently, if the Russian early-warning system detects a Trident missile launch, they could not know which warhead is on the incoming missile.

The Trump administration's counterargument is that the discrimination problem is not unique, because there is operational uncertainty regarding the yield of the air-delivered weapons too.[29] That is unquestionably true. Moreover, as Austin Long from RAND noted, the indistinguishability of US and UK Tridents presents the same issue since the UK also possibly has a lower-yield SLBM capability.[30] In sum, although the W76-2 did not introduce this issue, the escalation potential rooted in the discrimination problem is still real.

### Ambiguities with Targeting

The State Department's background paper argues that the US strategy for deterring limited nuclear war is capacity-based and not target-based.[31] However, if the warhead is intended to be a credible deterrent, there must be appropriate targets, in case deterrence fails.[32]

For understandable reasons, the US is being ambiguous in this regard. But that does not make the problem go away: if the response to Russian limited nuclear use is aimed at targets inside

Warhead', 24 April 2020, p. 5, <https://www.state.gov/wp-content/uploads/2020/04/T-Paper-Series-4-W76.pdf>, accessed 15 July 2020.

27. US Department of State, Bureau of Arms Control, Verification and Compliance, 'Strengthening Deterrence and Reducing Nuclear Risks', p. 5.
28. Vipin Narang, 'The Discrimination Problem: Why Putting Low-Yield Nuclear Weapons on Submarines is so Dangerous', *War on the Rocks*, 8 February 2018.
29. US Department of State, Bureau of Arms Control, Verification and Compliance, 'Strengthening Deterrence and Reducing Nuclear Risks', pp. 5–6.
30. Austin Long, 'Discrimination Details Matter: Clarifying an Argument About Low-Yield Nuclear Warheads', *War on the Rocks*, 16 February 2018.
31. US Department of State, Bureau of Arms Control, Verification and Compliance, 'Strengthening Deterrence and Reducing Nuclear Risks', p. 3.
32. George Perkovich, 'Critiquing the State Department's Nuclear Posture Clarification', Carnegie Endowment for International Peace, 6 May 2020.

Russia that might accelerate escalation regardless of how tailored the strike is, because it is highly questionable whether yield differences would mean anything in that case – and of course, Russian deterrence posture is capitalising on this fear of escalation.[33]

Decision-makers would have to consider what military objectives would necessarily require nuclear weapons use, even if Russia fired first. Targeting a third party such as Belarus or the invading Russian units on NATO soil raise additional difficult questions. Wargames that addressed this scenario – two during President Barack Obama's administration, one by RAND in 2019 and one under Secretary Esper in February 2020 – clearly reflect these concerns.[34]

## The Russian Reaction

Looking at the Russian reaction to the deployment, two factors stand out. Most importantly, it can be observed that so far, the Russian reaction is only rhetorical. Neither the political leadership nor experts have called for developing new capabilities in reaction to the W76-2. This means that they do not perceive a capability gap as a result of its deployment. In fact, Deputy Foreign Minister Sergei Ryabkov stated that Moscow does not see this deployment as a threat to Russian security.[35]

Nevertheless, Russian officials framed the deployment in their public narrative as an example of irresponsible nuclear posturing that 'lowers the nuclear threshold and increases the risk of a nuclear conflict'.[36] Along the same lines, Russian declaratory policy is aimed at convincing the

---

33. Gerald Brown, 'Conflict and Competition: Limited Nuclear Warfare and the New Face of Deterrence', *Global Security Review*, 16 December 2019, <https://globalsecurityreview.com/conflict-competition-limited-nuclear-warfare-new-face-deterrence>, accessed 15 July 2020; President of Russia, 'Presidential Address to the Federal Assembly', 1 March 2018, <http://en.kremlin.ru/events/president/news/56957>, accessed 15 July 2020.
34. Fred Kaplan, *The Bomb: Presidents, Generals, and the Secret History of Nuclear War* (New York, NY: Simon and Schuster, 2020), pp. 276–77; Davis et al., *Exploring the Role Nuclear Weapons Could Play in Deterring Russian Threats to the Baltic States*; Fred Kaplan, 'The Senseless Danger of the Military's New "Low-Yield" Nuclear Warhead', *Slate*, 18 February 2020, <https://slate.com/news-and-politics/2020/02/low-yield-warhead-nuclear-weapons-navy-trident-submarines.html>, accessed 15 July 2020; Marcus Weisgerber, 'Esper Plays Nuclear War: Russia Nukes Europe, US Fires Back', *Defense One*, 21 February 2020, <https://www.defenseone.com/politics/2020/02/esper-plays-nuclear-war-russia-nukes-europe-us-fires-back/163268>, accessed 15 July 2020.
35. *Kommersant*, 'Rossiya obespokoena razmeshcheniem yadernykh zaryadov na podlodkakh SShA' ['Russia is Concerned About Nuclear Deployment on US Submarines'], 5 February 2020, <https://www.kommersant.ru/doc/4243329>, accessed 15 July 2020.
36. Maria Zakharova, 'Briefing by Foreign Ministry Spokesperson Maria Zakharova, April 29, 2020', 29 April 2020, <https://www.mid.ru/foreign_policy/news/-/asset_publisher/cKNonkJE02Bw/content/id/4108704>, accessed 15 July 2020.

US that Moscow makes no distinction between yields of incoming warheads, thus even a limited strike against Russia would trigger a full-scale nuclear response.[37]

However, it is difficult to believe this claim, because if this were true, it would question the whole purpose of Russia's non-strategic nuclear arsenal. It is important to see that in their narratives both sides claim that escalation cannot be controlled, and it is very dangerous to even think about that, but at the same time, both sides invest in capabilities that potentially enable escalation management.[38]

## Future Prospects

There are at least two aspects where the new low-yield warhead could change future Euro-Atlantic security dynamics. First, this new low-yield option in the US arsenal could play a part in the NATO nuclear-sharing debate. The case for the deployment of the W76-2 further undermines the deterrence rationale behind forward-deployed US nuclear weapons. Therefore, the debate on the political dimensions of nuclear sharing could intensify in light of recent anti-nuclear sharing sentiments in multiple European host countries.

Second, in addition to this low-yield SLBM, the NPR also outlined the need for a modern sea-launched nuclear cruise missile.[39] This other programme is still at the early stage of the analysis of alternatives and could be deployed in seven to 10 years, provided that Congress continues to approve funding.[40] Although in the present environment non-strategic nuclear arms control appears to be an unrealistic prospect, it should be noted that the 2018 NPR signalled a belief that the development of low-yield capabilities could generate leverage for future discussions on non-strategic nuclear arms control.[41] Existing and the future low-yield capabilities could thus become a bargaining chip in US-Russia negotiations.

## Conclusion

In conclusion, hedging against the Russian non-strategic nuclear arsenal and its potential coercive use is undoubtedly reasonable. However, the variety of Russian de-escalation missions that NATO could theoretically face should be discussed more comprehensively.

The W76-2 warhead indeed strengthens US nuclear deterrence, as it is a more credible deterrent than air-delivered low-yield capabilities in terms of assured delivery and survivability, and it

37. President of Russia, 'Presidential Address to the Federal Assembly'.
38. Michael Kofman, 'Nuclear Deterrence with Russia and China: Are U.S. Course Corrections Needed?', CATO Institute, 26 May 2020, <https://www.cato.org/events/nuclear-deterrence-russia-china-are-us-course-corrections-needed>, accessed 15 July 2020.
39. US Department of Defense, 'Nuclear Posture Review 2018', p. 54.
40. Aaron Mehta, 'Initial Analysis of New Sub-Launched Nuclear Cruise Missile Coming 'Shortly', *Defense News*, 1 June 2020.
41. US Department of Defense, 'Nuclear Posture Review 2018', p. 55.

complicates Russian risk calculations. Nevertheless, the discrimination problem and dilemmas linked to targeting remain as unresolved risks with considerable escalation potential that should not be overlooked.

This paper highlights the fact that although both sides claim escalation cannot be controlled and de-escalation attempts would lead to catastrophic consequences, both sides develop and maintain capabilities, which, beyond their obvious deterrent value, could also be used for escalation management.

# IX. Hypersonic Missile Defence, Stopping the Unstoppable

Aaron Kennedy, Jacob Allen, Jonathan Balakumar, Mark Hutchings and Daniel Cook

WESTERN RESEARCH AND development of hypersonic vehicles began with the North American X-15 in 1961, followed by the NASA X-43 in 2004 and the Boeing X-51 in 2013.[1] Such vehicles unveiled the possibility of controlled flight at Mach 5+, catching the attention of strategic military groups. Several nations with histories of intercontinental ballistic missile (ICBM) development have initiated hypersonic weapon development in the last decade, including:

- Common Hypersonic Glide Body (US)[2]
- Avangard (Russia)[3]
- 3M22 Zircon (Russia)[4]
- KH-47M2 Kinzhal (Russia)[5]
- BrahMos-II (India)[6]
- DF-ZF (China)[7]
- Xingkong-2 (China)[8]

---

1. Yvonne Gibbs, 'NASA Armstrong Fact Sheet: X-15 Hypersonic Research Program', NASA, 7 August 2017, <https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-052-DFRC.html>, accessed 6 July 2020; Zach Rosenberg, 'Hypersonic X-51 Programme Ends in Success', FlightGlobal, 3 May 2013, <https://www.flightglobal.com/hypersonic-x-51-programme-ends-in-success/109619.article>, accessed 7 July 2020.
2. *Economic Times*, 'US Successfully Tests Nuclear-Capable Hypersonic Missile', 21 March 2020, <https://economictimes.indiatimes.com/news/defence/pentagon-says-successfully-tested-hypersonic-missile/articleshow/74735632.cms?from=mdr>, accessed 7 June 2020.
3. *Al Jazeera*, 'Putin Hails Successful Test of Russia's New Hypersonic Missile', 27 December 2018, <https://www.aljazeera.com/news/2018/12/putin-hails-successful-test-russia-hypersonic-missile-181227021622587.html>, accessed 7 June 2020.
4. Missile Defense Advocacy Alliance, '3M22 Zircon', 2019, <https://missiledefenseadvocacy.org/missile-threat-and-proliferation/missile-proliferation/russia/3m22-zircon/>, accessed 7 June 2020.
5. Missile Threat, Center for Strategic and International Studies (CSIS) Missile Defense Project, 'Kinzhal', 27 March 2018, <https://missilethreat.csis.org/missile/kinzhal/>, accessed 7 June 2020.
6. *India Today*, 'India to Develop BrahMos-II Missile', 3 August 2009, <https://www.indiatoday.in/headlines-today-top-stories/story/india-to-develop-brahmos-ii-missile-53475-2009-08-03>, accessed 7 June 2020.
7. Ankit Panda, 'Introducing the DF-17: China's Newly Tested Ballistic Missile Armed With a Hypersonic Glide Vehicle', *The Diplomat*, 28 December 2017.
8. Dave Makichuk, 'Xingkong-2: China's New Missile Threat?', *Asia Times*, 2 December 2019.

Failing to catch up to rivals' progress in hypersonic weapon capability could lead to shifts in perceived military power, potentially leading to escalation outside the ICBM domain. Hypersonic weapons combine 'the speed of ballistic weapons with the low altitude flight and manoeuvring capabilities of cruise missiles'.[9] These characteristics prove advantageous in evading traditional missile defence systems, which leads to the question of how to stop them.[10] A possible answer is directed energy.

In its simplest form, directed electromagnetic radiation is a logical potential defence solution given that projection occurs at the speed of light.[11] The relative maturity of laser systems makes them a candidate for further study. Russia's 'Peresvet',[12] deployed with the Strategic Missile Forces since December 2019, is thought to be capable of countering missile guidance systems by blinding the guidance module so that the missile cannot find its target.[13] Furthermore, the potential to target low-orbit reconnaissance satellites by disrupting their electro-optical sensors suggests a range and tracking ability that could engage hypersonic glide vehicles (HGVs).[14] China exhibited the 'Silent Hunter' in 2017,[15] a 30 kilowatt (kW) low-altitude laser air defence system, and claims that similar systems have neutralised a number of small aircraft.[16] More recently, the People's Liberation Army Navy reportedly dazzled a US Navy maritime patrol aircraft with a

9. Jill Hruby, 'Russia's New Nuclear Weapon Delivery Systems: An Open-Source Technical Review', NTI, 13 November 2019, <https://www.nti.org/analysis/reports/russias-new-nuclear-weapon-delivery-systems-open-source-technical-review/>, accessed 7 June 2020.
10. *Ibid*.
11. Henry R Jeffress III, 'Hypersonic Threats to the Home Land Strategic Options', Air War College, Air University, 28 March 2017.
12. Kyle Mizokami, 'Russia Deploys New Ground-Based Laser Weapon', *Popular Mechanics*, 5 December 2018, <https://www.popularmechanics.com/military/weapons/a25414008/russia-deploys-new-ground-based-laser-weapon/>, accessed 7 June 2020.
13. *RIA News*, 'V Rossii zavershili razvertivanie ustanovok "perecvet", zayavil Shoigu', ['Shoigu: Completed Deployment of Peresvet Laser Systems'], 3 March 2020, <https://ria.ru/20191224/1562774710.html>, accessed 1 July 2020.
14. Ilya Kramnik, 'Laser Weapons: From Fantasy to Reality', Valdai Discussion Club, 9 May 2020, <https://valdaiclub.com/a/highlights/laser-weapons-from-fantasy-to-reality/>, accessed 1 July 2020.
15. Jeff Martin, 'Check out What China Brought to One of the World's Largest Defense Exhibitions', *Defense News*, 17 February 2019.
16. C Wen, 'A Week of Military Sentiment: The Current Status of Laser Weapons in China is Also Mixed', *DW News*, 25 February 2017, <https://www.dwnews.com>, accessed 1 July 2020; *Maritime Executive*, 'China Tests Laser Weapon Similar to U.S. Navy Prototype', 10 April 2019, <https://www.maritime-executive.com/article/china-tests-laser-weapon-similar-to-u-s-navy-prototype>, accessed 1 July 2020.

'weapons-grade laser'.[17] The US tested its own ship-based system when it fired a high-powered laser weapon at a UAV, and plans to develop this into a 150 kW beam.[18]

However, hypersonic vehicles constitute an entirely different target. Unlike UAVs, they require a Thermal Protection System (TPS) to protect the structure and internal warhead from the intense heat generated by high-Mach atmospheric flight. Hence the kill mechanisms of the respective targets must differ. By assuming an ablative TPS, a laser could provide local heating to the surface in addition to aerothermal heating experienced during flight and increase the ablation rate. This could lead to an asymmetric loss of material, which would change the aerodynamic forces on the body and thus could affect the vehicle's ability to manoeuvre to the target. Alternatively, directing a focussed beam at the surface causes increased heating, in turn causing decreasing effectiveness of thermal protection. This leads to increased temperatures in the vehicle structure, and hence a detrimental change in material properties such as yield strength and stiffness. This subsequently makes the structure more susceptible to failure under aerodynamic flight stresses. It is hypothesised that lasers could be used in such a way to defend against HGVs. This idea is explored to advance the current discourse on how emerging technology could be employed to disrupt and destroy HGVs.

Local, laser-aerothermal combined ablation of carbon-carbon TPSs was the focus of the China Aerodynamics Research and Development Centre's paper 'Laser Lethality of Hypersonic Vehicles under Aero-Heating'.[19] This work concludes that the laser leads to more rapid ablation, and that coupling between the laser and the aerothermal heating adds an additional 25–30% to the ablation rate. This is compared to the sum of the equivalent laser and aerothermal ablation rates in isolation. This highlights the potential effectiveness of laser defence applied to hypersonic vehicles.

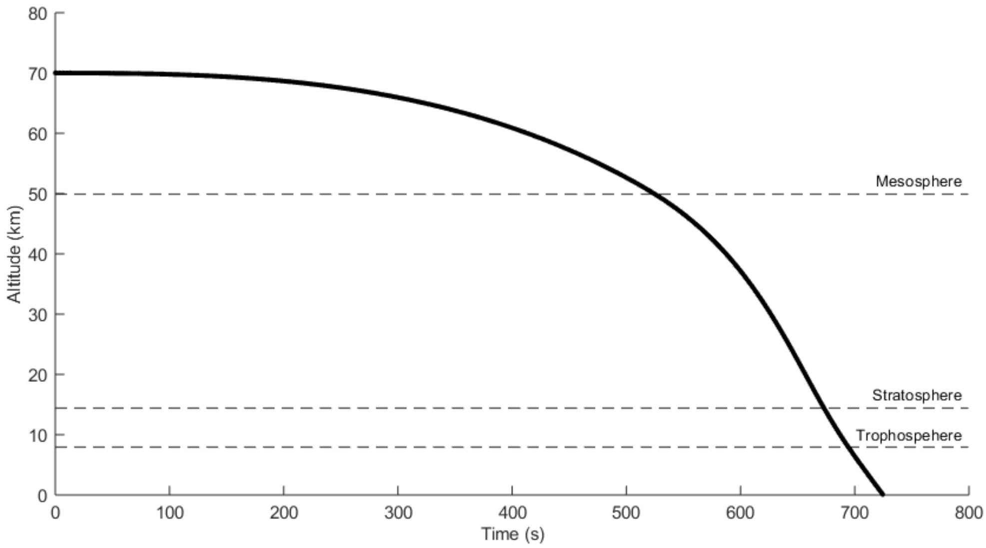
## Method, Modelling and Simulation

A Lockheed Martin UK proprietary code FIRRST 3D (F3D) was used to assess the effectiveness of laser heating to increase the ablation rate. A six degree of freedom HGV model with an external TPS consisting of ablative carbon–carbon was created in F3D, and the corresponding aerodynamic coefficients were calculated. This allowed the glide vehicle trajectory to be calculated as depicted in Figure 1. Following this, the thermal environment could be predicted with an additional 100 kW laser heating effect added at this step. The thermal prediction gave

17. Kyle Mizokami, 'A Chinese Destroyer Fired a Laser at a U.S. Navy Patrol Aircraft', *Popular Mechanics*, 29 February 2020, <https://www.popularmechanics.com/military/navy-ships/a31159120/chinese-destroyer-laser/>, accessed 1 July 2020.
18. Megan Eckstein, 'Video: USS Portland Fires Laser Weapon, Downs Drone in First At-Sea Test', *USNI News*, 12 June 2020, <https://news.usni.org/2020/05/22/video-uss-portland-fires-laser-weapon-downs-drone-in-first-at-sea-test>, accessed 1 July 2020.
19. Shi Weibo et al., 'Laser Lethality of Hypersonic Vehicles Under Aero-Heating', *High Power Laser and Particle Beams* (Vol. 22, No. 6, 2010), pp. 1215–18.

the basis for calculating the ablation rates with and without the added laser radiation, which allows the effectiveness of the laser solution to be assessed.

**Figure 1:** Simplified Trajectory of Hypersonic Glide Vehicle from Maximum Altitude




*Source: Author generated.*

For modelling simplicity, a glide trajectory starting at an altitude of 70 km, an angle of attack of 20 degrees and a velocity equivalent to approximately Mach 18 was used instead of complex trajectories such as skip-glides.[20] The HGV was assumed to carry a 20 mm carbon-carbon TPS.

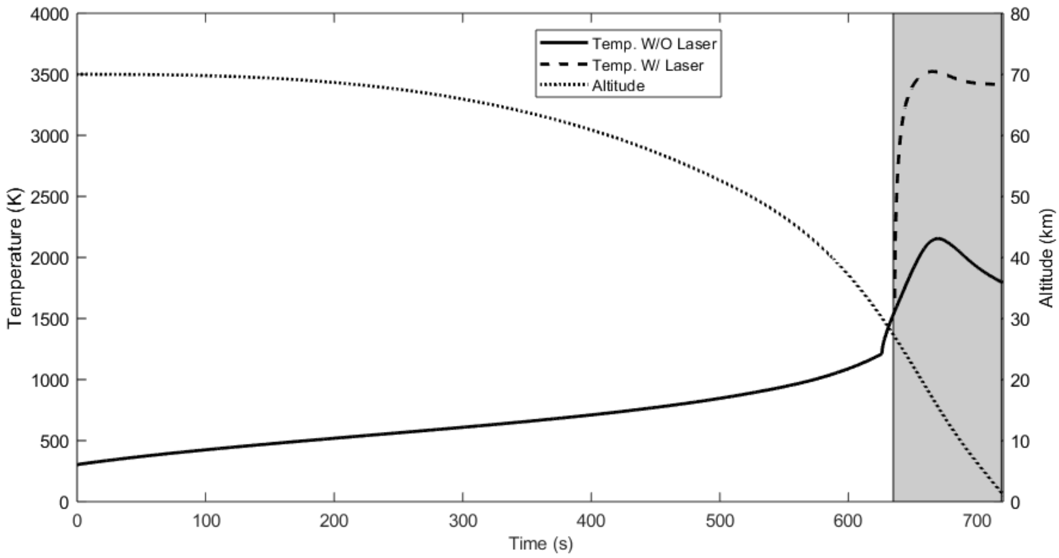
It was assumed that the HGV remained in visual line of sight once within range, and that the observer maintained an uninterrupted field of view on any horizon. Atmospheric effects such as thermal blooming were ignored and the laser remained focused on the same point on the vehicle for the duration of the illumination. The ability of the laser to deliver 100 kW onto the target is not the objective of this paper, rather the feasibility of TPS degradation. In addition, the modelling does not consider the laser's ability to penetrate a plasma sheath that could form around the HGV in certain flight conditions. This is a topic that is recommended for further work.

20. James M Acton, 'Hypersonic Boost-Glide Weapons', *Science & Global Security* (No. 23, 2015), pp. 191–219; Glenn Research Center, 'Mach Number', NASA, 9 October 2019, <https://www.grc.nasa.gov/www/k-12/airplane/mach.html>, accessed 5 July 2020; Peter Erbland, 'Falcon HTV-2', Defence Advanced Research Projects Agency, <https://www.darpa.mil/program/falcon-htv-2>, accessed 5 July 2020; Shaoxin Feng and Yasheng Zhang, 'Analysis of Near Space Hypersonic Glide Vehicle Trajetory Characteristics and Defense Difficulties', paper presented at 5th International Conference on Advanced Materials and Computer Science, Qingdao, China, 26–27 March 2016.

## Results and Discussion

Carbon-carbon ablative heat shields are designed to lose mass through ablation, but at a rate where the vehicle remains protected up until the target. Heat flux is transferred into the carbonaceous layer, initiating oxidation and sublimation of the material. Oxidation is the prevailing mechanism up to 3,000–3,500 Kelvin (approximately 3,300–3,800 degrees Celsius) with sublimation dominating thereafter. Sublimation causes a mass-loss rate at an order of magnitude greater than oxidation, where the solid carbon transitions directly to the gas phase. The aforementioned reactions added to the inflight mechanical erosion ultimately leads to gradual recession of the TPS.[21] Modelling revealed an increase of over 1,000 Kelvin on the surface of the HGV on application of laser irradiation, indicating a heat flux likely to overwhelm the TPS and potentially enter the sublimation regime (Figure 2).

**Figure 2:** Modelled Surface Temperature at a Point on the Lower Surface of the Body with and Without Laser Irradiation

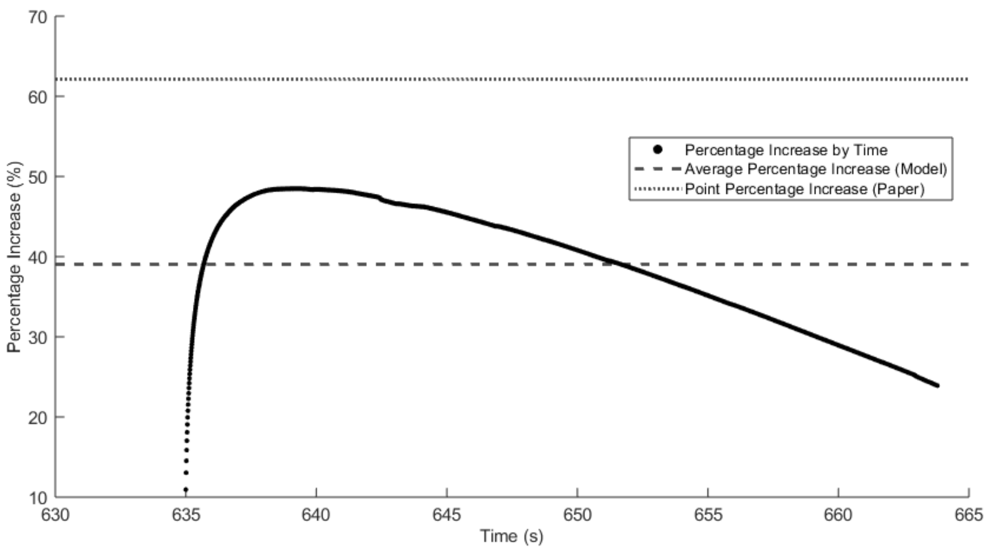



*Note: The laser is activated at 635 seconds shown by the shaded area.*

*Source: Author generated.*

21. J W Metzger, M J Engel and N S Diaconis, 'Oxidation and Sublimation of Graphite in Simulated Re-Entry Environments', *American Institute of Aeronautics and Astronautics* (Vol. 5, No. 3, 1967), pp. 451–60.

**Figure 3:** Percentage Increase in the Thermal Protection System Ablation Rate with the 100 kW Laser Radiation Incident on the Surface




*Note: Modelling results are indicated by the points and the coarse dashed line, with the percentage increase calculated from the literature by the fine dashed line.*

*Source: Author generated.*

A significantly increased ablation rate is observed for the simulated carbon-carbon layer. On average the ablation rate was over 38% greater than was predicted for aerothermal heating alone for the duration of the laser illumination (Figure 3). There is a difference between the increase in ablation rates from the modelling work and the literature, shown in Figure 3. The literature shows an increase of over 60% whereas the highest instantaneous percentage increase is approximately 50% for the modelling results. This could be caused by a difference in modelling assumptions and conditions, for instance the geometry of the body used and the point used to calculate the heating and ablation. Aerothermal heat flux varies spatially and temporally throughout the trajectory. Flow conditions impact the heat flux calculations and cannot be neglected. A lack of specific parameter values in the literature does not readily facilitate replication, invalidating any like-for-like comparison with F3D. However, as expected, there is a solid agreement that the incident laser radiation does increase the ablation rate. Hence this simulation has shown that directing a laser onto an HGV during flight has the potential to increase the rate of recession of ablative shields. This is effectively a reduction in the TPSs ability to manage excess heating, which could be exploited to end its flight prematurely.

Furthermore, the observed temperature increase in Figure 2 allows the effects to be considered on alternative TPSs. Systems such as cooled structures which rely on circulating coolant, and hot structures using conduction and radiation to remain within operating temperatures could also be affected. With the temperatures generated in hypersonic flight coupled with the desire to keep costs and mass low, it is reasonable to assume that the TPS operates near or approaching the limits of their useful material properties. This is a view derived from the material properties and operating environment of a TPS used for space shuttle re-entry.[22] Therefore the conjecture is this technique could also be employed for alternative TPS types.

## Atmospheric Effects

Unfortunately, the turbulent and unpredictable behaviour of the lower atmosphere presents a critical issue with long-range laser defence systems. Molecules and thermal effects ultimately deflect, broaden or otherwise diminish the laser power that reaches the target, as shown below:[23]

- Molecular absorption: Resonant absorption by the rotational and vibrational motion of di- and tri-atomic molecules for a particular spectrum of wavelengths.
- Molecular and aerosol scattering: Rayleigh and Mie scattering by molecules in the atmosphere that have a diameter much smaller or of a similar size to the wavelength of the beam.
- Atmospheric turbulence: Fluctuations in the refractive index of the air due to rising convective cells can lead to rapid changes in the beam's intensity, beam wander and beam broadening.
- Thermal blooming: A Gaussian beam distribution can heat the central beam axis, altering the refractive index and ultimately creating a lens which focuses or defocuses the beam.

Inclement weather can also attenuate the total power applied to the target. Poor visibility leads to scattering and the slightest amount of precipitation could prevent engagement, even at a 5 km range.[24] This highlights a significant issue regarding ground-based lasers as a viable defence mechanism for HGVs. This is due to the need for the laser to potentially propagate through to the upper atmosphere, in order to successfully engage a target.

## Operational Analysis

To overcome the limitations of ground-based laser defence systems (for example, limited field of view, weather vulnerability), such a weapon could be airborne or orbital-based. Airborne systems offer a reduction in range-to-target and can be placed above weather systems. The Boeing YAL-1 was an example of a megawatt-class laser-wielding aircraft, designed to target ballistic missiles in the boost phase. However, this was ultimately cancelled due to a lack of

22. Wayne Hale et al. (eds), *Wings in Orbit Scientific and Engineering Legacies of the Space Shuttle 1971–2010* (Scotts Valley, CA: CreateSpace Independent Publishing Platform, 2011).
23. David H Titterton, *Military Laser Technology and Systems* (Norwood, MA: Artech House, 2015), chapter 5.
24. Chris R Fussman, 'High Energy Laser Propagation in Various Atmospheric Conditions Utilizing a New, Accelerated Scaling Code', thesis, Naval Postgraduate School, June 2014.

beam power and misalignment issues. Moreover, for continuous coverage a considerable fleet of aircraft would be required to provide protection.[25]

Space-based systems avoid attenuation by atmospheric effects and could provide the greatest coverage with a constellation. The Russian Polyus was thought to be a megawatt-class laser capable of engaging US anti-missile defences, although ultimately it failed to reach orbit.[26] The enormous cost of placing complex systems into space is likely to prove the largest obstacle.[27] In addition, any power supply is likely to be limited to solar or thermal sources. A further complication is that positioning lasers in orbit could be considered a violation of the Outer Space Treaty 1967.[28]

## Conclusion

In this investigation modelling work predicted that a laser directed energy beam applied to the ablative TPS of a hypersonic vehicle can significantly increase the rate of ablation. This shows degradation of the TPS under laser illumination and suggests its ability to protect the internal structure for the duration of flight is reduced. The application of lasers to alternative TPS types was also briefly discussed. It was suggested that similar principles of failure can be considered when assuming the TPS is operating close to its design limit. Therefore, directed energy weapons in the form of lasers show potential for being a solution against HGVs.

However, atmospheric propagation is still a major obstacle for lasers and would severely impact the heating performance with increasing range. Therefore, ground-based solutions are likely to be ineffective, and the focus should instead turn to the potential of airborne or space-based systems. It is apparent that further work is required to definitively conclude whether lasers could really be the solution to stopping the ‘unstoppable.’[29]

---

25. Berenice Baker, ‘Will DARPA’s Airborne Laser Succeed Where Boeing’s YAL-1 Failed?’, *Army Technology*, 16 September 2014, <https://www.army-technology.com/features/featurewill-darpas-airborne-laser-succeed-where-boeings-yal-1-failed-4376518/>, accessed 5 July 2020.
26. Ed Grondine, ‘Polyus’, *Astronautix*, 2019, <http://www.astronautix.com/p/polyus.html>, accessed 5 July 2020.
27. Jon Harper, ‘The Pentagon Could Put Directed Energy Weapons in Space’, *National Defense*, 25 April 2019, <https://www.nationaldefensemagazine.org/articles/2019/4/25/special-report-the-pentagon-could-put-directed-energy-weapons-in-space>, accessed 5 July 2020.
28. United Nations Office for Outer Space Affairs, ‘Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies’, <https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html>, accessed 29 July 2020.
29. R Jeffrey Smith, ‘Hypersonic Missiles are Unstoppable. And They’re Starting a New Global Arms Race’, *New York Times Magazine*, 19 June 2019.

# X. Does Socioeconomic Status Affect Young People's Views on Nuclear Weapons?

Matt Korda

ALTHOUGH THE CAREER pipeline of the nuclear policy field has not yet been the subject of much empirical study, it is common for nuclear policy professionals to anecdotally note that they either discovered or cultivated their interest in nuclear weapons during the pursuit of higher education.[1] If this is indeed the case, then does entry into the nuclear weapons field – or even just knowledge of nuclear weapons issues more broadly – depend on one's relative privilege, specifically in terms of access to higher education? And given the connection between higher education levels and higher income brackets, does that imply a divergence in how young people of different socioeconomic classes think about nuclear weapons?

Based on recently published survey data from the International Committee of the Red Cross (ICRC), this paper considers these questions, and ultimately suggests that socioeconomic status does play a significant role in how young people from nuclear-armed states assess the nuclear threat, in addition to how they prioritise policy choices such as deterrence, non-proliferation and disarmament.[2]

These are important conclusions, because opportunities to fill positions of political power tend to be restricted to those in higher education and income brackets.[3] This is no different within the nuclear policy space: recent analysis by Sarah Bidgood demonstrates that there is an uneven distribution of WMD-related courses between American public and private universities, thus implying a correlation between access to private university education and entry into the WMD policy field.[4] Additionally, as Bidgood notes, 'public universities enroll significantly more African Americans, first-generation college students, and students from low-income backgrounds by

1. Heather Hurlburt et al., 'The "Consensual Straitjacket": Four Decades of Women in Nuclear Security', *New America*, 5 March 2019, <https://www.newamerica.org/political-reform/reports/the-consensual-straitjacket-four-decades-of-women-in-nuclear-security/>, accessed 21 July 2020; *N Square*, 'Greater Than: Nuclear Threat Professionals Reimagine Their Field', 21 December 2019, <https://nsquare.org/2019/12/20/greater-than/>, accessed 21 July 2020.
2. The five nuclear-armed states considered in the ICRC report are France, Israel, Russia, the UK and the US.
3. Andy Beckett, 'PPE: The Oxford Degree That Runs Britain', *The Guardian*, 23 February 2017.
4. Sarah Bidgood, 'Undergraduate Disarmament and Nonproliferation Education: Gaps, Opportunities, and New Approaches', *Nonproliferation Review* (Vol. 26, 2019), pp. 329–40.

far than do their private counterparts'.[5] Therefore, it is easy to see why a recent *N Square* report concludes that the US nuclear policy field disproportionately excludes and marginalises individuals from those specific socioeconomic circumstances.[6]

Taking all of this into account, it ultimately follows that if individuals from higher socioeconomic statuses are the ones performing or advising the nuclear decision-making process, it is possible that they are making decisions that the rest of their country's population neither understands nor supports.

## Nuclear War is Not a 'Great Equalizer'

Due to its uniquely existential nature, nuclear war is often described as a 'Great Equalizer'.[7] Although this framing can be rhetorically useful, it effectively flattens the effects of nuclear weapons by suggesting that each individual – regardless of their socioeconomic status – would experience nuclear war in the same way.

This rhetorical claim, however, stands in stark contrast to existing analyses demonstrating that class disparities affect how individuals experience other global crises, such as pandemics and climate change. Despite the fact that these types of existential crises are also commonly termed 'great equalizers', empirical data demonstrates that both crises disproportionately harm racialised communities, and particularly low-income and vulnerable individuals within those communities.[8] This is because crises of this nature tend to exacerbate existing inequalities within civil institutions; given that socioeconomic status affects one's degree of access to necessities like healthcare, food, shelter and financial support, any societal reduction in those services due to crisis ensures that those occupying the bottom rungs ultimately get excluded. Many

5. *Ibid.*, p. 332.
6. *N Square*, 'Greater Than'.
7. Examples of this phrase being used include hydrogen bomb designer Richard Garwin: 'Nuclear weapons are the great equalizer', quoted in James Sterngold, 'Nuclear Weapons No Longer Tools of the Mightiest Nations: North Korea, Others Want a Few for Strategic Advantage', *SFGate,* 22 October 2006, <https://www.sfgate.com/news/article/Nuclear-weapons-no-longer-tools-of-the-mightiest-2467820.php>, accessed 9 July 2020, and former US Defense Secretary Les Aspin: 'Nuclear weapons still serve the same purpose––as a great equalizer. But it is the United States that is now the potential equalizee', in 'Shaping Nuclear Policy for the 1990s: A Compendium of Views: Report of the Defense Policy Panel of the Committee on Armed Services, House of Representatives, One Hundred Second Congress, Second Session Vol. 4', 1993, p. 551, accessed 9 July 2020.
8. S Nazrul Islam and John Winkel, 'Climate Change and Social Inequality', United Nations Department of Economic and Social Affairs, DESA Working Paper No. 152, ST/ESA/2017/DWP/152, October 2017, <https://www.un.org/esa/desa/papers/2017/wp152_2017.pdf>, accessed 7 July 2020; Gregorio A Millett et al., 'Assessing Differential Impacts of COVID-19 on Black Communities', *Annals of Epidemiology* (Vol. 47, 2020); Stephen A Mein, 'COVID-19 and Health Disparities: The Reality of "the Great Equalizer"', *Journal of General Internal Medicine* (Vol. 35, No. 8, 2020).

who study the effects of nuclear detonations recognise these class differences as well; in 2015, researchers from the UK-based organisation Article 36 concluded that, ‘As with all disasters, the socio-economic costs of a nuclear weapon explosion will not be borne equally by all’.[9]

Therefore, if socioeconomic status affects how individuals would experience the effects of nuclear war, does it also affect how individuals think about nuclear weapons? Specifically, does it have an impact on an individual’s level of subject matter expertise, as well as on their corresponding policy preferences? The introduction of new survey data into the discourse enables the interrogation of these questions in an empirical manner.

In January 2020, the ICRC released the results of a comprehensive survey of millennials’ views on war.[10] The survey included 16,000 respondents aged 20–35 from 16 countries and territories – five of which are nuclear-armed. By isolating the class-based factors of the survey in particular – education and income levels – it is possible to interrogate the data and see whether young people from different socioeconomic statuses in nuclear-armed states think about nuclear weapons differently.

## Threat Assessments and Policy Preferences

The similarity between the ICRC survey and studies conducted in the 1980s allows for some historical comparison. In those studies, American high-school seniors not planning on attending college consistently had more pessimistic responses about the likelihood of nuclear war than those planning on attending college.[11] Interestingly, this finding is echoed in the 2020 ICRC report – not just for the US, but for all five nuclear-armed states surveyed. As shown in Table 1, when asked whether nuclear war was likely to occur in the next decade, a pattern can be seen that respondents at higher income and education levels across all five countries have much more ‘optimistic’ views – believing that nuclear war is *less* likely – than their less affluent and less educated counterparts.

9. Article 36, ‘Economic Impacts of a Nuclear Weapon Detonation’, Briefing Paper, March 2015, <http://www.article36.org/wp-content/uploads/2015/08/Economic-impact.pdf>, accessed 15 April 2020.
10. International Committee of the Red Cross, ‘They Didn’t Start The Fire: Millennial Views on War and Peace’, 2020, <https://www.icrc.org/en/millennials-on-war>, accessed 20 February 2020.
11. William R Beardslee, ‘Children’s and Adolescents’ Perceptions of the Threat of Nuclear War: Implications of Recent Studies’, in Fred Solomon and Robert Q Marston (eds), *The Medical Implications of Nuclear War* (Washington, DC: National Academies Press, 1986).

**Table 1:** Respondents' Reflections on the Likelihood of Nuclear War

| | | Total | Education | | Income | | | |
|---|---|---|---|---|---|---|---|---|
| Country | | | Up to uni | Uni and above | Lower | Middle | Upper | Prefer not to say |
| US | SUM + | 58.3 | 56.1 | 59 | 59.3 | 61.2 | 55.8 | 46.6 |
| | SUM - | 33.7 | 33.3 | 33.8 | 30.1 | 30.5 | 39.6 | 43.6 |
| UK | SUM + | 52 | 52.1 | 51.9 | 54.2 | 51.2 | 50.4 | 52.6 |
| | SUM - | 39.3 | 37.3 | 41.2 | 34.3 | 39.8 | 43.8 | 38.4 |
| France | SUM + | 45.2 | 49.2 | 43.1 | 47 | 43.8 | 43.1 | 47.9 |
| | SUM - | 46.7 | 39.7 | 50.4 | 44 | 50.6 | 50.8 | 39.4 |
| Russia | SUM + | 47.7 | 46.5 | 50.1 | 48.6 | 48.3 | 44.2 | 53.1 |
| | SUM - | 44.6 | 44.6 | 44.4 | 42.7 | 51.4 | 51.4 | 23.7 |
| Israel | SUM + | 44.7 | 45.8 | 43.4 | 50.2 | 40.5 | 40.5 | 40.1 |
| | SUM - | 47.7 | 46.4 | 49.2 | 40.7 | 56.7 | 56.7 | 45.8 |
| Note | 'SUM +' is the sum of 'very likely' and 'somewhat likely';<br>'SUM -' is the sum of 'very unlikely' and 'somewhat unlikely'. | | | | | | | |

*Source: International Committee of the Red Cross (ICRC), 'They Didn't Start the Fire: Millennial Views on War and Peace', 2020, <https://www.icrc.org/en/millennials-on-war>, accessed 20 February 2020.*

Why might this be the case? While optimism bias among wealthier respondents is certainly possible – although further study of class correlation with cognitive biases remains sorely lacking – an alternative possibility is that individuals from higher socioeconomic statuses inherently have a greater sense of their own agency.[12] This was highlighted in Cold War-era studies, in which one psychologist noted, 'Poorer children may appear less concerned about the arms race simply because they don't see any way to translate their concern into action. It's the same way they

12. The idea that wealthier people tend to be more optimistic is one that is often reinforced in self-help or get-rich-quick blogs; however, the correlation between wealth, power and optimism is one that has yet to be empirically studied in detail. An example of the above blogs is Gerri Detweiler, 'Why Optimists Make More Money Than Pessimists', *Nav*, 6 June 2018, <https://www.nav.com/blog/why-optimists-make-more-money-than-pessimists-29676/>, accessed 27 July 2020.

feel helpless about many aspects of their lives'.[13] Regardless of the reason, given the implication that there appears to be a class-based divergence in assessments of the nuclear threat, it should logically follow that there would also be a class-based divergence in assessments of how to best mitigate that threat – specifically through strategies like non-proliferation, disarmament or enhanced deterrence. The ICRC data ultimately supports this theory.

When asked to comment on whether 'countries which don't have nuclear weapons should not develop or obtain them', the data displayed in Table 2 shows that across the nuclear-armed states – with the exception of Russia, where this trend is not evident – respondents with higher education and higher income levels have more positive views of non-proliferation than those who receive less education and exist at lower income levels.

**Table 2:** Respondents' Reflections on Nuclear Non-Proliferation

| | | Total | Education | | Income | | | |
|---|---|---|---|---|---|---|---|---|
| **Country** | | | **Up to uni** | **Uni and above** | **Lower** | **Middle** | **Upper** | **Prefer not to say** |
| **US** | SUM + | 66.4 | 61.1 | 68.2 | 62.6 | 61.2 | 55.8 | 46.6 |
| | SUM - | 9.8 | 11.2 | 9.3 | 9.8 | 30.5 | 39.6 | 43.6 |
| **UK** | SUM + | 68 | 63.1 | 72.5 | 62.5 | 51.2 | 50.4 | 52.6 |
| | SUM - | 10 | 10.1 | 9.9 | 8.4 | 39.8 | 43.8 | 38.4 |
| **France** | SUM + | 61.5 | 61.4 | 61.6 | 57.3 | 43.8 | 43.1 | 47.9 |
| | SUM - | 10.4 | 9 | 11.1 | 12 | 50.6 | 50.8 | 39.4 |
| **Russia** | SUM + | 57.8 | 57.7 | 57.9 | 56.7 | 48.3 | 44.2 | 53.1 |
| | SUM - | 14.8 | 13.2 | 18.1 | 17.3 | 51.4 | 51.4 | 23.7 |
| **Israel** | SUM + | 67.8 | 65.7 | 70.1 | 64.5 | 40.5 | 40.5 | 40.1 |
| | SUM - | 8.4 | 10.2 | 6.4 | 12.1 | 56.7 | 56.7 | 45.8 |
| Note | 'SUM +' is the sum of 'very likely' and 'somewhat likely';<br>'SUM -' is the sum of 'very unlikely' and 'somewhat unlikely'. | | | | | | | |

*Source: ICRC, 'They Didn't Start the Fire'.*

13. Fox Butterfield, 'Experts Disagree on Children's Worries About Nuclear War', *New York Times*, 16 October 1984.

When respondents considered whether 'nuclear weapons are an effective instrument of deterrence', the results, displayed in Table 3, are more mixed. Across the board, respondents in the highest income brackets have the most positive assessments of nuclear weapons as an effective deterrent. However, this does not always translate into a similar result among those with the highest education levels. In certain countries, like the US and Israel, respondents at higher education levels have more negative views of nuclear deterrence, despite the fact that respondents at higher income levels in those same countries have more positive views of deterrence.

**Table 3:** Respondents' Reflections on Nuclear Deterrence

| | | Total | Education | | Income | | | |
|---|---|---|---|---|---|---|---|---|
| Country | | | Up to uni | Uni and above | Lower | Middle | Upper | Prefer not to say |
| US | SUM + | 38.2 | 42.6 | 36.7 | 34.8 | 41.4 | 40 | 30.8 |
| | SUM - | 30.2 | 23.1 | 32.7 | 32.3 | 26 | 32.4 | 29.2 |
| UK | SUM + | 36.5 | 30.3 | 42.3 | 29.6 | 36 | 45 | 31.3 |
| | SUM - | 34 | 32.4 | 35.5 | 35.4 | 32.1 | 33.6 | 37.3 |
| France | SUM + | 55.9 | 48.8 | 59.6 | 52 | 55.2 | 66.1 | 47.2 |
| | SUM - | 14.8 | 15.9 | 14.2 | 17.2 | 15.3 | 11.8 | 12.4 |
| Russia | SUM + | 72.1 | 72.5 | 71.1 | 71.4 | 71 | 75.5 | 67.2 |
| | SUM - | 12.8 | 13.2 | 11.9 | 13.7 | 12.9 | 12.3 | 6.1 |
| Israel | SUM + | 57.7 | 60 | 55.1 | 53.2 | 55 | 61.9 | 62.7 |
| | SUM - | 23.2 | 19.9 | 26.9 | 25.1 | 24.9 | 23.5 | 15.5 |
| Note | 'SUM +' is the sum of 'very likely' and 'somewhat likely';<br>'SUM -' is the sum of 'very unlikely' and 'somewhat unlikely'. | | | | | | | |

*Source: ICRC, 'They Didn't Start the Fire'.*

Turning to the disarmament-specific questions, some responses appear to be correlated much more strongly with other factors, such as nationality and gender, than with socioeconomic status.[14] For example, in the UK, respondents at higher education levels believe more strongly

14. In addition to socioeconomic status, it is worth noting that certain questions relating to disarmament and deterrence correlated strongly with gender. For example, across all five

than those at lower education levels that 'countries which have nuclear weapons should eliminate them', but in France it was the opposite – respondents at higher education levels oppose disarmament much more strongly than respondents at lower education levels.

That said, certain questions revealed stronger correlations between the class-based factors and a particular viewpoint. For example, respondents at the highest income brackets across all five nuclear-armed countries had much stronger support for retaining their country's nuclear weapons than respondents at lower income brackets. Similarly, those at the highest income brackets across all five nuclear-armed countries had a much more positive view that nuclear weapons make their country safer.

## Correlations and Conclusions

Given these results, it is clear that despite the connection between education and income levels, it does not *always* follow that those at higher education levels respond to questions in the same way as those at higher income levels. The same is true with those at lower education and lower income levels. That said, the ICRC data shows that socioeconomic status *does* appear to play a role in affecting how young people from nuclear-armed states perceive the threat of nuclear war, and in turn, how best to prevent it through strategies such as deterrence, disarmament, and non-proliferation.

In particular, it is evident that the responses from those at the highest income brackets appear to echo what is effectively the status quo for nuclear-armed countries. Having positive views of both deterrence and non-proliferation, and negative views of disarmament, is effectively national policy for all five nuclear-armed countries.[15] One could hypothesise that this correlation is emblematic of the natural tendency between higher-income earners to reinforce the system

nuclear-armed states, male-identifying respondents expressed much stronger support for the statement 'nuclear weapons make my country safer' than female-identifying respondents, and male-identifying respondents similarly expressed much stronger support for the statement 'nuclear weapons are an effective instrument of deterrence' than female-identifying respondents. Conversely, female-identifying respondents expressed much stronger support for the statement 'the existence of nuclear weapons is a threat to humanity' than male-identifying respondents. Given these findings, a parallel study investigating how gender correlates to nuclear policy preferences is certainly warranted.

15. This statement is broadly true but should certainly not be understood to suggest that all five nuclear-armed countries surveyed in the ICRC report have equivalent declaratory policies, nuclear doctrines or commitments to disarmament. In the UK, for example, a commitment to nuclear disarmament is a long-held and core belief on the political left, and particularly in Scotland, where the UK's Trident submarines are based. As a result, the future of the nuclear deterrent is more publicly and politically questioned in the UK than perhaps in any other nuclear-armed state.

that allowed them to reach a higher socioeconomic status.[16] However, this is just one potential explanation, and more research is needed to interrogate this question further.

It is additionally worth taking note of the strongest pattern that is evident in the ICRC data: for nearly *every single question* about nuclear weapons – no matter whether it was about deterrence, disarmament, non-proliferation or nuclear use, and no matter which country the respondents were from – those at lower education levels consistently answered 'don't know' to a much higher degree than those at higher education levels.

This finding reinforces Bidgood's analysis that knowledge of nuclear weapons issues is strongly correlated with access to more elite levels of higher education, and indicates that a lack of access to nuclear weapons content at lower education levels is not just an American phenomenon, but in fact cuts across all nuclear-armed countries. If this continues, it is reasonable to conclude that a significant percentage of young people who do not attend university – either by choice or due to socioeconomic limitations – will have much lower levels of knowledge about nuclear weapons than their more educated counterparts, despite themselves living in nuclear-armed states. Therefore, if it is in the nuclear community's common interest to make the nuclear policy field more accessible and equitable – and additionally, if it is in one's particular interest to challenge the 'nuclear status quo' – then it is incumbent upon nuclear policy professionals to consider ways to reverse this trend and ensure that both knowledge about and influence on nuclear policy is not just limited to those in the highest income and education brackets.

16. A useful explanation of this self-reinforcing relationship between wealth and power can be found in Owen Jones, 'The Establishment Uncovered: How Power Works in Britain', *The Guardian*, 26 August 2014.

# XI. The Global Artificial Intelligence Race and Strategic Balance: Which Race Are We Running?

Charlotte Levy

ARTIFICIAL INTELLIGENCE (AI) has the potential to affect ever more aspects of military and civilian life as part of the fourth industrial revolution. Countries are racing for global AI dominance, and whoever 'wins' shall reap the economic and geopolitical power expected to result. However, AI-enhanced technologies could pose new security risks that have not been encountered before.

This paper discusses some military and defence implications of AI development and assesses potential threats to Euro-Atlantic security. China has been identified as potentially threatening because of its high AI capability rankings, use of AI for military applications and poise to become the global 5G leader.

Ultimately, this paper argues that the UK and the EU should approach outsourcing critical communications infrastructure with caution and take recent security concerns involving China more seriously.

## Current AI Capability

AI has been likened to electricity in its potential transformative impact on the economy and enablement of other innovations.[1] Many expect that the 'winners' of the AI development race will dominate the coming decades economically and geopolitically, thus exacerbating tensions between countries and transforming elements of national power.[2]

1. US-China Economic and Security Review Commission, 'Emerging Technologies and Military-Civil Fusion – Artificial Intelligence, New Materials, and New Energy', 2019 Annual Report to Congress of the US-China Economic and Security Review Commission, US-China Competition, chapter 3, Section 2.
2. Claudio Feijóo et al., 'Harnessing Artificial Intelligence (AI) to Increase Wellbeing for All: The Case for a New Technology Diplomacy', *Telecommunications Policy* (Vol. 44, No. 6, 2020), pp. 1019–88.

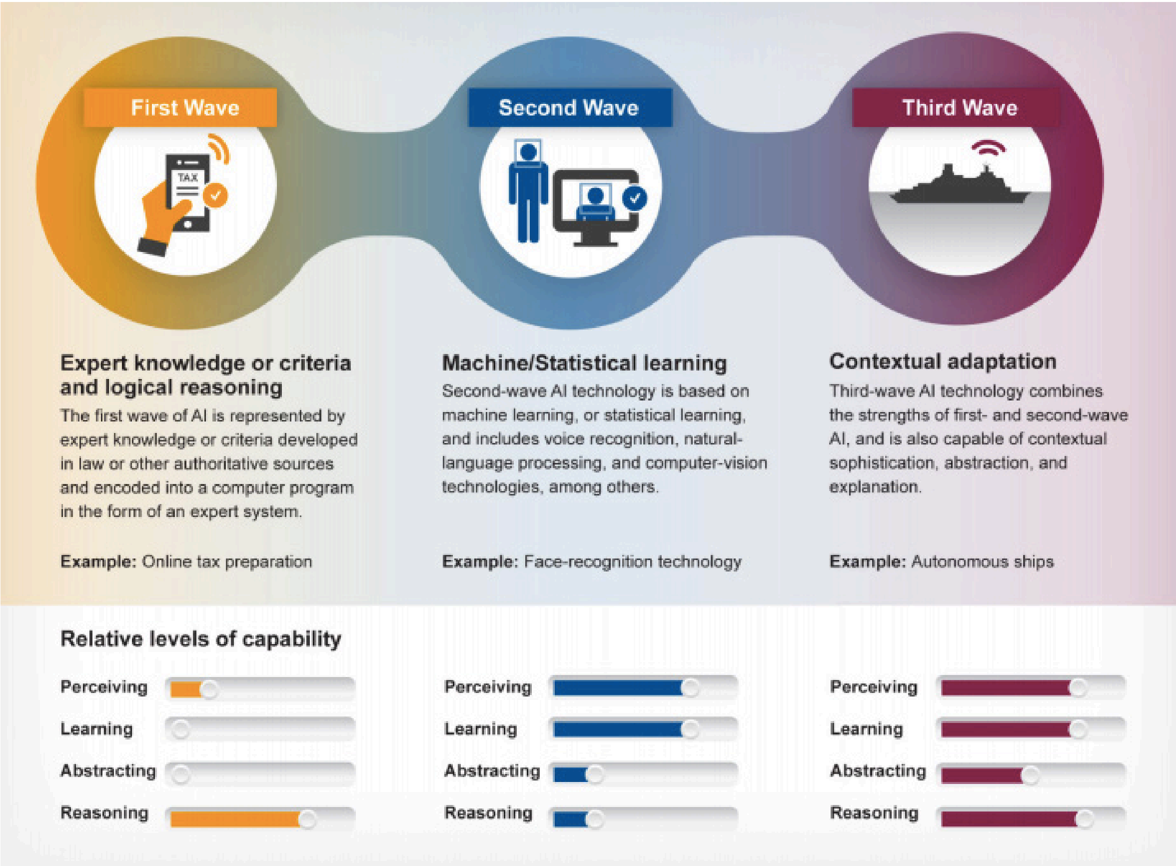
The US remains ahead in most AI capability metrics, with the UK running third, behind China.[3] Other sources use different metrics to generate their rankings.[4] AI applied to the military is large on the agenda of the US, China, Russia and Israel.[5] The implication is that whichever country leads in AI development will have a military advantage both in terms of cyber and traditional warfare.[6]

According to the framework provided by John Launchbury, AI can be conceptualised as having three waves, each based on a different capability, as depicted in Figure 1.[7] The world is still in the realm known as 'weak' or 'narrow' AI, in which AI is optimised for specific, narrow tasks such as speech recognition and performing repetitive functions. Strong AI, or artificial general intelligence (AGI), in which a machine will have human-like cognitive capability, remains a significant technical challenge.

---

3. Tortoise Media, 'The Global AI Index', <https://www.tortoisemedia.com/intelligence/ai>,\accessed 3 April 2020.
4. Stanford University, 'The 2019 AI Index Report. Human-Centered Artificial Intelligence', 2019, <https://hai.stanford.edu/research/ai-index-2019>, accessed 30 June 2020; Oxford Insights, 'Government Artificial Intelligence Readiness Index 2019', 2019, <https://www.oxfordinsights.com/ai-readiness2019>, accessed 30 June 2020; Sarah O'Meara, 'Will China Lead The World in AI by 2030?', *Nature* (Vol. 572, 2019), pp. 427–28.
5. Congressional Research Service, 'Artificial Intelligence and National Security', updated 26 August 2020, <https://fas.org/sgp/crs/natsec/R45178.pdf>, accessed 30 June 2020; Forrest E Morgan and Raphael S Cohen, 'Military Trends and the Future of Warfare: The Changing Global Environment and Its Implications for the US Air Force', RAND Corporation, 2020; Samuel Bendett et al., 'Russian Unmanned Vehicle Developments: Syria and Beyond', in Center for Strategic and International Studies (CSIS), 'Improvisation and Adaptability in the Russian Military', 30 April 2020, pp. 38–47; Vincent Boulanin and Maaike Verbruggen, 'Mapping the Development of Autonomy in Weapon Systems', SIPRI Publications, November 2017; Pax, 'Don't Be Evil?', August 2019, <https://www.paxforpeace.nl/publications/all-publications/dont-be-evil>, accessed 30 June 2020.
6. J Scott Brennen, Philip N Howard and Rasmus Kleis Nielsen, 'An Industry-Led Debate: How UK Media Cover Artificial Intelligence', Factsheet, Reuters Institute for the Study of Journalism, December 2018.
7. John Launchbury, 'A DARPA Perspective on Artificial Intelligence', DARPA, 2016, <https://www.darpa.mil/attachments/AIFull.pdf>, accessed 1 July 2020.

**Figure 1:** AI Conceptualisation Framework




*Source: United States Government Accountability Office, 'Artificial Intelligence: Emerging Opportunities, Challenges, and Implications', Report to the Committee on Science, Space, and Technology, House of Representatives, GAO-18-142SP, March 2018, <https://www.gao.gov/assets/700/690910.pdf>, accessed 16 May 2020.*

There are two major limitations in current AI technology: large amounts of labelled data are needed to train systems; and context is still poorly understood by the systems.[8] The next five years will likely see a lot of real-world piloting while building crucial datasets.[9] Opinions differ regarding the timeline for the development of AGI.[10] It has been predicted that computers will

8. US-China Economic and Security Review Commission, 'Emerging Technologies and Military-Civil Fusion – Artificial Intelligence, New Materials, and New Energy'.
9. Congressional Research Service, 'Artificial Intelligence and National Security'.
10. Leopold Schmertzing, 'Trends in Artificial Intelligence and Big Data', European Parliamentary Research Service (EPRS) Ideas Paper Series, 2019, <https://espas.secure.europarl.europa.eu/orbis/sites/default/files/generated/document/en/Trends%20in%20Artificial%20Intelligence%20and%20

routinely pass the Turing test by 2029 and the technological singularity will occur by 2045.[11] However, some sources consider AGI development unlikely for the next 20 years, if at all.[12] It is also believed that the capacity for at least some aspects of decision-making could be achieved by 2040.[13]

## The Fourth Industrial Revolution (Industry 4.0)

Industry 4.0 involves the development of smart and connected machines and systems, in which waves of further breakthroughs in areas ranging from AI, the Internet of Things (IoT), leveraging Big Data, and quantum computing will take place.[14]

Big Data is high-volume, high-velocity and/or high-variety information, known as the 3Vs.[15] The IoT, which broadly encompasses the increased connectivity of people and things, has been recognised as a key civil technology that could potentially affect US power.[16] The main purpose of the increasing number and types of IoT objects is to produce useful data about our surroundings to make them smarter.[17] IoT is expected to be a major producer of Big Data, the fusion and analysis of which enables accurate and reliable decision-making and management of ubiquitous environments; this is a grand future challenge in which AI plays a key role.[18] AI and Big Data have already changed the economy and advanced the productivity of entire markets, and Cisco predicts that 94% of global workloads will be processed in the cloud in 2021.[19] AI is

---

Big%20Data%20-%20ESPAS%20Ideas%20Paper%20-%20Leopold%20Schmertzing.pdf>, accessed 4 August 2020.

11. Roman V Yampolskiy, ‘Artificial Intelligence Safety and Cybersecurity: A Timeline of AI Failures’, *Artificial Intelligence*, 2016.
12. D F Reding and J Eaton, ‘Science & Technology Trends 2020-2040: Exploring the S&T Edge’, NATO Science & Technology Organization, 2020, <https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf>, accessed 9 July 2020.
13. Edward Geist and Andrew J Lohn, ‘How Might Artificial Intelligence Affect the Risk of Nuclear War?’, RAND Corporation, 2018.
14. Klaus Schwab, ‘The Fourth Industrial Revolution’, World Economic Forum, 2016.
15. Gartner, ‘Gartner Glossary’, 2020, <https://www.gartner.com/en/information-technology/glossary/big-data>, accessed 5 August 2020; Doug Laney, ‘Application Delivery Strategies’, META Group Inc., 2001, <https://blogs.gartner.com/doug-laney/files/2012/01/ad949-3D-Data-Management-Controlling-Data-Volume-Velocity-and-Variety.pdf>, accessed 5 August 2020.
16. SRIC-BI, ‘Disruptive Civil Technologies: Six Technologies With Potential Impacts on US Interests Out to 2025’, National Intelligence Council Conference Report, SRI Consulting Business (SRIC-BI) Intelligence, 2008, p. 48.
17. Furqan Alam et al., ‘Data Fusion and IoT for Smart Ubiquitous Environments: A Survey’, *IEEE Access* (Vol. 5, 2017), pp. 9533–54.
18. *Ibid.*
19. Schmertzing, ‘Trends in Artificial Intelligence and Big Data’.

emerging as a solution for managing large amounts of data, especially for making predictions based on the data sets.[20]

## AI in Defence

The European Defence Agency (EDA) has analysed what it considers to be the 10 key most disruptive innovations (Table 1), and the connecting technology regarding the development of those highlighted is AI.

**Table 1:** The 10 Most Disrupting Defence Innovations to Come

| | |
|---|---|
| AI and cognitive computing in defence | Robotics in defence |
| Defence Internet of Things | Autonomy in defence: systems, weapons, decision-making |
| Big Data analytics for defence | Future advanced materials for defence applications |
| Blockchain technology in defence | Additive manufacturing in defence |
| AI-enabled cyber defence | Next generation sequencing (NGS) for biological threat preparedness |

*Source: European Defence Matters, 'Disruptive Defence Innovations Ahead!',* Magazine of the European Defence Agency*, Issue 14, 2015, <https://www.eda.europa.eu/webzine/issue14/cover-story/disruptive-defence-innovations-ahead>, accessed 1 July 2020.*

Increased autonomy in weapons systems could provide an advantage on the battlefield, potentially allowing weaker nuclear-armed states to reset the imbalance of power, but exacerbating fears that stronger states may further solidify their dominance and engage in more provocative actions.[21] Competition between global leaders may lead to the proliferation of weaponised AI.[22]

20. Daoqu Geng et al., 'Big Data-Based Improved Data Acquisition and Storage System for Designing Industrial Data Platform', *IEEE Access* (Vol. 7, 2018), pp. 44574–82.
21. Franz-Stefan Gady, 'Elsa B. Kania On Artificial Intelligence And Great Power Competition', *The Diplomat*, 31 December 2019; Lora Saalman, 'The Impact of AI on Nuclear Deterrence: China, Russia, and the United States', East-West Center, <https://www.eastwestcenter.org/publications/the-impact-ai-nuclear-deterrence-china-russia-and-the-united-states>, accessed 14 May 2020.
22. Amy Ertan, 'What, Who, Where, How: The Impact of Recent Military AI Innovation in Security Terms', Defence and Security Doctoral Symposium (DSDS19), 2015, <https://cord.cranfield.ac.uk/articles/What_Who_Where_How_The_Impact_of_Recent_Military_AI_Innovation_in_Security_Terms/11536539/1>, accessed 14 May 2020; James Johnson, 'Artificial Intelligence in Nuclear Warfare: A Perfect Storm of Instability?', *Washington Quarterly* (Vol. 43, No. 2, 2020), pp. 197–211.

Additionally, the co-mingling of both AI-augmented nuclear and strategic non-nuclear weapons will exacerbate the risk of inadvertent escalation by undermining strategic stability.[23]

The US, China and Russia have all declared strategies to achieve offset advantage through robotics and AI.[24] C4ISR has been identified as a potential area of impact over the next 20 years, in which AI-enabled autonomous systems will be employed by war-fighting units.[25] It has been acknowledged that both the EU and NATO are just beginning to grapple with the issue of AI in defence, whereas Russia and China have already started thinking strategically about it.[26]

## 5G, Security and Political Stability

The introduction of 5G will see the number of IoT sensors collecting data proliferate; 5G is up to 20 times faster than 4G, has record-setting low latency, and it will allow developers to create near real-time applications.[27] This, however, will not be possible without AI.[28] The use of Big

23. James M Acton et al., 'Entanglement: Chinese and Russian Perspectives on Non-Nuclear Weapons and Nuclear Risks', Carnegie Endowment for International Peace, 2017; James Johnson, 'The End of Military-Techno *Pax Americana*? Washington's Strategic Responses to Chinese AI-Enabled Military Technology', *Pacific Review*, 2019; James Johnson, 'VIII. The Impact of Artificial Intelligence on Strategic Stability, Escalation and Nuclear Security', 2019 UK Project on Nuclear Issues (UK PONI) Annual Conference Papers, 2019.
24. Ministry of Defence (MoD), 'Joint Concept Note 1/18: Human-Machine Teaming', 2018, <https://www.gov.uk/government/publications/human-machine-teaming-jcn-118>, accessed 6 July 2020.
25. United States Government Accountability Office, 'Artificial Intelligence: Emerging Opportunities, Challenges, and Implications', Report to the Committee on Science, Space, and Technology, House of Representatives, GAO-18-142SP, 2018; James S Johnson, 'Artificial Intelligence: A Threat to Strategic Stability', *Strategic Studies Quarterly*, Spring 2020.
26. Ulrike Esther Franke, 'Not Smart Enough: The Poverty of European Military Thinking on Artificial Intelligence', European Council on Foreign Relations, 2019, <https://www.ecfr.eu/publications/summary/not_smart_enough_poverty_european_military_thinking_artificial_intelligence>, accessed 14 May 2020; EU-NATO Relations and Artificial Intelligence Conference, co-organised by the EU Institute for Security Studies (EUISS) and the Finnish Presidency of the Council of the EU at the Permanent Representation of Finland to the EU, Brussels, 14 November 2019, <https://www.iss.europa.eu/content/eu-nato-and-artificial-intelligence-new-possibilities-cooperation>, accessed 14 May 2020.
27. Mark Howden, '5G Opportunities for App Developers', Samsung Insights, 2019, <https://insights.samsung.com/2019/10/28/5g-opportunities-for-app-developers/>, accessed 3 August 2020; Moayad Aloqaily et al., 'Design Guidelines for Blockchain-Assisted 5G-UAV Networks', *Networking and Internet Architecture*, 2020, <https://arxiv.org/abs/2007.15286>, accessed 4 August 2020.
28. Karen Hao, 'DARPA is Betting on AI to Bring the Next Generation of Wireless Devices Online', *MIT Technology Review*, 25 October 2019, <https://www.technologyreview.com/2019/10/25/102492/5g-ai-darpa-next-generation-of-wireless-devices/>, accessed 3 August 2020; Geng et al., 'Big Data-Based Improved Data Acquisition and Storage System for Designing Industrial Data Platform'.

Data creates a trade-off between performance versus privacy; if operators fail to leverage it in an ethical manner, data confidentiality issues regarding large amounts of sensitive personal information (names, ID numbers, locations, passwords) become apparent.[29]

Countries are under pressure to protect their citizens and even political stability in the face of possible malicious/biased uses of AI and Big Data.[30] Because 5G networks are the future backbone of our increasingly digitised economies and societies, ensuring its security and resilience is essential.[31] Even at current capability levels, AI can be used in the cyber domain to augment attacks on cyberinfrastructure.[32] There is no such thing as perfect security, only varying levels of insecurity.[33] These 'smart' technologies rely on bidirectional wireless links to communicate with devices and global services, which gives a larger 'attack surface' that cyber threats target.[34] Thus, 5G networks may lead to politically divided and potentially noninteroperable technology spheres of influence, where one sphere would be led by the US and another by China, with some others in between (for example the EU, South Korea and Japan).[35]

All of these concerns are most significant in the context of authoritarian states but may also undermine the ability of democracies to sustain truthful public debates.[36] For example, 'deepfake' (stemming from 'deep learning' and 'fake') algorithms can create fake images and videos that cannot easily be distinguished from authentic ones by humans. It is threatening to

29. Roxana Mihet and Thomas Philippon, 'The Economics of Big Data and Artificial Intelligence', *Disruptive Innovation in Business and Finance in the Digital World* (Vol. 20, 2019), pp. 29–43; Ying He et al., 'Big Data Analytics in Mobile Cellular Networks', *IEEE Access* (Vol. 4, 2016), pp. 1985–96.
30. Feijóo et al., 'Harnessing Artificial Intelligence (AI) to Increase Wellbeing for All'; Schmertzing, 'Trends in Artificial Intelligence and Big Data'.
31. European Commission, 'Report On EU Coordinated Risk Assessment Of 5G: Member States Publish A Report On EU Coordinated Risk Assessment Of 5G Networks Security', 2019, <https://ec.europa.eu/commission/presscorner/detail/en/IP_19_6049>, accessed 3 August 2020.
32. Feijóo et al., 'Harnessing Artificial Intelligence (AI) to Increase Wellbeing for All'.
33. Yampolskiy, 'Artificial Intelligence Safety and Cybersecurity'.
34. James Hayes, 'Hackers Under The Hood', Institute of Engineering and Technology, 2020, <https://eandt.theiet.org/content/articles/2020/03/hackers-under-the-hood/>, accessed 6 July 2020; Idaho National Laboratory, 'Cyber Threat and Vulnerability Analysis of the US Electric Sector', US Department of Energy Office of Scientific and Technical Information, 2016, <https://www.osti.gov/biblio/1337873>, accessed 6 July 2020; European Commission, 'Report on EU Coordinated Risk Assessment of 5G'.
35. Paul Triolo, Kevin Allison and Clarise Brown, 'Eurasia Group White Paper: The Geopolitics of 5G', Eurasia Group, 2018, <https://www.eurasiagroup.net/siteFiles/Media/files/1811-14%205G%20special%20report%20public1).pdf>, accessed 5 August 2020; Feijóo et al., 'Harnessing Artificial Intelligence (AI) to Increase Wellbeing for All'.
36. Miles Brundage et al., 'The Malicious Use of Artificial Intelligence: Forecasting, Prevention, and Mitigation Authors are Listed in Order of Contribution Design Direction', Future of Humanity Institute, 2018, <https://img1.wsimg.com/blobby/go/3d82daa4-97fe-4096-9c6b-376b92c619de/downloads/1c6q2kc4v_50335.pdf>, accessed 5 August 2020.

global security if deepfake methods are employed to promulgate misinformation. Additionally, they are a huge threat to privacy and identity. The proposal of technologies that can assess the integrity of digital media is therefore indispensable.[37]

Safety and control are also areas in which AI will need to be regulated, and some also call for banning or severely limiting R&D in fields of AI such as autonomous weapons, superintelligent AI and offensive cyber capabilities.[38] Virtually all AI models include a 'black box' aspect to the software that even the creators do not fully understand, which adds to the major challenge of preserving algorithm openness.[39]

The implications of AI for EU and UK security and defence are largely unknown at this stage.[40] Europe is behind other global players.[41] Yet, successive EU strategies have continued to reinforce the desire for European technical autonomy and even outright 'sovereignty' in areas of key strategic importance, including 5G and 6G.[42] The EU has declared the need for a high level of data protection, digital rights and ethical standards in AI and robotics, and insists on ethical standards as well as preparedness for the social changes caused by AI.[43]

The China 2025 strategy is about making China 'a major cyber power' and its capacity to shape the international governance of cyberspace according to its own interests. Some refer to the digital revolution underway and the deepening Sino-American competition as a new arms race.[44]

---

37. Gady, 'Elsa B. Kania on Artificial Intelligence and Great Power Competition'; Thanh Thi Nguyen et al., 'Deep Learning for Deepfakes Creation and Detection: A Survey', Computer Vision and Pattern Recognition, <https://arxiv.org/abs/1909.11573>, accessed 5 August 2020.
38. Schmertzing, 'Trends in Artificial Intelligence and Big Data'.
39. Feijóo et al., 'Harnessing Artificial Intelligence (AI) to Increase Wellbeing for All'.
40. Daniel Fiott and Gustav Lindstrom, 'Artificial Intelligence: What Implications for EU Security and Defence?' EUISS, <https://www.jstor.org/stable/resrep21476>, accessed 17 May 2020.
41. *Ibid.*
42. Andrés Ortega Klein, 'The US-China Race and the Fate of Transatlantic Relations: Part II: Bridging Differing Geopolitical Views', CSIS, 2020; EU-NATO Relations and Artificial Intelligence conference, co-organised by the EEUISS and the Finnish Presidency of the Council of the EU, Permanent Representation of Finland to the EU, Brussels.
43. European Group on Ethics in Science and New Technologies, 'Statement on Artificial Intelligence, Robotics and Autonomous Systems', <http://ec.europa.eu/research/ege/pdf/ege_ai_statement_2018.pdf>, accessed 5 August 2018; European Commission, 'Artificial Intelligence for Europe', (COM2018) 237 final, <https://ec.europa.eu/transparency/regdoc/rep/1/2018/EN/COM-2018-237-F1-EN-MAIN-PART-1.PDF>, accessed 5 August 2020.
44. François Godement et al., 'The China Dream Goes Digital: Technology in the Age of Xi', European Council on Foreign Relations, 2018, <https://www.ecfr.eu/publications/summary/the_china_dream_digital_technology_in_the_age_of_xi>, accessed 5 August 2020.

## Is China a Threat?

China was recently poised to become the global leader in 5G technology despite Huawei's products and services being assessed as highly insecure.[45] In January, the UK announced that Huawei will be allowed to build part of the country's 5G core network. The US, citing Huawei equipment's high-risk nature to critical infrastructures, responded with threats of restricting intelligence cooperation.[46] The UK's Huawei Cyber Security Evaluation Centre Oversight Board reported in 2018 that 'security critical third-party software used in a variety of products was not subject to sufficient control'; Huawei replied that it may need three to five years to mitigate these two flaws, but by then, most decisions about 5G contracts will have been taken and the construction of 5G networks will already be underway.[47] Once introduced, it will be an 'unextractable' part of British infrastructure.[48]

It can be argued that the prevailing practice of Big Data in China is much less attuned to the social, political and ethical implications that a human-centric approach would demand. Consequently, Chinese technologies and government policies have attracted growing international attention and scrutiny.[49] China is implementing extensive social surveillance and an AI-based social credit scheme, which would be considered controversial in other countries and enable the collection of user behaviour data to later potentially give or deny access to a range of services provided by the state. The regime's increasing dependence on its AI and Big Data systems builds a digital authoritarian regime.[50]

---

45. Elsa B Kania, 'Securing Our 5G Future: The Competitive Challenge and Considerations for US Policy', Center for a New American Security (CNAS), 2019, <https://www.cnas.org/publications/reports/securing-our-5g-future>, accessed 6 July 2020.
46. Valentin Weber, 'Making Sense of Technological Spheres of Influence', London School of Economics and Political Science, 2020, <http://www.lse.ac.uk/ideas/publications/updates/technological-spheres-of-influence>, accessed 6 July 2020.
47. Valentin Weber, 'Finding a European Response To Huawei's 5G Ambitions', Norwegian Institute of International Affairs (NUPI), 2019, <https://www.jstor.org/stable/resrep19875>, accessed 6 July 2020.
48. Sarah Young, 'UK Defence Committee to Probe Security of 5G Network on Huawei Concerns', *Reuters*, 2020.
49. Min Jiang and King-Wa Fu, 'Chinese Social Media and Big Data: Big Data, Big Brother, Big Profit?', *Policy & Internet* (Vol. 10, Issue 4, 2018), pp. 372–92; Gaurav Shukla, 'Google Removes Viral Indian App That Deleted Chinese Ones: 10 Points', Gadgets360°, 2020, <https://gadgets.ndtv.com/apps/news/remove-china-apps-google-play-store-removal-top-10-things-2239894>, accessed 5 August 2020; Leo Kelion, 'TikTok: How Would the US Go About Banning the Chinese App?', *BBC News*, 3 August 2020, <https://www.bbc.co.uk/news/technology-53621492>, accessed 5 August 2020.
50. Valentin Weber, 'AI, China, Russia, and the Global Order: Technological, Political, Global, and Creative Perspectives', Centre for Technology and Global Affairs, University of Oxford, 2019; Max Craglia et al., 'Artificial Intelligence: A European Perspective', Publications Office of the EU, 2020, <https://op.europa.eu/en/publication-detail/-/publication/ed2148f3-0288-11e9-adde-01aa75ed71a1/language-en>, accessed 3 August 2020; Christina Larson, 'Who Needs Democracy

If many critical components of a country's 5G infrastructure are of Chinese origin, it gives China easier access to spy on or disrupt that country's online communications.[51] The UK needs to understand how the risks that come with foreign equipment can be mitigated, because even now, little is known about how the UK counters potential security breaches that may come with the Chinese-produced surveillance equipment installed in various London boroughs.[52] Jeremy Warner of *The Telegraph* states that the UK risks 'leaving the future to China in our rush to data protection'.[53]

In June 2019, China issued its first AI ethics code: the Beijing AI principles. This is the first public signal of some willingness within the country to discuss the ethics of AI.[54] Earlier in 2020, the US Commerce Department released new regulations restricting access to US technology by various Chinese companies.[55] The need for future regulation will depend a lot on the technological progress of AI, as policy and regulation may subvert its development (and vice versa).[56] An international, collaborative governance and the potential for a new technology diplomacy may be key in attaining stability during Industry 4.0.[57]

## Conclusions

The implications of AI technologies on national security remain largely unknown at this stage. However, the UK's actions in recent times appear to be to isolate itself strategically from its allies by initially going against the US's wishes of banning Huawei from its 5G infrastructure and deciding to leave the EU, which has its own strategic priority to prove geopolitical relevance. Only very recently has the UK government decided to phase out Huawei's 5G role from the country.[58] It is still extremely important, though, for the UK to fully understand the surveillance equipment already in use by identifying potential gaps in existing frameworks and enforcement mechanisms.[59]

---

When You Have Data?', *MIT Technology Review*, 20 August 2018, <https://www.technologyreview.com/2018/08/20/240293/who-needs-democracy-when-you-have-data/>, accessed 5 August 2020.

51. Weber, 'Making Sense of Technological Spheres of Influence'.
52. *Ibid*.
53. Brennen, 'An Industry-Led Debate'.
54. Feijóo et al., 'Harnessing Artificial Intelligence (AI) to Increase Wellbeing for All'.
55. Dieter Ernst, 'Catching Up in a Technology War: China's Challenge in Artificial Intelligence', East-West Center, 16 June 2020, <https://www.eastwestcenter.org/publications/catching-in-technology-war%E2%80%94chinas-challenge-in-artificial-intelligence>, accessed 3 August 2020.
56. Feijóo et al., 'Harnessing Artificial Intelligence (AI) to Increase Wellbeing for All'; Schmertzing, 'Trends in Artificial Intelligence and Big Data'.
57. Feijóo et al., 'Harnessing Artificial Intelligence (AI) to Increase Wellbeing for All'.
58. Aishwarya Nair and Daniel Wallis, 'UK PM Johnson to Phase Out Huawei's 5G Role Within Months – The Telegraph', *Reuters*, 4 July 2020.
59. NIS, 'EU Coordinated Risk Assessment of the Cybersecurity of 5G Networks', NIS Cooperation Group, 9 October 2019, <https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=62132>, accessed 6 August 2020.

The EDA should engage with non-traditional defence R&D communities and innovators to speed up access to emerging and potentially disruptive research and identify areas for additional investment to fully address future defence capability needs.[60] Consideration should also be given to the development of European industrial capacity.[61]

Countries that have fallen behind in AI may have only two options: to join the race and possibly develop niche AI or to regulate its uses to mitigate potentially undesirable applications.[62]

International policy coordination remains a necessary instrument to tackle the ethical and political repercussions of AI to facilitate the global alignment of AI policy and governance.[63]

60. European Defence Matters, 'Disruptive Defence Innovations Ahead!', *Magazine of the European Defence Agency* (No. 14, 2017), <https://www.eda.europa.eu/webzine/issue14/cover-story/disruptive-defence-innovations-ahead>, accessed 1 July 2020; Loredana Ceccacci, 'The Ethics of Big Data', European Economic and Social Committee, 2017, <https://www.eesc.europa.eu/en/our-work/publications-other-work/publications/ethics-big-data>, accessed 18 May 2020.
61. NIS, 'EU Coordinated Risk Assessment of the Cybersecurity of 5G Networks'.
62. Yuval Noah Harari, 'Who Will Win the AI Race?', *Foreign Policy* (Winter 2019), pp. 52–55.
63. Feijóo et al., 'Harnessing Artificial Intelligence (AI) to Increase Wellbeing for All'.

# XII. Human vs Machine: The Role of Artificial Intelligence in Nuclear Weapons Systems

Jonathan Roberts, Adam Tunbridge, Paul Neale, Jennifer Insley and Rebecca Desmond

FUELLED BY TECHNOLOGICAL advances, the world is currently in an artificial intelligence (AI) summer – a period of increased interest and funding in AI research.[1] AI is beginning to shape our society and its power is being harnessed to both supplement human performance and replace it.[2] The media is awash with headlines highlighting how AI is benefiting humanity, but there are also stark warnings of the dangers. This study presents a technical exploration of the risks and opportunities AI can bring to nuclear weapons systems and the impact this might have on the level of human involvement. The definitions of key technical terms used in this study are as follows:

- **Artificial intelligence**: A computer system that mimics human cognitive functions, such as learning and problem solving.[3]
- **Nuclear weapons system**: Considered in a broad sense – not just the nuclear warheads and delivery systems but also all the nuclear force-related systems such as platform, command and control, and early warning.[4]

Based on these definitions, the computation techniques used in Cold War-era nuclear weapons systems are classed as 'precursors to AI'; examples of which are briefly outlined in this paper. Additionally, a retaliatory nuclear firing sequence has been defined (Figure 1) and analysed to illustrate specific ways human involvement can be supplemented or replaced.

---

1. Sebastian Schuchmann, 'History of the First AI Winter', 12 May 2019, <https://towardsdatascience.com/history-of-the-first-ai-winter-6f8c2186f80b>, accessed 7 July 2020.
2. H James Wilson and Paul R Daugherty, 'Collaborative Intelligence: Humans and AI are Joining Forces', *Harvard Business Review* (Vol. 96, No. 4, 2018), pp. 114–23; Mohammad M H Jarrahi, 'Artificial Intelligence and the Future of Work: Human-AI Symbiosis in Organizational Decision Making', *Business Horizons* (Vol. 61, No. 4, 2018), pp. 577–86; Luke Dormehl, 'The Best Examples of Robots Replacing Jobs Around the World', *Digital Trends*, 5 November 2018, <https://www.digitaltrends.com/cool-tech/examples-of-robots-replacing-jobs/>, accessed 7 July 2020.
3. Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 3rd Edition (Upper Saddle River, NJ: Prentice Hall, 2009).
4. Vincent Boulanin, 'Introduction', in Vincent Boulanin (ed.), 'The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk: Volume I, Euro-Atlantic Perspectives', Stockholm International Peace Research Institute (SIPRI), May 2019, pp. 3–9.

**Figure 1:** Retaliatory Nuclear Firing Sequence


*Note: Running left to right: initially a nuclear threat is detected, then the decision to respond is made, then the receipt of the command by the weapon platform, then targeting, then launch and engagement, and finally an engagement assessment.*

*Source: Author generated.*

## Nuclear AI Precursors

The benefits of computation and autonomy have long been incorporated into nuclear weapons systems.[5] Outlined below are some examples of Soviet AI precursors, although the US had similar counterparts.[6]

First, the Oko system, a satellite-based early-warning system that used image recognition to detect missile launch exhausts from infrared satellite imagery.[7] This early-warning technology decreased the time from launch to identify threats, affording more time for response decision-making.[8] However, the technology was not entirely reliable and prone to reporting false positives.[9] A major malfunction occurred in 1983, nearly causing a catastrophe when the system mistakenly identified sunlight reflected off high-altitude clouds as an incoming US missile attack.[10] Fortunately, the officer on duty believed the readings to be erroneous and decided not to follow orders to report them to his superiors (who would most likely have elected to retaliate in kind).[11]

5. Matt Field, 'As the US, China, and Russia Build New Nuclear Weapons Systems, How Will AI Be Built In?', *Bulletin of the Atomic Scientists*, 20 December 2019.
6. Federation of American Scientists, 'NORAD at 40: Historical Overview', 2020, <https://fas.org/nuke/guide/usa/airdef/norad-overview.htm>, accessed 6 July 2020; Federation of American Scientists, 'Emergency Rocket Communications System (ERCS)', 1998, <https://fas.org/nuke/guide/usa/c3i/ercs.htm>, accessed 6 July 2020.
7. Pavel Podvig, 'History and the Current Status of the Russian Early-Warning System', *Science and Global Security* (Vol. 10, No. 1, 2002), pp. 21–60.
8. Podvig, 'History and the Current Status of the Russian Early-Warning System'.
9. *Ibid*.
10. *Ibid*.; Geoffrey Forden, Pavel Podvig and Theodore A Postol, 'False Alarm, Nuclear Danger', *IEEE Spectrum* (Vol. 37, No. 3, 2000), pp. 31–39.
11. Pavel Aksenov, 'The Man Who May Have Saved The World', *BBC News*, 26 September 2013.

Another system of interest is the Dead Hand system, which ensured nuclear retaliatory capability.[12] At its most capable, the system was able to operate in a semi-automated mode that did not require a command authority to launch. In this case, the system would detect nuclear impacts in the USSR, and in the event that the Soviet command and control infrastructure was destroyed, would pass the ultimate authority to a small team of duty officers, who could then invoke the Perimeter system to communicate and coordinate launch orders to the remaining nuclear arsenal.[13] Benefits of this system included an increased robustness of second strike, allowing more decision time to the firing authority, reducing the likelihood of rash decisions.[14]

## AI Augmentation of the Retaliatory Nuclear Firing Sequence

Applications of AI are becoming increasingly prevalent in modern society. The advances are revolutionising technologies and enhancing processes, allowing for the development of self-driving cars, rapid iterative design solutions and computer conversational interfaces, to name a few. The same underpinning AI technologies can be applied to the Nuclear Firing Sequence (Figure 1), as discussed in a number of recent articles.[15] This, along with the following established AI applications, provides a speculative framework detailing how the role of AI could develop nuclear weapons systems up to 2040.

A number of key terms are defined below:

- **Pattern recognition**: 'the recognition of data patterns or data regularities in a given scenario'.[16]
- **Image recognition**: the recognition of 'people, animals, objects or other targeted subjects through the use of algorithms and machine learning concepts'.[17]
- **Data fusion**: the process of combining data from multiple sources to build high-fidelity, reliable and accurate information about subjects of interest.[18]

---

12. Boulanin (ed.), 'The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk*:* Volume I, Euro-Atlantic Perspectives', pp. 46–53.
13. Boulanin (ed.), 'The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk*:* Volume I, Euro-Atlantic Perspectives'.
14. *Ibid*.
15. Phil Stewart, 'Deep in the Pentagon, a Secret AI Program to Find Hidden Nuclear Missiles', *Reuters*, 5 June 2018; Jeenho Hahm, 'Artificial Intelligence and the New Nuclear Age', *Columbia Public Policy Review*, 2018, <http://www.columbiapublicpolicyreview.org/2018/06/artificial-intelligence-and-the-new-nuclear-age/>, accessed 7 July 2020.
16. Techopedia.com, 'What is Pattern Recognition?', 2020, <https://www.techopedia.com/definition/8802/pattern-recognition-computer-science>, accessed 7 July 2020.
17. Techopedia.com, 'What is Image Recognition?', 2020, <https://www.techopedia.com/definition/33499/image-recognition>, accessed 14 July 2020.
18. Silvia Beddar-Wiesing and Maarten Bieshaar, 'Multi-Sensor Data and Knowledge Fusion – A Proposal for a Terminology Definition', Cornell University, 13 January 2020.

- **Autonomy**: seeks to use the above three techniques to allow systems to perform their functions without human assistance.

### Detection

The physical detection of a nuclear threat currently uses information from sensors such as early-warning radars and satellites.[19] An immediate enhancement AI could bring to these individual capabilities is intelligent data fusion, which can provide enhanced credibility to detection events with the ability to intelligently cross reference information from an array of detectors.[20] Furthermore, more recent techniques such as deep learning have the potential to produce predictions far more accurate than any preceding system – resulting in less emphasis on the need for human verification.[21] These augmentations lengthen the window of opportunity to respond and therefore increase the likelihood of success of any response, bolstering the deterrence argument.

### Firing Authority

The firing authority stage, if augmented with AI, could perform analysis of complex and fast-changing large datasets that provide a deeper level of analysis than any human or hard programmed system could, and continue to supplement data up to this point drawn from detection. This might involve the detection of subtle patterns such as the prevailing social media sentiment, troop movements and posturing of countries of interest.[22] All of this information can inform the response decision planning. It is possible that this stage could be completely automated or limit the human input to the final decision.

---

19. Philip A Ingwersen and William Z Lemnios, ‘Radars for Ballistic Missile Defense Research’, *Lincoln Laboratory Journal* (Vol. 12, No. 2, 2000), pp. 245–66; Meimei Z Tidrow and Walter R Dyer, ‘Infrared Sensors For Ballistic Missile Defense’, *Infrared Physics & Technology* (Vol. 42, No. 3–5, 2001), pp. 333–36.
20. David L Hall and James Llinas, ‘An Introduction to Multisensor Data Fusion’, *Proceedings of the IEEE* (Vol. 85, No. 1, 1997), pp. 6–23.
21. Yan LeCun, Yoshua Bengio and Geoffrey Hinton, ‘Deep Learning’, *Nature* (Vol. 521, No. 7553, 2015), pp. 436–44; Ian Goodfellow, Yoshua Bengio and Aaron Courville, *Deep Learning* (Cambridge, MA: Massachusetts Institute of Technology, 2016); Jürgen Schmidhuber, ‘Deep Learning in Neural Networks: An Overview’, *Neural Networks* (Vol. 61, 2015), pp. 85–117; Jessica Hamzelou, ‘AI System is Better Than Human Doctors at Predicting Breast Cancer’, *New Scientist*, 1 January 2020.
22. Hsinchun Chen and David Zimbra, ‘AI and Opinion Mining’, *IEEE Intelligent Systems* (Vol. 25, No. 3, 2010), pp. 74–80; Bogdan Batrinca and Philip C Treleaven, ‘Social Media Analytics: A Survey of Techniques, Tools and Platforms’, *AI & Society* (Vol. 30, No. 1, 2015), pp. 89–116; M Haridas, ‘Redefining Military Intelligence Using Big Data Analytics’, *Scholar Warrior,* Autumn 2015, pp. 72–78; Kevjn Lim, ‘Big Data And Strategic Intelligence’, *Intelligence and National Security* (Vol. 31, No. 4, 2016), pp. 619–35.

### Platform Authority

Within the confines of the 2040 timeframe, a limited scope for AI augmentation at the platform authority stage can be assumed, with the likely implementation being an increase in autonomy. An automatic system would have the potential to process the firing command faster than a human system and could carry out a more robust authorisation verification process.[23] This possibility of removing the human completely from the system could allow for significant changes to the design of the delivery platform and process.[24]

### Target

AI augmentation of the targeting phase is likely to have little impact on the extant human involvement, as in most cases this is predominantly computational with use of inertial navigation systems combined with stellar referencing systems.[25] AI has the potential to use multi-sensor data fusion, making use of real time on- and off-board data sources to optimise the flight path, launch time and entry profiles to avoid potential interceptors and maximise mission success.

### Engage

The engagement phase of the firing chain potentially boasts the most opportunity for AI augmentations. This could be achieved via direct interactions with the delivery system or by enhancing countermeasure performance. AI technology could be used to update the missile flight path in real time based on weather conditions and defences, using autonomy and data fusion.[26] With the continued development of countermeasures, there is potential for AI to aid performance with operations such as actively jamming sensors and processing situational

23. Ashish A Dongare and R D Ghongade, 'Artificial Intelligence Based Bank Cheque Signature Verification System', *International Research Journal of Engineering and Technology* (Vol. 3, No. 1, 2016).
24. Tim Hardy and Gavin Barlow, 'Unmanned Underwater Vehicle (UUV) Deployment and Retrieval Considerations for Submarines', paper presented at the International Naval Engineering Conference and Exhibition, Hamburg, April 2008.
25. Neil Barbour, 'Inertial Components – Past, Present, and Future', paper presented at the American Institute of Aeronautics and Astronautics, Guidance, Navigation, and Control Conference and Exhibit, Montreal, 6–9 August 2001, <https://arc.aiaa.org/doi/10.2514/6.2001-4290>, accessed 25 September 2020; Missile Threat, CSIS Missile Defense Project, 'Trident D-5', 2018, <https://missilethreat.csis.org/missile/trident/>, accessed 7 July 2020; Glenn J Kleinhesselink, 'Stellar Augmented Inertial Guidance for Ballistic Missiles', *IEEE Transactions on Military Electronics* (Vol. 1, 1963), pp. 19–22.
26. Pennsylvania State University, 'Using Artificial Intelligence to Better Predict Severe Weather: Researchers Create AI Algorithm to Detect Cloud Formations That Lead to Storms', *ScienceDaily*, 2 July 2019, <https://www.sciencedaily.com/releases/2019/07/190702160115.htm>, accessed 7 July 2020; International Committee of the Red Cross, 'Autonomy, Artificial Intelligence and Robotics: Technical Aspects of Human Control', 20 August 2019, <https://www.icrc.org/en/

awareness data to adapt to threats and threat environments.[27] In addition, during coordinated attacks, machine learning techniques could be used to learn from the failures of preceding attacks.[28] Another benefit of the increased situational awareness could be the ability to detect changing conditions including those leading to the need for an aborted launch.

**Assess**

The methodologies employed during the assessment phase are similar to those used during detection. The use of AI has the potential to increase the speed and accuracy of the data evaluation, saving critical time during the mission success assessment and resulting decision-making process.[29]

## Safety Assurance

Assuring the safety of AI systems is challenging because they are generally incredibly complex, layered and unpredictable, and are highly dependent on the data they have been trained on.[30] There is a lack of transparency in their decision-making processes so it is difficult for humans to understand the logical reasoning behind some of the AI's inferences.[31] There have been a number of notable accidents involving AI systems, especially in autonomous vehicles.[32]

---

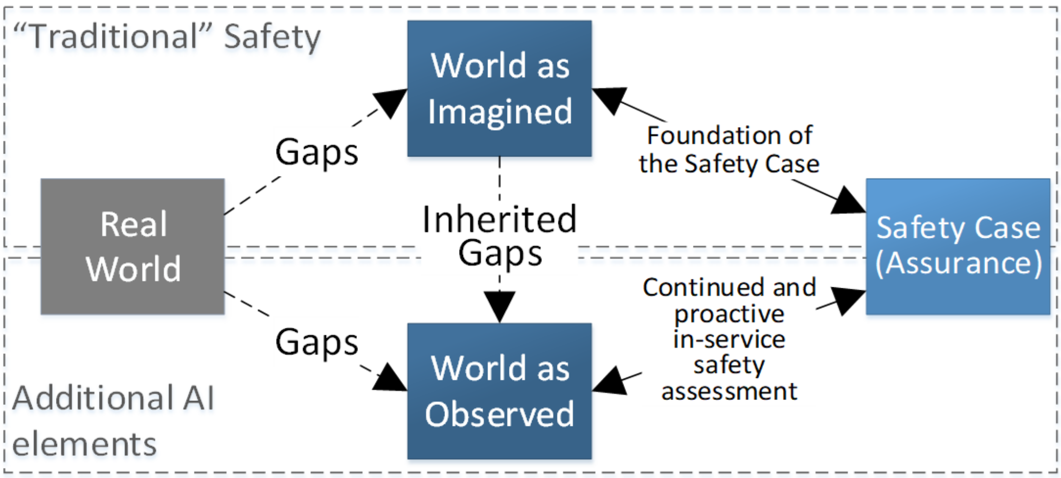
document/autonomy-artificial-intelligence-and-robotics-technical-aspects-human-control>, accessed 7 July 2020.

27. Steve Fetter et al., 'Countermeasures: A Technical Evaluation of the Operational Effectiveness of the Planned US National Missile Defense System', Union of Concerned Scientists and MIT Security Studies Program, April 2000, <https://drum.lib.umd.edu/bitstream/handle/1903/4333/2000-UCS-CM.pdf?sequence=1&isAllowed=y>, accessed 25 September 2020.
28. Ethem Alpaydin, *Introduction to Machine Learning* (Cambridge, MA: MIT Press, 2020); Donald Michie, David J Spiegelhalter and Christine Taylor, 'Machine Learning', *Neural and Statistical Classification* (Vol. 13, 1994), pp. 1–298.
29. James S Johnson, 'Artificial Intelligence: A Threat to Strategic Stability', *Strategic Studies Quarterly* (Vol. 14, No. 1, 2020).
30. Jacob Steinhardt, 'Long-Term and Short-Term Challenges to Ensuring the Safety of AI Systems', Academically Interesting, 24 June 2015, <https://jsteinhardt.wordpress.com/2015/06/24/long-term-and-short-term-challenges-to-ensuring-the-safety-of-ai-systems/>, accessed 7 July 2020.
31. Steinhardt, 'Long-Term and Short-Term Challenges to Ensuring the Safety of AI Systems'.
32. National Transportation Safety Board, 'Collision Between Vehicle Controlled by Developmental Automated Driving System and Pedestrian', 18 March 2018, <https://www.ntsb.gov/investigations/Pages/HWY18FH010.aspx>, accessed 8 July 2020; *The Economist*, 'Why Uber's Self-Driving Car Killed a Pedestrian', 29 May 2018; Tom Krisher, 'Tesla's Autopilot System Faces Increased Scrutiny After 3 Crashes, 3 Deaths', *Global News*, 3 January 2020; Tao Li et al., 'Opinion Mining at Scale: A Case Study of the First Self-Driving Car Fatality', paper presented at IEEE International Conference on Big Data, Seattle, 10–13 December 2018, pp. 5378–80.

### Safety Gaps

With traditional safety management, safety assessment can be carried out prior to development and remains largely valid throughout life.[33] With AI, there are added difficulties and gaps. In addition to gaps between the real world and the world as we imagine it, there are also inherited gaps between the world as we imagine it and how an AI system might imagine it, as seen in Figure 2.[34]

**Figure 2:** Traditional Safety vs AI Gaps



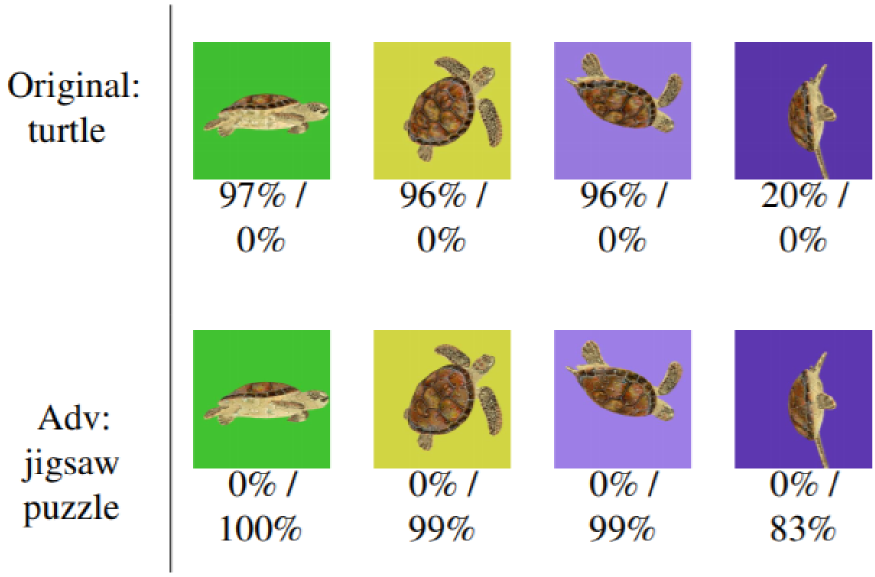

*Source: Adapted from John A McDermid, Yan Jia and Ibrahim Habli, 'Towards a Framework for Safety Assurance of Autonomous Systems', Artificial Intelligence Safety (August 2019), pp. 1–7.*

### AI Inferences

In real-world applications, as there are many different scenarios, permutations and variations of events, AI systems require continued and proactive assessment in operation. AI systems perceive the world in completely different ways to humans and it is sometimes very confusing to see how they make their inferences.[35] Figures 3 and 4 demonstrate how almost imperceptible changes to an image can completely alter the classification given by a neural network. Furthermore, these images are examples of adversarial images – synthetically generated to fool networks – and serve as a reminder that AI systems can be misled by being fed false data.[36]

33. John A McDermid, Yan Jia and Ibrahim Habli, 'Towards a Framework for Safety Assurance of Autonomous Systems', *Artificial Intelligence Safety* (August 2019), pp. 1–7.
34. *Ibid*.
35. Anish Athalye et al., 'Synthesizing Robust Adversarial Examples', paper presented at International Conference on Machine Learning, Stockholm, 10–15 July 2018, pp. 284–93.
36. Margarita Osadchy et al., 'No Bot Expects the Deepcaptcha! Introducing Immutable Adversarial Examples, With Applications to CAPTCHA Generation', *IEEE Transactions on Information Forensics*

**Figure 3:** Synthetic Adversarial Examples




*Note: The top row shows a series of original images of a turtle and the bottom row shows very similar images that have been generated as 'adversarial images', to fool the classifier into thinking they show a jigsaw puzzle. The percentages show the classifier confidence in the true/adversarial classes. The images were classified using Google's Inception V3 image classifier.*[37]

*Source: Anish Athalye et al., 'Synthesizing Robust Adversarial Examples', paper presented at the International Conference on Machine Learning, Stockholm, 10–15 July 2018, pp. 284–93.*

*and Security* (Vol. 12, No. 11, 2017), pp. 2640–53; Jiliang Zhang and Chen Li, 'Adversarial Examples: Opportunities and Challenges', *IEEE Transactions On Neural Networks and Learning Systems* (Vol. 31, No. 7, 2019); Nicholas Papernot et al., 'Practical Black-Box Attacks Against Machine Learning', paper presented at Proceedings of the 2017 ACM on Asia Conference on Computer and Communications Security, Abu Dhabi, April 2017, pp. 506–19; Moustapha M Cisse et al., 'Houdini: Fooling Deep Structured Visual and Speech Recognition Models with Adversarial Examples', paper presented at Neural Information Processing Systems Conference, 2017, pp. 6977–87, <https://papers.nips.cc/paper/7273-houdini-fooling-deep-structured-visual-and-speech-recognition-models-with-adversarial-examples.pdf>, accessed 7 July 2020; Pin-Yu Chen et al., 'EAD: Elastic-Net Attacks to Deep Neural Networks Via Adversarial Examples', paper presented at Thirty-Second AAAI Conference on Artificial Intelligence, New Orleans, 2–7 February 2018.

37. Christian Szegedy et al., 'Going Deeper With Convolutions', Proceedings of the 28th IEEE Conference on Computer Vision and Pattern Recognition, Boston, 7–12 June 2015, pp. 1–9; Olga Russakovsky et al., 'Imagenet Large Scale Visual Recognition Challenge', *International Journal of Computer Vision* (Vol. 115, No. 3, 2015), pp. 211–52; Guillaume Alain and Yoshua Bengio, 'Understanding Intermediate Layers Using Linear Classifier Probes', *arXiv preprint arXiv:1610.01644*, 5 October 2016.

**Figure 4:** Another Synthetic Adversarial Example


*Note: The figure shows the original image of an ostrich (a) along with the altered adversarial examples with their target class labels (b). As in Figure 3, the images were classified using Google's Inception V3 image classifier.*

*Source: Pin-Yu Chen et al., 'EAD: Elastic-Net Attacks to Deep Neural Networks Via Adversarial Examples', paper presented at Thirty-Second AAAI Conference on Artificial Intelligence, New Orleans, 2–7 February 2018.*

### Requirements for Safe AI

Making an AI system safe is a challenging and somewhat unprecedented endeavour, although there are some suggestions on how to achieve this. For example, Dario Amodei and colleagues propose the following requirements for a safe system:

- **Avoid negative side effects**.
- **Avoid reward hacking**: for example, when trained to play Tetris, an AI paused the game indefinitely to avoid losing.[38]
- **Scalable oversight**: human interaction to both monitor and confirm decisions made.
- **Safe exploration**: avoiding hazards from previously unconsidered scenarios.
- **Robustness to distributional shift**: adaptation to changing environments.[39]

With regard to the assurance of AI safety, Simon Burton and colleagues[40] provide suggestions for autonomous systems. First, continued assurance is important; current regulations do not cover AI, but the use of industry codes of practice is a good starting point. Second, governing

38. Cade Metz, 'Forget Doomsday AI—Google is Worried About Housekeeping Bots Gone Bad', *Wired*, June 2016.
39. Dario Amodei et al., 'Concrete Problems In AI Safety', *arXiv preprint arXiv:1606.06565*, 2016.
40. Simon Burton et al., 'Mind the Gaps: Assuring the Safety of Autonomous Systems from an Engineering, Ethical, and Legal Perspective', *Artificial Intelligence* (Vol. 297, 2020).

bodies embracing a more agile approach to regulation and governance may allow for a more dynamic means of oversight for AI and autonomous systems.

## Risks and Opportunities of AI Augmentation

The analysis presented thus far indicates that there are some significant opportunities for AI to be augmented into nuclear weapons systems. AI has the potential to vastly supplement the information available to decision-makers and to increase engagement performance and success. However, a lot of these opportunities come with some serious risks. With AI systems there is always a question as to the reliability of the system, and due to its complexity, it is often hard for humans to understand how they make their inferences. It is hard to forget how close the world came to a catastrophe with the false positives during the Cold War,[41] which begs the question: Is it ever safe to take the human out of the loop?

An interesting way to address this is to consider how much the human is actually in the loop. Modern warfare is spread out and complex. Commanders and strategists do not see the battlespace with their own eyes – information that is manipulated and fused is relayed to them via screens.[42] As these processing stages are carried out by machines (with or without AI), then arguably, the human viewing the information cannot provide an independent check.[43] Safeguards need to be considered and included in designing right from the start.[44]

## Conclusion

In summary, this study has shown that there are numerous substantial benefits to the incorporation of AI into nuclear weapons systems. Given the stakes, however, the associated risks should not be ignored. Safety should be paramount in any system design. Human oversight should not be undervalued or superfluous. It is prudent to conclude with the following words from a prominent AI researcher, Eliezer Yudkowsky: ‘By far the greatest danger of Artificial Intelligence is that people conclude too early that they understand it’.[45]

---

41. Bruno Tertrais, ‘“On The Brink” – Really? Revisiting Nuclear Close Calls Since 1945’, *Washington Quarterly* (Vol. 40, No. 2, 2017), pp. 51–66.
42. Sydney J Freedberg Jr, ‘Why A “Human in The Loop” Can’t Control AI: Richard Danzig’, *Breaking Defense*, 1 June 2018, <https://breakingdefense.com/2018/06/why-a-human-in-the-loop-cant-control-ai-richard-danzig/>, accessed 7 July 2020.
43. Richard Danzig, ‘Technology Roulette: Managing Loss of Control as Many Militaries Pursue Technological Superiority’, Center for a New American Security, 20 May 2018.
44. *Ibid*.
45. Eliezer Yudkowsky, ‘Artificial Intelligence as a Positive and Negative Factor in Global Risk’, *Global Catastrophic Risks* (Vol. 1, No. 303, 2018), p. 184.

# XIII. Emerging Technology, the Managed System of Deterrence, and Empathy

Alice Spilman

According to a host of experts, the risk of nuclear use is greater now than it has been since the end of the Cold War.[1] The two interlinked systems that constitute the global nuclear order, the managed system of deterrence and the system of abstinence enshrined in the Treaty on the Non-Proliferation of Nuclear Weapons (NPT),[2] are both at risk of unravelling.[3] Experts have put forward a number of reasons for the decline: reckless nuclear rhetoric; the return of great power rivalry; the collapse of arms control; and the erosion of nuclear norms.[4] A particularly salient concern is emerging technology.

Through the framing of the managed system of deterrence, this paper gives an overview of how emerging technology is collectively challenging the core pillars of arms control and deterrence based on mutual vulnerability. It argues that it is the perceptions of an adversary's capabilities and intentions that matter more in assessing the impacts of emerging technology than the actual capabilities themselves. This leads to a discussion on the utility of empathy in finding ways to manage emerging technology.

---

1. House of Lords, Select Committee on International Relations, 'Rising Nuclear Risk, Disarmament, and the Non-Proliferation Treaty. Report of Session 2017-19', 2019, <https://publications.parliament.uk/pa/ld201719/ldselect/ldintrel/338/338.pdf>, accessed 5 June 2020.
2. William Walker, 'Nuclear Order and Disorder', *International Affairs* (Vol. 76, No. 4, 2000), p. 703.
3. Rebecca Davis Gibbons, 'The Future of the Nuclear Order', *Arms Control Association*, April 2019, <https://www.armscontrol.org/act/2019-04/features/future-nuclear-order >, accessed 5 June 2020.
4. See, for example, Steven E Miller, Robert Legvold and Lawrence Freedman, *Meeting the Challenges of the New Nuclear Age: Nuclear Weapons in a Changing Global Order* (Cambridge, MA: American Academy of Arts and Sciences, 2019), pp. 21–26; Nina Tannenwald and James Acton, with an introduction by Jane Vaynman, *Meeting the Challenges of the New Nuclear Age: Emerging Risks and Declining Norms on the Age of Technological Innovation and Changing Nuclear Doctrines* (Cambridge, MA: American Academy of Arts and Sciences, 2018); House of Lords, Select Committee on International Relations, 'Rising Nuclear Risk, Disarmament, and the Non-Proliferation Treaty'.

## The Managed System Of Deterrence

The managed system of deterrence developed during the Cold War enabled recognised nuclear powers to pursue deterrence and attain stability in their relations through the system of rules and restraint.[5] At its core was an emphasis on strategic arms control and a conception of deterrence based on mutual vulnerability and restraint as articulated by early deterrence theorists.[6] Mutual vulnerability exists when a nuclear exchange would cause unacceptable levels of damage to both sides, which occurs when both actors possess invulnerable second-strike capabilities.[7] As such, mutual vulnerability is often considered a 'core principle for strategic stability' as the lack of first-strike incentives contributes to crisis stability.[8] Acceptance of mutual vulnerability during the Cold War has been debated.[9] However, some scholars have suggested that the presence and recognition of mutual vulnerability significantly contributed to stability between the superpowers during the Cold War, and continues to do so now.[10] The superpowers' recognition of mutual vulnerability culminated in treaties that saw limitations placed on destabilising technologies and deployments of the time. These included the Limited Test-Ban Treaty of 1963, the Anti-Ballistic Missile Treaty of 1972 which limited missile defence facilities and interceptors based on the assessment that 'to be secure, one had to leave oneself vulnerable to attack',[11] SALT I in 1972, and the INF treaty of 1987, which eliminated an entire category of missiles and reduced pressure to make nuclear launch decisions quickly.[12]

---

5. Walker, 'Nuclear Order and Disorder', p. 707.
6. See, for example, Bernard Brodie, 'The Anatomy of Deterrence', *World Politics* (Vol. 11, No. 2), pp. 173–91; Bernard Brodie, *The Absolute Weapon* (New York, NY: Harcourt, 1946); Thomas C Schelling, *The Strategy of Conflict* (Cambridge, MA: Harvard University Press, 1960); Glenn H Snyder, *Deterrence and Defense* (Princeton, NJ: Princeton University Press, 1961).
7. For a discussion on mutual vulnerability, see Caroline R Milne, 'Hope Springs Eternal: Perceptions of Mutual Vulnerability Between Nuclear Rivals', dissertation submitted to Princeton University, November 2017. Others discuss this condition of mutual vulnerability as 'assured destruction' and have suggested that such a condition is currently not a policy choice, 'but a fact to be accepted and managed'. See Linton Brooks, 'The End of Arms Control?', *Daedalus* (Vol. 149, No. 2, 2020), p. 85.
8. See Zenel Garcia, 'Strategic Stability in the Twenty-First Century: The Challenge of the Second Nuclear Age and the Logic Of Stability Interdependence', *Comparative Strategy* (Vol. 36, No. 4, 2017), p. 355; Frank P Harvey, 'The Future Of Strategic Stability And Nuclear Deterrence', *International Journal* (Vol. 58, No. 2, 2003), p. 322.
9. Milne, 'Hope Springs Eternal', pp. 1–3.
10. For example, Kenneth Waltz has made the controversial claim that because nuclear weapons reduced the chance of war during the Cold War, due to the possible immense costs to both sides, the spread of nuclear weapons might further reduce the chances of war elsewhere. See Kenneth Waltz, 'More May Be Better', in Kenneth Waltz and Scott Sagan, *The Spread of Nuclear Weapons: An Enduring Debate*, 3rd Edition (New York, NY: W W Norton & Co, 2013), pp. 3–30.
11. John Brook Wolfsthal, 'Why Arms Control?', *Daedalus* (Vol. 149, No. 2, 2020), p. 106.
12. *Ibid.*, p. 108.

The managed system of deterrence currently faces numerous disrupters.[13] The following section outlines some of the challenges emerging technologies pose to the central elements of the system: arms control and perceived mutual vulnerability.

## Arms Control

Emerging technologies can be categorised in many ways.[14] For the purpose of this paper, they are loosely divided into 'hard' (tangible) capabilities that can be observed, measured and verified, such as hypersonic missiles, and 'soft' (intangible) capabilities that are difficult to measure because they do not present as a material good, such as artificial intelligence (AI).[15]

The development of such capabilities raises questions about the future of arms control.[16] Two core challenges are often cited within this commentary. The first is that the emerging technologies which could be subject to traditional arms control, notably the 'hard' capabilities, are not

---

13. Disrupters to the managed system of deterrence include, but are not limited to, weapon possession by non-state actors, challenges posed to deterrence by multipolarity, and challenges to the logic of nuclear deterrence by TPNW supporters.
14. For example, the UK Ministry of Defence (MoD) organises emerging technology into seven technology families. See MoD, 'Defence Technology Framework', September 2019, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/830139/20190829-DTF_FINAL.pdf>, accessed 17 August 2020; the NATO Science & Technology Organization identifies eight interrelated areas of science and technology that are likely to be disruptive. See NATO Science & Technology Organization, 'Science & Technology Trends 2020-2040', March 2020, <https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf>, accessed 17 August 2020.
15. A similar distinction is made by Bidwell et al., 'Emerging Disruptive Technologies', p. 34. This is an oversimplified distinction between capabilities that misses out the potential for novel convergence between existing and emerging hard and soft technologies that have disruptive potentials. For example, see NATO Science & Technology Organization, 'Science and Technology Trends, 2020–2040', pp. 23–25.
16. Michael T Klare, 'The Challenges of Emerging Technologies', *Arms Control Association*, 2018 <https://www.armscontrol.org/act/2018-12/features/challenges-emerging-technologies>, accessed 17 August 2020; James Andrew Lewis, 'Emerging Technologies and Next Generation Arms Control', Center for Strategic and International Studies, 2019, <https://www.csis.org/analysis/emerging-technologies-and-next-generation-arms-control>, accessed 17 August 2020. For analysis of specific technologies, see Angela Kane and Noah Mayhew, 'Global Trends Analysis: The Future of Nuclear Arms Control: Time for an Update', *Stiftung Entwicklung und Frieden* [*Development and Peace Foundation*], 17 August 2020, <https://www.sef-bonn.org/en/publications/global-trends-analysis/012020>, accessed 17 August 2020; Erin D Dumbacher, 'Limiting Cyberwarfare: Applying Arms-Control Models To An Emerging Technology', *Nonproliferation Review* (Vol. 25, No. 3–4, 2018), pp. 203–22; Heather Williams, 'Asymmetric Arms Control and Strategic Stability: Scenarios for Limiting Hypersonic Glide Vehicles', *Journal of Strategic Studies* (Vol. 42, No. 6, 2019), pp. 789–813.

covered by existing treaties.[17] The second issue is that the 'soft' capabilities are unlikely to ever be subject to arms control as we know it in the nuclear domain, because of the immeasurable and unverifiable nature of such capabilities.[18] Looking outside nuclear, there has been success in placing prohibitions on the development and production of chemical and biological weapons in the respective Chemical Weapons Convention and Biological Weapons Convention. The prohibition model, however, is both challenging and undesirable given the private sector involvement in the development of 'soft' capabilities such as AI, which means the know-how for these technologies is widespread. Moreover, the potential positive applications of technologies in both the public and private sectors make prohibition unlikely.[19] The subsequent lack of rules surrounding emerging technology has the potential to enable arms races. For example, the US, Russia and China are already competing over the development and deployment of hypersonic glide vehicles, out of fear of falling behind.[20] Similarly, Russian President Vladimir Putin stated in 2017 that 'whoever becomes the leader in this sphere (AI) will become ruler of the world', a target China has already set for itself.[21]

## Mutual Vulnerability

The other foundation of the managed system of deterrence that is being challenged by emerging technology is the balance of mutual vulnerability described above. The potential strategic impacts of some individual technologies are highlighted in Table 1. The overall assessment suggests that emerging technology collectively can raise the risks of deterrence breakdown and decrease stability in the following ways.

### Lower the Perceived Survivability of Second Strike

By improving an actor's ability to track and trace targets, decapitate an adversary's command and control, send missiles that would evade detection and swarming technologies that could overwhelm defences, emerging technologies are enabling a new era of counterforce which could challenge the credibility of second-strike capabilities.

---

17. Of particular concern are hypersonic glide vehicles which are not captured by existing arms control agreements. See Williams, 'Asymmetric Arms Control', p. 796.
18. Bidwell et al., 'Emerging Disruptive Technologies', p. 34.
19. James Butcher and Irakli Beridze, 'What is the State of Artificial Intelligence Governance Globally?', *RUSI Journal* (Vol. 164, No. 5–6, 2019), pp. 88–96.
20. Williams, 'Asymmetric Arms Control', p. 797.
21. James Vincent, 'Putin Says the Nation That Leads in AI "Will Be Ruler of the World"', *The Verge*, <https://www.theverge.com/2017/9/4/16251226/russia-ai-putin-rule-the-world>, accessed 5 June 2020.

### Increase First-Strike Incentives

If an actor believes their second-strike capabilities are sufficiently threatened, it can also result in a perceived first-strike advantage. This is exacerbated by the shortened decision-making time that many of these emerging technologies create.

### Increase Uncertainty Which Breeds Misperception

The number of new capabilities, combined with limited transparency and cooperation on verification, leaves adversaries increasingly unsure of each other's capabilities.[22] Uncertainty can raise concerns about the reliability of an actor's deterrent, encourage hedging against potential but unconfirmed capabilities, and increase the risks of misperceiving an adversary's actual capabilities and intent.

The above implications can create asymmetries in vulnerability that may decrease stability and raise the risk of deterrence breakdown. Mutual vulnerability, however, will still exist between the great powers, as long as each actor retains the ability to conduct a second strike. Perhaps more concerning is the perception that some actors may be looking for ways out of the condition of mutual vulnerability through the pursuit of advanced technology. Even if an actor is only seeking to *limit* their vulnerability, it may appear that they are trying to *eliminate* it, which can only exacerbate the risks identified above. The question then is: How do we manage the risks posed by emerging technology?

22. Susi Synder, 'Nuclear Weapons in the Digital Age, What Now?', *PAX for Peace,* February 2020, <https://nonukes.nl/wp-content/uploads/2020/02/202002_DigitalAge_Nuclear_weapons_final.pdf>, accessed 5 June 2020.

**Table 1:** Potentially Stabilising and Destabilising Characteristics of Select Emerging Technologies

| Technology | Characteristics/Key Impacts | Covered by Arms Control | Suitable for Arms Control | Ambiguity/ Dual Purpose* | Arms Race Dynamics Present?** | Decision-Making Time | Impact of Crisis Stability |
|---|---|---|---|---|---|---|---|
| **Hypersonic** | • Increased speed and manoeuvrability<br>• Decreased predictability | No | Yes | Yes | Yes | ↓ | ↓Survivability<br>↑ First-strike incentives |
| **Artificial Intelligence** | • Speed of analysis<br>• Ability to locate and track targets<br>• Autonomous weapons systems | No | No | Yes | Yes | ↓ | ↓Survivability<br>↑ First-strike incentives |
| **Cybertechnology (Intersection with AI)** | • Weaponised software such as hacking, spoofing.<br>• Increases vulnerability of command and control | No | No | Yes | Yes | ↓ | ↓Survivability<br>↑ First-strike incentives |

*Ambiguity refers to nuclear/non-nuclear ambiguity and offensive/defensive ambiguity.
**Arms race dynamics present when two or more states are increasing the size and quality of weapons/systems with the intention of gaining advantage over the other.

*Source: Author's assessment of emerging technology literature, including Christopher A Bidwell, J D and Bruce W MacDonald, 'Emerging Disruptive Technologies and Their Potential Threat to Strategic Stability and National Security', Federation of American Scientists, September 2018, <https://fas.org/wp-content/uploads/media/FAS-Emerging-Technologies-Report.pdf>, accessed 5 June 2020; Christopher Chyba, 'New Technologies & Strategic Stability',* Daedalus *(Vol. 149, No. 2, 2020), pp. 150–70; Michael Horowitz, 'When Speed Kills: Lethal Autonomous Weapon Systems, Deterrence and Stability',* Journal of Strategic Studies *(Vol. 42, No. 6, 2019), pp. 764–88; Heather Williams, 'Asymmetric Arms Control and Strategic Stability: Scenarios for Limiting Hypersonic Glide Vehicles',* Journal of Strategic Studies *(Vol. 42, No. 6, 2019).*

## The Importance of Perception

A number of scholars offer a less pessimistic view of the impact of emerging technologies, suggesting that the impacts on strategic stability are over-exaggerated given their lengthy timelines and imperfect nature.[23] The central argument of this paper, however, is that perceptions of another's capabilities, their intentions and their resolve matter more than the actual capabilities. Political psychologists have demonstrated that threat perceptions are rarely based on objective assessments of material power alone.[24] Instead, threat perceptions can be influenced by a number of factors including identity,[25] security dilemmas,[26] emotions[27] and inherent bad faith models.[28] In the context of emerging technology, judgements on the threat posed by new capabilities and their stabilising or destabilising effects will be based on far more than an objective assessment of their material capability.

Take the example of US ballistic missile defence (BMD). In 2001, President George W Bush withdrew the US from the ABM treaty and began deploying BMD across the US, Western Europe and East Asia. While the US articulated that BMD was employed to deter possible North Korean and Iranian threats,[29] Russia and China both expressed concerns that this could undermine their nuclear deterrents.[30] For them, US BMD demonstrated Washington's desire for strategic supremacy, not stability as it claimed.[31] Examining Chinese reactions to US nuclear

23. See, for example, Andrew Reddie, 'Hypersonic Missiles: Why the New "Arms Race" is Going Nowhere Fast', *Bulletin of the Atomic Scientists*, January 2020, <https://thebulletin.org/2020/01/hypersonic-missiles-new-arms-race-going-nowhere-fast/>, accessed 5 June 2020.
24. Janice Gross Stein, 'Threat Perception in International Relations', in Leonie Huddy, David O Sears and Jack S Levy (eds), *The Oxford Handbook of Political Psychology*, 2nd Edition (Oxford Handbooks Online, 2013), <https://www-oxfordhandbooks-com.ezproxye.bham.ac.uk/view/10.1093/oxfordhb/9780199760107.001.0001/oxfordhb-9780199760107-e-012>, accessed 17 August 2020.
25. Dennis L Rousseau, *Identifying Threats and Threatening Identities* (Stanford, CA: Stanford University Press, 2006).
26. Accurate perceptions of threat are more difficult to discern when intentions are hard to read under security dilemma conditions. See Robert Jervis, 'Cooperation Under the Security Dilemma', *World Politics* (Vol. 30), pp. 167–214.
27. Stein, 'Threat Perception in International Relations', pp. 382–83.
28. Ole R Holsti, 'Cognitive Dynamics and Images of the Enemy', *Journal of International Affairs* (Vol. 21, No. 1, 1967), pp. 16–39.
29. See, for example, US Department of Defense, *Ballistic Missile Defense Review Report, 2010* (Washington, DC: US Department of Defense, 2010), p. 12, which states that 'the homeland missile defense capabilities are focused on regional actors such as Iran and North Korea' and the GMD system 'does not have the capacity to cope with large scale Russian or Chinese missile attacks, and is not intended to affect the strategic balance with those countries'; US Department of Defense, *Missile Defense Review, 2019* (Washington, DC: US Department of Defense, 2019), p. VII.
30. Vladimir Putin, 'Presidential Address to the Federal Assembly', 1 March 2020, <http://en.kremlin.ru/events/president/news/56957>, accessed 17 August 2020; Jing-dong Yuan, 'Chinese Responses to U.S. Missile Defenses: Implications for Arms Control and Regional Security', *Nonproliferation Review* (Vol. 10, No. 1, 2003), p. 81.
31. Ministry of Foreign Affairs of the Russian Federation, 'Comment by the Information and Press Department on the New US Missile Defence Review', 18 January 2019, <https://www.mid.ru/en/foreign_policy/news/-/asset_publisher/cKNonkJE02Bw/content/id/3479839>, accessed 17 August

posture, analysts have found repeated concerns that 'U.S. missile defence development demonstrates a desire and technical possibility to escape mutual vulnerability'.[32] Russia and China have consequently used BMD as a justification for a push to enhance their own nuclear and conventional capabilities, in particular their pursuit of hypersonic capabilities.[33] In this situation, it does not matter that the US's BMD is not intended for Russia or China, or that it is still not particularly effective, because regardless of these facts, Moscow and Beijing believe that BMD poses a current or potential future threat to which they must respond if they wish to maintain some parity.[34]

The key point here is that people 'are not motivated by facts: they are motivated by their perceptions of the facts'.[35] If an actor views an adversary's emerging capability as disrupting the perceived balance of mutual vulnerability, then that technology is likely to be destabilising.

Empathy does not require tolerance or recognition of another's values. It simply means to understand one's enemy.[36] Empathy can be operationalised into three reflective processes:

1. The perception of an adversary's capabilities, intentions and nature (what you think of another).
2. Perceptions of one's own image, including capabilities, intention and nature (what you think of yourself).
3. A perceived adversary's view of oneself (what you think the adversary thinks of you).[37]

---

2020; Sha Zukang, 'Statement by Mr Sha Zukang at 2nd China-US Conference on Arms Control, Disarmament and Non-Proliferation', Ministry of Foreign Affairs of the People's Republic of China, 28 April 1999, <https://www.fmprc.gov.cn/mfa_eng/wjdt_665385/zyjh_665391/t24939.shtml>, accessed 17 August 2020.

32. Fiona S Cunningham and M Taylor Fravel, 'Assuring Assured Retaliation: China's Nuclear Posture and U.S.-China Strategic Stability', *International Security* (Vol. 40, No. 2, 2015), p. 19.
33. In his 2018 presidential address, Putin stated, in the context of expanding US BMD, that 'Russia has developed, and works continuously to perfect highly effective but modestly priced systems to overcome missile defence'. See Putin, 'Presidential Address to the Federal Assembly', 2018. Analysts have also linked China's modernisation to US investments in BMD. See, for example, Eleni Ekmektsioglou, 'Hypersonic Weapons and Escalation Control in East Asia', *Strategic Studies Quarterly* (Vol. 9, No. 2, 2015), pp. 43–68; Yoa Yunzhu, 'Chinese Nuclear Policy and the Future of Minimum Deterrence', in Christopher Twomey (ed.), *Perspectives on Sino-American Strategic Nuclear Issues* (New York, NY: Palgrave Macmillan, 2008), pp. 111–24; Zenel Garcia, 'Strategic Stability in the Twenty-First Century: The Challenge of the Second Nuclear Age and the Logic of Stability Interdependence', *Comparative Strategy* (Vol. 36, No. 4, 2017), pp. 357–58.
34. Matt Korda and Hans M Kristensen, 'US Ballistic Missile Defenses, 2019', *Bulletin of the Atomic Scientists* (Vol. 75, No. 6, 2019), p. 295.
35. Oliver Ramsbotham, Tom Woodhouse and Hugh Miall, *Contemporary Conflict Resolution* (Cambridge: Polity, 2005), p. 290.
36. Daniel Frei, 'Empathy in Conflict Management', *International Journal* (Vol. 40, No. 4, 1985), p. 589.
37. Frei, 'Empathy in Conflict Management', p. 589.

This poses a question: to what extent do one's own perceptions match up with the perceptions of another? To return to the case of US missile defence, a significant amount of mismatch is likely to be found. Each side considers itself to be demonstrating benign intent and contributing to stability, but this is not confirmed in the eyes of the adversary. When signals are not interpreted as the sender intended, it can lead to misperceptions on both parts, which in turn can lead to escalation.[38] Empathy is a way of identifying and attempting to correct these misperceptions.[39]

How can empathy be employed in the context of emerging technology?

In order to effectively deter, one must know what is important to an adversary, but in order to maintain stability, one must also know when actions might lead to escalation driven by fear rather than ambition. For example, the UK has already acknowledged the importance of empathy when thinking about deterrence policy with its emphasis on comprehension. In a 2019 Joint Doctrine note, the Ministry of Defence explains:

> Understanding how the UK itself is perceived by such adversaries is also critical to formulating a successful deterrence posture and, consequently, the military contribution to that posture.[40]

What the UK does as a self-reflective process is a step in the right direction. This constitutes the first recommendation for how states can engage in empathy with emerging technology: critical self-reflection. All nuclear armed states should be encouraged to reflect on how their nuclear and conventional modernisation efforts may be perceived by adversaries by engaging in the three reflective processes above.

Two further possibilities for engaging with empathy are presented below.

### Repeated Bilateral Face-To-Face Interactions

State officials at multiple levels should engage in repeated face-to-face interactions with the purpose of developing mutual understanding. Face-to-face interactions are preferable as they provide an environment for social bonding to occur.[41] Individuals need to engage in

38. Robert Jervis, 'War and Misperception', *Journal of Interdisciplinary History* (Vol. 18, No. 4, 1988), pp. 675–700.
39. Naomi Head, 'Transforming Conflict: Trust, Empathy and Dialogue', *International Journal of Peace Studies* (Vol. 17, No. 2, 2012), pp. 33–55; Nicholas Wheeler, 'Investigating Diplomatic Transformations', *International Affairs* (Vol. 89, No. 2, 2013), p. 478.
40. Ministry of Defence, 'Deterrence: The Defence Contribution', Joint Doctrine Note 1/19, February 2019, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/860499/20190204-doctrine_uk_deterrence_jdn_1_19.pdf>, accessed 5 June 2020.
41. Nicholas Wheeler, *Trusting Enemies: Interpersonal Relationships In International Conflict* (Oxford: Oxford University Press, 2018); Josh Baker, 'The Empathic Foundations of Security Dilemma De-Escalation', *Political Psychology* (Vol. 40, No. 6, 2019), p. 1255.

a process of active listening, where they acknowledge (while not necessarily accepting) an adversary's concerns.

### Multilateral Forum for Discussing Emerging Technology and Deterrence

Given the challenges multipolarity also brings to deterrence, states would benefit from opportunities to discuss the issues surrounding emerging technology in a multilateral setting. The purpose should be to try and uncover the issues that preclude arms control. One possibility is for states to engage in a process of guided reflexive dialogue.[42] Typically used as an intervention in identity politics, reflexive dialogue involves a process of 'interactive introspection' whereby actors talk about their needs and interests in the presence of their adversaries, enabling exploration of separate subjective realities in the hope of developing a shared intersubjective reality.[43] Such a shared understanding, albeit difficult to achieve, can act as the basis for cooperation. The focus, in the first instance, should be on reflexive dialogue at the international level between state elites as this remains the key site for transformation.[44] However, it must be recognised that empathic developments at the elite/international level do not necessarily translate to a transformation at the aggregate level and it is worth further exploring how empathy can be developed at multiple levels.

It is important to emphasise, however, that empathy is not a panacea. It is not the solution to emerging technology, but it might help actors get to a point where they can find a solution. At the same time, empathy cannot be expected to always reveal positive outcomes. In the case of genuine malign intent, empathy is only appropriate in so far as it can help an actor determine how best to deter an adversary.

The ideas presented in this paper are simply a starting point intended to encourage further research on the possibilities for empathy in the field of emerging technology.

42. Jay Rothman, 'Reflexive Dialogue as Transformation', *Mediation Quarterly* (Vol. 13, No. 4, 1996), pp. 345–52; Head, 'Transforming Conflict', pp. 33–55.
43. Rothman, 'Reflexive Dialogue as Transformation', pp. 345–47.
44. Head, 'Transforming Conflict', p. 50.

# About the Authors

**Jacob Allen** is a Graduate Materials Engineer at Lockheed Martin. He is thoroughly enjoying the introduction to complex systems engineering and tackling multi-domain objectives across the Civil Space and Vehicles programmes. His academic background is in Materials Science and he has a Master's from Cambridge University, where he investigated electro-thermal mechanical fatigue of nickel-based superalloys. His research interests include fatigue, fracture mechanics and the development of new materials for the increasingly harsh demands of aerospace.

**Ramesh Balakrishnan** is a Master's candidate in International Affairs at the Norman Paterson School of International Affairs (NPSIA), Carleton University, Ottawa. He was a Graduate Research Fellow at the Centre for Security, Intelligence and Defence Studies at NPSIA for 2019–20. He is the recipient of the Baillie Gifford Fellowship (2014–15), the Lee Foundation Scholarship (2016–17), the Joubin-Selig Scholarship (2019–20) and the Global Affairs Canada/Simons Foundation Canada Graduate Research Award (GRA) for Disarmament, Arms Control and Nonproliferation (2018–19). In summer 2019, he was a Research Fellow at the Rideau Institute, Ottawa and worked on a comparative study of the nuclear disarmament strategies of Canada, Ireland and Norway.

**Jonathan Balakumar** has a Master's in Systems Engineering from Loughborough University and completed an industrial placement year at Ransomes Jacobsen as a manufacturing intern, before joining Lockheed Martin as a Graduate Engineer. He has gained a wide range of experience and knowledge in various fields of study, including civil and military space, armoured fight vehicles, mission support and internal research and design. The exposure he has had to military space has sparked his interest in hypersonic vehicles and he is keen to broaden his knowledge and skills in this area.

**Julia Balm** is a PhD student at King's College London in the Freeman Air and Space Institute. She recently completed her Master's in Nonproliferation at King's and she also has a BA (Hons) in History and Art History from the University of Toronto. Her research interests include nonproliferation, space security, nuclear modernisations and the ambiguities of space technologies.

**Geoffrey Chapman** is a PhD student at King's College London and a Research Assistant at the Centre for Science and Security Studies. His thesis examines the role of tacit knowledge within Britain's nuclear weapons programme. His other research projects include examining the future of arms control and the use of chemical weapons in the Syrian Civil War.

**Daniel Cook** is a Graduate Engineer at Lockheed Martin currently working on armoured fighting vehicles. Prior to this, he worked in a different department focusing on modelling and simulation which he first came to enjoy while studying for his Mathematics degree at the University of

Hertfordshire. He developed a passion for this type of work during his time at university and has always wanted to explore areas of industry that are not well defined. Hypersonics provides the perfect opportunity to apply these traits and develop his ability.

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

**Rebecca Desmond** has been a Graduate Engineer at Lockheed Martin since 2018. She has a Master's in Aeronautical Engineering from Brighton University.

**Lorne Dryer** is a first-year student at the University of Exeter studying Politics and International Relations. He has gained experience from the Nuclear Decommissioning Authority via an Arkwright Scholarship and the Youth Organization of the Comprehensive Nuclear Test-Ban Treaty Organization. Previous research projects have ranged from popular fiction in Professional Military Education to the impact of sub-threshold activities on deterrence and strategic stability.

**Emily Enright** is a Master's candidate in International Conflict Studies at King's College London. She is a Research and Administrative Assistant with the Centre for Science and Security Studies at King's and works on NPT and nuclear leadership issues. A former Australian civil servant, Emily completed her BA (Hons) at Melbourne University in 2018 and holds a Certificate in International Affairs and Strategy from Sciences Po Paris in Reims. Emily's research interests include nuclear diplomacy and discursive practices, nuclear ethics, critical approaches to violence and security, and the politics of nonproliferation and disarmament.

**Marina Favaro** is a Policy Analyst at the British American Security Information Council (BASIC), where she manages the strategic risk reduction portfolio. Prior to joining the team at BASIC, Marina worked as a Security and Defence Analyst at RAND Europe, where her research focused on space governance and technologies, cybersecurity and the impact of emerging technologies on society. Marina is experienced in futures and foresight methods including horizon scanning, scenario development and wargaming.

**Artúr Hőnich** is a Master's candidate in Science and International Security at King's College London as part of a dual Master's degree with Sciences Po, Paris School of International Affairs. He also has a BA in International Relations with distinctions from the Corvinus University, Budapest. He has interned at the Ministry of Defence in Hungary and the Hungarian Academy of Sciences. Artúr's interests include nuclear policy and transatlantic defence issues.

**Mark Hutchings** is a Graduate Engineer at Lockheed Martin and has previously worked in the Ground Based Air Defence and Armoured Fighting Vehicle and Civil Space programmes. Since graduating from Loughborough University in 2018 with a Master's in Materials Engineering, he has been passionate about materials. Hypersonic travel presents an extraordinary challenge, as the environmental conditions would destroy most materials in seconds. It is this exciting engineering challenge which has led Mark to this project, and he is looking forward to continuing to develop as a professional engineer at Lockheed Martin.

**Jennifer Insley** is a Graduate Safety Engineer, working at Lockheed Martin since 2018. She has a Master's in Safety and Human Factors in Aviation from Cranfield University, and a BEng (Hons) in Aircraft Engineering from the University of the Highlands and Islands.

**Aaron Kennedy** is a Graduate Engineer at Lockheed Martin. He has worked in numerous fields in the industry, such as civil space, ground-based air defence and armoured fighting vehicles, as well automotive vehicle testing during a placement year at Millbrook Proving Ground. He has a Master's in Mechanical Engineering from Loughborough University, where he developed an interest in modelling and simulation projects. This led him to his current area of focus, modelling scenarios in the hypersonic regime, in which he is keen to develop further skills.

**Matt Korda** is a Research Associate for the Nuclear Information Project at the Federation of American Scientists, where he co-authors the Nuclear Notebook with Hans Kristensen. Previously, he worked for the Arms Control, Disarmament, and WMD Non-Proliferation Centre at NATO headquarters in Brussels. He has a Master's in International Peace and Security from the Department of War Studies at King's College London, where he subsequently worked as a Research Assistant on nuclear deterrence and strategic stability. Matt's research interests and recent publications focus on nuclear deterrence and disarmament, progressive foreign policy, and the nexus between nuclear weapons, climate change and injustice.

**Charlotte Levy** is now nearing the end of the Safety Engineering Graduate Scheme with Babcock International to see a transition into the industrial sector. She has a degree in Applied Chemistry and a PhD in Physical Chemistry. Currently, she is working with the Test Team by assisting in the writing of automated software tests in Python. Previous placements over the past 18 months have seen Charlotte work with various submarine projects based in Devonport, and a three-month secondment to the Submarine Portfolio Office in Abbeywood. Charlotte hopes to undertake a Probabilistic Safety Assessment role in the near future.

**Paul Neale** has a BSc in Physics from the University of Surrey with an Industrial Placement Year carried out at the Defence Science and Technology Laboratory. Paul is currently on the Lockheed Martin UK Graduate Scheme as a second-year Graduate Systems Engineer.

**Jonathan Roberts** has a Master's in Physics from Warwick University. He is currently on the Lockheed Martin Graduate Scheme, and has worked as a Graduate Systems Engineer since 2018.

**Alice Spilman** is a first-year PhD candidate at Birmingham University looking at the concept of responsibility in the nuclear sphere. Alice is also a Researcher at the British American Security Information Council (BASIC), working on the Programme on Nuclear Responsibilities. Other research interests include security dilemmas and the role of perception, trust and empathy in managing security dilemmas and nuclear diplomacy.

**Adam Tunbridge** has worked at Lockheed Martin since 2018, currently in an Integration and Test role. He has a Master’s in Mechanical Engineering from Portsmouth University.