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Disruptive Technology Impacts on International Security

Squadron Leader Bart Birrell

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Exercise Solo Flight

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Disruptive Technology Impacts on International Security

Squadron Leader Bart Birrell

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HIGH SPEED GAME CHANGERS: DISRUPTIVE TECHNOLOGY IMPACTS ON INTERNATIONAL SECURITY

Emerging and Disruptive Technologies have and will continue to shape international security. These technologies provide opportunities for one side, be it sovereign or via an alliance, to rapidly change the status quo of the environment. This advantage pivot creates a disruption effect – or dilemma – that an adversary or future threat must contend with in order to remain relevant or secure within the international community. This paper will discuss and analyse the impact that emerging and disruptive technologies have on international security, using hypersonic weapon systems as an example. The United States (US), seeking to maintain its military supremacy in the global order, has identified a *Third Offset Strategy*, the intent of which is to ensure it is continually innovating technology to maintain and achieve improvements that support its technological and military advantages. This goal is illustrated in former US Defense Secretary Chuck Hagel's assertion that he would "not send our troops into a fair fight", when speaking at a defence industry meeting about advancing technology innovation processes.¹ Whilst the Third Offset Strategy and Hagel's comments will invigorate investment within the United States – for disruptive technologies and prioritise the focus areas of their industry – as this paper will show, the arrival of disruptive technologies has the potential to ignite an arms race to counter competition of advantage and counter-advantage between the US and its adversaries. Disruptive technology, can influence

¹ "U.S. Military Lags on Disruptive Technology." *Signal* 69, no. 2 (2014): 10; The Diplomat, "A Tale of Two Offset Strategies", last accessed 16 April 2022, <https://thediplomat.com/2014/11/a-tale-of-two-offset-strategies/>.

international security and provide a military advantage that can: render an opponent's defences impotent; nullify deterrence measures; force a change in national and military strategies; and force nations to expend significant resources to counter the ensuing arms and technology races.

To begin, this paper will define and discuss the concept of disruptive technologies, providing examples related to the military environment. It will then use the thesis to discuss international security concepts, focussing on military advantages, offsets and deterrence. Subsequently the paper will discuss the national requirement to maintain a desired level of capability and balance, and how this could contribute to an arms and technology race, one which can leverage and influence disruptive technologies. The paper will then introduce the concept of dual-use technologies and their relationship to disruptive technologies in order to show that states and non-state actors can achieve game changing effects. Drawing from the thesis statement, this paper will then discuss how the introduction of *Hypersonic Weapon Systems* has the potential to influence international security. A review of this concept will then occur by discussing and analysing: hypersonic weapon system capabilities; the decision space dilemma they introduce to nations and military commanders; and their impacts to the offence-defence balance between nation states. The last point of discussion will apply an International Security framework to hypersonic weapon systems to demonstrate that disruptive technologies can affect international security. This will show that the thesis is valid, and that disruptive technologies are an important consideration for nation states and their defence practitioners.

Disruptive technologies, sometimes labelled *emerging and disruptive technologies*, are those that introduce *game changing* characteristics to their

environment.² There are differences, however, between *emerging* and *disruptive* technologies. Emerging technologies are those that are: not yet mature; not widely in use; and when analysing them from an international security point of view, may not have an effect upon defence or security. On the other hand, the expectation is that disruptive technologies will significantly influence the defence and security environment, and in a potentially revolutionary way.³ Given this is a paper on international security and defence matters, it will focus on those technologies that are disruptive to both.⁴

The term and theory of disruptive technology was coined by Clayton Christensen, who when working at Harvard Business School as a Professor of Business Administration, partnered with Professor Joseph Bower to write an article that described and discussed disruptive factors which changed the marketplace.⁵ Christensen determined that businesses needed to chase and manage disruptive innovation, and the technology – or change – it has the potential to introduce. If done effectively, it ensures decisions consider the future needs and not merely to maintain the status quo.⁶ Despite the concept being borne from the studies of business and commercialisation, disruptive technologies as a notion, are applicable to global security. This is due to their ability to significantly change the security environment and provide entities with an advantage over others.

² Margaret E. Kosal, Springer ebook, and Springer Link. *Disruptive and Game Changing Technologies in Modern Warfare: Development, use, and Proliferation*. Cham, Switzerland: Springer, 2020; 2019, 1; Tadas Limba, Andrius Stankevičius, and Antanas Andrulevičius. "Industry 4.0 and National Security: The Phenomenon of Disruptive Technology." *Entrepreneurship and Sustainability Issues* 6, no. 3 (2019): 1529.

³ North Atlantic Treaty Organisation, *Science and Technology Trends 2020-2040: Exploring the S&T Edge* (Brussels: NATO, 2020), 2.

⁴ This paper will define *International Security* as being when internal and external threats are not challenging a state's security, or its national interests. The Defence environment is that which considers the use of military forces to achieve a state's interest; the ability to prevent and wage war.

⁵ Joseph L. Bower and Clayton M. Christensen, "Disruptive Technologies: Catching the Wave," *Harvard Business Review* 73, no. 1 (1995): 43.

⁶ Bower and Christensen, *Disruptive Technologies: Catching the Wave*, 53.

Therefore, disruptive technologies are an important consideration to defence practitioners in ensuring their ability to meet the requirements of their nation.

In a military context, disruptive technologies are those that introduce game changing characteristics to the defence environment or “significantly changes the rules or conduct of conflict within one or two generations”.⁷ However, this does not mean they must solely be weapons or the platforms that deliver them; they may also be other military enablers. The North Atlantic Treaty Organisation (NATO), through its Science and Technology Office (STO), recognised the importance of disruptive technologies in enabling the future needs of the alliance.⁸ To ensure NATO has a clear strategy for disruptive technology, the STO produced *Science and Technology Trends (2020-2040)*. This not only addresses NATO's own disruptive technology development roadmap, but also seeks to understand the impacts and threats from those being developed and introduced by potential adversaries.⁹

Science and Technology Trends (2020-2040) identifies eight areas of concern for NATO with respect to emerging and disruptive technology. The emergent technologies are: *Quantum Technologies; Bio and Human Enhancement Technologies; and Novel Materials and Manufacturing*. Whereas, the disruptive technologies are: *Big Data and Advanced Analytics; Artificial Intelligence (AI); Autonomy; Space Technologies; and Hypersonic Weapon Systems*.¹⁰ Whilst each of the disruptive technologies have the ability to bring about or contribute to Revolutions in Military Affairs (RMA) – given they have

⁷ Ajey Lele, *Disruptive Technologies for the Militaries and Security*, Vol. 132; Singapore: Springer, 2019; 2018, 34.

⁸ North Atlantic Treaty Organisation, *Science and Technology Trends 2020-2040*, 1.

⁹ North Atlantic Treaty Organisation, 2.

¹⁰ North Atlantic Treaty Organisation, vii; Denise M. Crimmins, "Cognitive Enhancement, the Super Soldier and Beyond: Expanding Discourse Over Emerging Disruptive Technology." ProQuest Dissertations Publishing, 2019, 47.

the ability to cause *game changing* impacts to conflicts – this paper will focus only on the impact to international security by the introduction and employment of hypersonic weapon systems.¹¹

International security is a poorly defined term within the study of International Relations, however *a collective feeling of security by all nations*, is the concept that this paper will use.¹² The components of state security include: authority; legitimacy; politics; and sovereignty.¹³ Furthermore, it is the ability of the state to protect and promote its national interests from ideologically opposed internal and external threats.¹⁴ From the point of view of this paper, two important components of security are: the ability to protect its sovereignty, through defence; and the protection and promotion of its interests, through – when required – offence.¹⁵

The international security Professors Barry Buzan and Lene Hansen, authors of *The Evolution of International Security Studies*, have proposed a security framework that consists of the following elements: *Complementary; Parallel; and Oppositional*.¹⁶ The Complementary element consists of: strategy; *deterrence*; and containment. Parallel addresses the characteristics of: *power*; sovereignty; and identity. Lastly, Oppositional considers *peace* and *risk*.¹⁷ Whilst all sub-elements are relevant, the italicised entities with in each element will support a discussion on military capability investment and relate to

¹¹ Kosal, *Disruptive and Game Changing Technologies*, 17; Barry Buzan and Lene Hansen, *The Evolution of International Security Studies*, Cambridge: Cambridge University Press, 2009; 2012; doi:10.1017/CBO9780511817762, 172, 178; Revolution of Military Affairs (RMA) occurs when changes to technology, operating concepts and organisational structure occur, and change the nature of conflict. This change in nature is significant and usually displays new levels of military capability and effectiveness in combat.

¹² Buzan and Hansen, *Evolution of International Security Studies*, 10-11.

¹³ Buzan and Hansen, 9.

¹⁴ Buzan and Hansen, 11.

¹⁵ This paper will use Australian English for spelling, unless it is directly citing a source.

¹⁶ Buzan and Hansen, *Evolution of International Security Studies*, 14.

¹⁷ Buzan and Hansen, 14.

the thesis of this paper. This is due to their direct relationship to disruptive technologies – notably hypersonic weapon systems – and their influences upon international security and a nation state’s military.

The ability to conduct effective military action, either defensive or offensive, requires a nation state to invest in its military capabilities. Typically, a nation state with a modern military should not upgrade its capabilities in major increments, or via wholesale replacement.¹⁸ It should instead pursue a concept of regular and continuous investments in order to maintain a consistent desired level of capability overmatch or status.¹⁹ This concept aligns with the writings of international relations scholar John Herz, who intimates that a nation will adopt a constant evolution of military capability development and investment to ensure it “can feel entirely secure in such a world of competing units.”²⁰ This concept, however, may raise international security threat levels, resulting in the start of an arms or technology race because one’s power is seen to be in constant competition with others.²¹ This is illustrated by then US Secretary of Defence Hagel’s aim to ensure his soldiers never enter “a fair fight”; and in President Obama’s 2015 National Security Strategy, where the US sought to ensure that it maintains and secures its military advantage.²² To maintain this capability edge against an adversary, be they

¹⁸ C. Wrigley *et al*, “*Air Force by Design: Applying Design for Transient Capability Advantage*”, 2020, 60, last accessed 08 Jan 2022, https://www.researchgate.net/publication/338902280_Air_Force_by_Design_Applying_Design_for_Transient_Capability_Advantages.

¹⁹ Australian Strategic Policy Institute, “*Special Report – Projecting National Power: Reconceiving Australian air power strategy for an age of high contest*”, 2019, last accessed 08 Jan 2022, https://ad-aspi.s3.ap-southeast-2.amazonaws.com/2019-08/SR%20142%20Projecting%20national%20power.pdf?VersionId=QeRRGJoyHVP0x2SH_8p.527emrIPIXaa.

²⁰ John H. Herz, “Idealist Internationalism and the Security Dilemma,” *World Politics* 2, no. 2 (1950): 157.

²¹ Herz, *Idealist Internationalism and the Security Dilemma*, 157.

²² “U.S. Military Lags on Disruptive Technology.” *Signal* 69, no. 2 (2014): 10; EXECUTIVE OFFICE OF THE PRESIDENT WASHINGTON DC. *National Security Strategy 2015*, 8, 16.

peer, non-peer, or a non-state actor (such as a terrorist organisation), the US military is required to pursue continuous technological upgrades.

This continual upgrade characteristic has spawned a different kind of technology race – one that can leverage disruptive technologies – where nation states are now seeking small and regular increases of military advantage. This concept of small capability updates is termed *Transient Capability Advantage*.²³ The theory behind it is to outpace and counter the adversary through incremental, and sometimes temporary, changes in military capabilities.²⁴ When disruptive technology brings about this sudden or step change in military capability, it forces the adversary to expend resources to conduct expensive and time-consuming research and development (R&D), or through other means, acquire the ability to match or counter this new imbalance of military capability.²⁵

This military capability imbalance has the capacity to influence and shape regional and international strategic security, and has in fact changed the defence strategies of nation states, including the US.²⁶ The US Department of Defense (DoD), to ensure it maintains its desired “*offense-defense balance*” against potential adversaries, has determined that the innovation of technology will be its *Third Offset Strategy*.²⁷ This drive towards innovation is likely to produce situations where military need produces technological advancements that are both disruptive, and have *dual uses*. The pursuit of a favourable balance aligns to the thesis of this paper as it illustrates that nations seek to

²³ C. Wrigley, *et al*, *Air Force by Design: Applying Design for Transient Capability Advantages*.

²⁴ Australian Strategic Policy Institute, *Special Report – Projecting National Power*.

²⁵ North Atlantic Treaty Organisation, *Science and Technology Trends 2020-2040*, 89.

²⁶ Lele, *Disruptive Technologies for the Militaries and Security*, xvii.

²⁷ Lele, 15; Kosal, *Disruptive and Game Changing Technologies*, 7-9; The Diplomat, “*A Tale of Two Offset Strategies*”, last accessed 16 April 2022, <https://thediplomat.com/2014/11/a-tale-of-two-offset-strategies/>.

maintain and achieve a preferred offence-defence balance, in response to the introduction of new capabilities to the international arena.

Dual use technologies are an important factor in any discussion on disruptive technologies and their subsequent impacts on international security. Such dual use technologies are those that have legitimate uses for: civil purposes such as science, R&D; and for nefarious and military uses.²⁸ It is this latter use of dual use technology which has the potential to provide rogue nations and non-state actors, such as terrorist organisations, with disruptive technology capabilities.²⁹ Dual use disruptive technology, when in the hands of a terrorist organisation, has the means to provide them with the ability to conduct highly effective and damaging attacks. For example, terrorist organisations are using communication devices, Unmanned Aerial Vehicles, and other common technologies to conduct increasingly sophisticated and damaging attacks.³⁰ It is this unplanned and nefarious use of innovative technology, which caused dual use technologies to be listed within President Obama's 2015 National Security Strategy, as one of the "greatest challenges facing the US in the modern era."³¹ To prevent the undesirable use of dual use technologies from occurring, the international community through organisations, alliances, and treaties, will need to put in place measures preventing the proliferation or inappropriate use of these potentially disruptive technologies.³² The inclusion of disruptive technologies in the US Security Strategy relates to the paper's thesis, given it has prioritised the need to drive technological

²⁸ Margaret Kosal, *Proliferation of Weapons- and Dual-use Technologies: Diplomatic, Information, Military, and Economic Approaches*, Cham: Springer International Publishing AG, 2021, 3, 27.

²⁹ Kosal, *Disruptive and Game Changing Technologies*, 3.

³⁰ Noni Kenny, "Meta-level Terrorism Futures: Constructing and deconstructing using Causal Layered Analysis" (doctor's thesis, Queensland University of Technology, 2013), 119, 120, 122, 137, 139.

³¹ Kosal, *Proliferation of Weapons- and Dual-use Technologies*, 3.

³² Kosal, *Disruptive and Game Changing Technologies*, 4.

innovation to maintain military advantage, and that the US will need to consider counter proliferation activities of such technologies.

The above information has demonstrated that disruptive technologies have the potential to influence and shape international security. This is due to disruptive technology's ability to bring about a sudden, dramatic, or multiple changes in military capabilities that can upset the status quo – in other words, the offence-defence balance. This change of balance requires a nation state, alliance, or organisation to react to maintain the capability edge or status they desire, which then has the potential to trigger an arms or technology race. Examples of reaction and future planning are in the current and recent strategies of both NATO and the US DoD. To better illustrate this point, this paper will now discuss and analyse hypersonic weapon systems, as an example of disruptive technology. This discussion will show that they have the potential to influence and shape international security through their ability to defeat current defences, nullify deterrence measure, force a change in national and military strategies, and trigger an arms or technology race.

Hypersonic weapon systems, as the name implies, are weapon systems that approach the target, or target area, at hypersonic speeds. Hypersonic speed is defined as anything that is travelling faster than five times the speed of sound, or Mach five plus (M5+).³³ This means the hypersonic weapon is travelling towards the target at no less than 6,125 kilometres an hour.³⁴ The primary intent of a hypersonic weapon is to strike a target with little to no warning by travelling at extremely high speeds and having the

³³ Congressional Research Service, *Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues*, CRS Report, 2021, 1.

³⁴ North Atlantic Treaty Organisation, *Science and Technology Trends 2020-2040*, 18.

ability to penetrate any air or missile defensive systems or barriers in place.³⁵ However, due to the complexities of the technology to establish hypersonic weapons, the threat has not yet been fully realised.³⁶ When hypersonic weapon systems are fully realised, and in routine service of nation states, it will be game changing for the militaries of the world.

The ability to propel an item, be it a vehicle or weapon, at hypersonic speeds has been a highly sought-after capability for almost 90 years. The civilian sector explored hypersonic technology for commercial transport options, and the military for aircraft and weapons.³⁷ The US and the Soviet Union conducted R&D in hypersonic vehicles and technology at the conclusion of World War II. Their efforts were built upon the hypersonic glide vehicle concept theorized by the Austrian aerospace engineer Eugen Sanger in the 1930s.³⁸ However, the technology of the time prevented the introduction of anything meaningful, the main obstacle being the extreme heat subjected upon the hypersonic vehicle as it traverses the atmosphere.³⁹ This remains a problem today for those seeking to advance hypersonic weapons technology.

There are two variants of hypersonic weapon systems currently under development, or in limited use. These are: the *hypersonic cruise missile*; and the *hypersonic glide vehicle*. A hypersonic cruise missile travels through the atmosphere

³⁵ Henry Jeffress III and AIR WAR COLL MAXWELL AFB AL United States, *Hypersonic Threats to the Homeland* 2017, 10-11.

³⁶ This paper will discuss the Russian use of hypersonic weapons against Ukraine when defining what hypersonic weapon systems are.

³⁷ Jason L. Sherman, "The Hypersonic Arms Race Heats Up: The U.S. Military Executes what it Says was a 'Successful' Mach 5 Weapon Test Over the Pacific. Have Russia and China had Even Greater Success?" *The Daily Beast*, 2017, 2; This paper will not focus on missiles or weapons that achieve hypersonic speeds through ballistic means only. An example of this is the warhead of an intercontinental ballistic missile that is able to achieve hypersonic speeds as it re-enters the atmosphere. The intent of this paper's discussion on hypersonic weapons systems is to discuss those designed to travel at hypersonic speeds within the Earth's atmosphere.

³⁸ Sherman, *Hypersonic Arms Race Heats Up*, 2.

³⁹ Sherman, 2.

propelled by a specialised propulsion system called a scramjet.⁴⁰ A scramjet is a *supersonic combustion ramjet*, which can theoretically propel a vehicle at speeds up to 15 times the speed of sound.⁴¹ However, in order to ignite the engine, the scramjet requires a *boost* to a speed that is approaching hypersonic – approximately Mach five (5). A rocket or missile is usually the means of producing this boost.⁴² The Russian *Kinzhal* ‘Dagger’, targeted against Ukraine in the 2022 war, is an aero-ballistic weapon that can achieve hypersonic speeds, but it is not a hypersonic missile.⁴³ The reason for this distinction is that the *Kinzhal* uses a combination of gravity and the engine of the missile to achieve its hypersonic speeds. This – the ability to have an air-breathing engine for sustained hypersonic flight – is a further demonstration of the advanced technology required for hypersonic weapon systems.

The second hypersonic weapon system is the hypersonic glide vehicle – also known as a *boost-glide vehicle*. This variant requires a missile or rocket to launch the hypersonic glide vehicle into space to enable it to enter a ballistic flight profile.⁴⁴ Following the missile’s or rocket’s launch, and once at the desired altitude, the vehicle separates from the booster and descends into the atmosphere at hypersonic speeds. Once it is within the atmosphere, it uses control surfaces to conduct a series of manoeuvres to penetrate any defences, and ultimately strike the target.⁴⁵ It is the use of a rocket or

⁴⁰ Congressional Research Service, *Conventional Prompt Global Strike*, 1.

⁴¹ Congressional Research Service, 43.

⁴² Congressional Research Service, 43-44.

⁴³ United Nations, “General Assembly Overwhelmingly Adopts Resolution Demanding Russian Federation Immediately End Illegal Use of Force in Ukraine, Withdraw All Troops”, last accessed 16 April 2022. <https://www.un.org/press/en/2022/ga12407.doc.htm>; Missile Threat – CSIS Missile Defense Project, ‘Kh-47M2 *Kinzhal*’, last accessed 19 April 2022, <https://missilethreat.csis.org/missile/kinzhal/>.

⁴⁴ Dan Goure, “A Real Missile Gap Is Looming In Hypersonic Weapons,” *United States Air Force Center for Unconventional Weapons Studies – Outreach Journal* 1313 (4 May 2018): 34, https://media.defense.gov/2019/Jun/13/2002144791/-1/-1/0/CUWS_OUTREACH1313.PDF.

⁴⁵ Sherman, *Hypersonic Arms Race Heats Up*, 1-2.

ballistic missile in the hypersonic weapon systems initial phase of employment that creates international security concern, as adversaries, or other nations, are not sure if it is a hypersonic weapon system or an Intercontinental Ballistic Missile (ICBM), and therefore do not know how to react.⁴⁶ The arrival of hypersonic weapon systems therefore supports the thesis, given nations will need to update their response strategies and introduce military capabilities that can distinguish them from an ICBM; the latter may also cause an arms race.

Both variants of hypersonic weapon systems have the potential to be fitted with conventional explosive, nuclear warheads, or a solid mass made of exquisite materials in the delivery vehicle.⁴⁷ While not evident from its description, the latter variant is an effective weapons capability due to the extremely high speeds at the point of impact with the target. This would rely on the kinetic energy of the vehicle – which is now travelling at approximately 1,900 kilometres an hour – to penetrate and destroy the target without the need of an explosive or nuclear warhead.⁴⁸ US hypersonic weapons programs and strategy are considering the use of conventional or solid mass warheads in the vehicles only, and not nuclear warheads.⁴⁹ However, Russian media has reported that their hypersonic weapons will be able to employ conventional and nuclear warheads, and that some of the latter warheads are currently in production.⁵⁰ The Kinzhal is an example of a Russian hypersonic weapon system that has the capability to employ conventional and

⁴⁶ Congressional Research Service, *Conventional Prompt Global Strike*, 38-39.

⁴⁷ Goure, *A Real Missile Gap Is Looming In Hypersonic Weapons*, 34; Jeffrey Smith, "Hypersonic Missiles are Unstoppable. And They're Starting a New Global Arms Race: Feature," New York Times (Online), 2019, 2.

⁴⁸ Smith, *Hypersonic Missiles are Unstoppable*, 2.

⁴⁹ Stephen Bryen, "Major Powers Starting to Deploy Hypersonic Weapons," *United States Air Force Center for Unconventional Weapons Studies – Outreach Journal* 1313 (4 May 2018): 36, last accessed 17 April 2022, https://media.defense.gov/2019/Jun/13/2002144791/-1/-1/0/CUWS_OUTREACH1313.PDF .

⁵⁰ Smith, *Hypersonic Missiles are Unstoppable*, 6.

nuclear warheads.⁵¹ China is also developing nuclear warheads for its hypersonic weapon systems.⁵² For example, a Chinese test in July 2021 saw a missile circumnavigate the globe and release a *nuclear capable* hypersonic glide vehicle that landed close to the desired target area.⁵³ It is the unknown warhead variable which causes a potential adversary to ask, “is the incoming weapon conventional or is it nuclear, and is it coming for me?” that has the potential to escalate a conflict.⁵⁴ Given that a nation may err on the side of caution and treat the incoming threat as a hypersonic weapon system, and not a nuclear enabled ICBM, it could allow the latter to penetrate the defence barriers and strike nuclear deterrence capabilities – or other vital infrastructure – unchallenged. Therefore, the introduction of hypersonic weapons could reduce the effectiveness of defensive and deterrence measures, altering the military advantage. The paper’s thesis identified these as two factors influencing international security.

To reduce the lack of clarity about weapon and warhead types, nation states that have hypersonic weapon systems may need to consider options that provide certainty to potential adversaries. One method considered by the US is to site its hypersonic weapon systems away from their nuclear ICBM silos.⁵⁵ These silos known and visited by Russia as part of the *New Strategic Arms Reduction Treaty (New START)*, are part of the nuclear deterrence triad for the US.⁵⁶ Therefore, by locating the hypersonic weapon systems, ideally at bases without nuclear storage infrastructure, this will remove any confusion on

⁵¹ Missile Threat – CSIS Missile Defense Project, *Kh-47M2 Kinzhal*.

⁵² *Behind Murky Claim of a New Hypersonic Missile Test, there Lies a very Real Arms Race*. Washington, D.C: NPR, 2021.

⁵³ Shannon Bugos, "China Tested Hypersonic Capability, U.S. Says," *Arms Control Today* 51, no. 9 (2021): 19.

⁵⁴ Congressional Research Service, *Conventional Prompt Global Strike*, 2.

⁵⁵ Congressional Research Service, 1.

⁵⁶ NPR, “To Find America’s Nuclear Missiles, Try Google Maps”, last accessed 16 April 2022, <https://www.npr.org/sections/thetwo-way/2014/07/31/336847318/to-find-america-s-nukes-try-google-maps>.

type of weapon launched during times of war.⁵⁷ The fact that the US is considering such an action is testament to the disruptive effects of hypersonic weapon systems and demonstrates they have the potential to influence international security.⁵⁸ Given the strategic implications hypersonic weapon systems impose upon the international community, they too could be included in treaties and inspections.

The inability to identify warhead type coupled with the excessive speed of a hypersonic weapon system presents a dilemma for modern day leaders. This creates an environment that magnifies regional and international tensions due to the unknown threat vector. In response to this threat, the US commenced its Conventional Prompt Strike Program (CPSP), in which it seeks to “attack targets around the world, in under an hour, with conventional warheads.”⁵⁹ Whilst the US has published that it is conducting the CPSP to support its “regional deterrence and reassurance goals”, it is also seeking to introduce a capability to provide a balance to Russian and Chinese hypersonic capabilities, to hold them at risk.⁶⁰ This is due to the reported capability gap that the US currently has no way of defending itself from the hypersonic weapon systems.⁶¹ The reasons for the lack of defensive measures are due to: the hypersonic weapon systems speed of travel; the difficulty in accurately and effectively locating and tracking them; and the difficulty in engaging it during all elements of the weapons employment phase.⁶²

⁵⁷ Congressional Research Service, *Conventional Prompt Global Strike*, 39.

⁵⁸ Stephan Frühling and Andrew O'Neil. *Alliances, Nuclear Weapons and Escalation: Managing Deterrence in the 21st Century*, edited by STEPHAN FRÜHLING, ANDREW O'NEIL. 1st ed. Canberra: ANU Press, 2021. doi:10.2307/j.ctv25m8dp0, 158, 159.

⁵⁹ Congressional Research Service, *Conventional Prompt Global Strike*, 1.

⁶⁰ Congressional Research Service, 1; Smith, *Hypersonic Missiles are Unstoppable*, 7.

⁶¹ Congressional Research Service, *Conventional Prompt Global Strike*, 2.

⁶² House of Representatives, House Armed Services Committee, *Statement of General Glen D. Vanherck, United States Air Force Commander United States Northern Command and North American Aerospace Defense Command*, 08 March 2022, 5, 7, 13, 16.

The establishment of the CPSP aligns with the paper's thesis, given it seeks to strengthen deterrence measures, but may also trigger arms and technology races.

As previously discussed, a hypersonic vehicle is travelling at speeds in excess of Mach five, with some reports claiming speeds as fast as M15.⁶³ At such speeds therefore, it is difficult for the sensors of a defensive system to find, fix and track the weapon.⁶⁴ Furthermore, even if it were possible to accurately detect and track a hypersonic weapon, the duration of the *decision space* available to the leaders and military of the targeted nation is perilously short.⁶⁵ For example, if China decides to launch a hypersonic weapon from their mainland bases against Guam, it would strike the target in approximately 15 to 20 minutes.⁶⁶ In this time of flight, the US would need to detect the incoming weapon and try to determine its likely target in order to prepare it for the impending attack – the target could be Guam itself, or a strategic asset, such as an aircraft carrier.⁶⁷ The commander would need to identify any countermeasure options, then consider and carry out the most appropriate response actions, which may also include seeking authority from higher headquarters.⁶⁸ All of these steps would need to be carried out before attempting to engage the incoming hypersonic weapon with the most appropriate defeat mechanism, if

⁶³ Jeffress and AIR WAR COLL MAXWELL AFB AL United States, *Hypersonic Threats*, 4.

⁶⁴ Goure, *A Real Missile Gap Is Looming In Hypersonic Weapons*, 34.

⁶⁵ Jeffress and AIR WAR COLL MAXWELL AFB AL United States, *Hypersonic Threats*, 8, House of Representatives, House Armed Services Committee, *Statement of General Vanherck*, 7; Smith, *Hypersonic Missiles are Unstoppable*, 3.

⁶⁶ Smith, 5; *Behind Murky Claim*; Bugos, *China Tested Hypersonic Capability*, 20; Additionally, some rudimentary math was done to support the time of flight in this example – 3000km at speeds between Mach 5 and Mach 10, is in line with the figures quoted on page 5 of the first citation.

⁶⁷ Andrew Futter, "Disruptive Technologies and Nuclear Risks: What's New and what Matters," *Survival* (London) 64, no. 1 (2022): 104.

⁶⁸ Smith, *Hypersonic Missiles are Unstoppable*, 3.

one is available. Currently the technology to do this is non-existent, or is in its infancy and therefore relatively ineffective.⁶⁹

Ideally, the defeat of a hypersonic weapon system uses another weapon that is faster and more agile than the incoming threat.⁷⁰ For ballistic missile and traditional intercepts, this usually consists of guiding another kinetic weapon to an intercept point in space – with the aim of either physically striking the threat or to get close enough that an explosion damages it.⁷¹ The latter either destroys the incoming weapon or causes it to malfunction in such a way that it becomes ineffective. When the technology for hypersonic weapon defences is available, and if it is militarily effective, it could include the use of directed energy weapon systems and electronic warfare.⁷² While directed energy weapons – lasers or high-powered microwaves – are available and in use for some defence activities and scenarios, they are not yet at a power level to damage a hypersonic weapon.⁷³ The electronic warfare defeat mechanism is likely to consist of electronic deception measures, with the intent of preventing the detection and tracking of targets by surveillance systems, thereby preventing the adversary from launching a hypersonic weapon.⁷⁴ Furthermore, electronic warfare may use *electronic attack* methods to disrupt the seekers and sensors of the hypersonic weapon system during its terminal phase of flight – thus denying it the ability to home in on its target.⁷⁵ There are options in

⁶⁹ Sherman, *Hypersonic Arms Race Heats Up*, 2; House of Representatives, House Armed Services Committee, *Statement of General Vanherck*, 16.

⁷⁰ Tom Karako and Masao Dahlgren, *Complex Air Defense: Countering the Hypersonic Missile Threat*: Center for Strategic and International Studies, 2022, 23.

⁷¹ Missile Threat – CSIS Missile Defense Project, “*Standard Missile-6 (SM-6)*”, last accessed 19 April 2022, <https://missilethreat.csis.org/defsyst/sm-6/>.

⁷² Karako and Dahlgren, *Complex Air Defense*, 14, 15; Congressional Research Service, *Hypersonic Weapons*, 3.

⁷³ Jeffress and AIR WAR COLL MAXWELL AFB AL United States, *Hypersonic Threats*, 5; Karako and Dahlgren, *Complex Air Defense*, 38.

⁷⁴ Karako and Dahlgren, 43.

⁷⁵ Karako and Dahlgren, *Complex Air Defense*, 39.

development to defeat hypersonic weapon systems, though the technology is not sufficiently mature at this time.⁷⁶ Therefore, until there are effective capabilities to defend against incoming hypersonic weapons, the deployment of hypersonic weapon systems – by friendly or adversary militaries – would produce a game changing effect to the military environment, the latter being a requirement for disruptive technologies. In line with the paper’s thesis, this would influence international security, as without a hypersonic defence capability, a nation cannot defend itself against the threat and its deterrence capabilities are at risk and therefore moot.

An additional issue with countering hypersonic weapons is the unknown and new directions of approach. The US and Canada established North American Aerospace Defense Command (NORAD) in 1957 to contribute to the defence of North America.⁷⁷ The recent Chinese hypersonic weapon test has revealed a potential problem for NORAD, a problem that at this time the United States – and by extension its NORAD partner, Canada – is reportedly unable to solve.⁷⁸ When testifying before the House Armed Services Committee, Commander NORAD stated the ballistic missile defence system he is responsible for “is not capable of intercepting hypersonic glide vehicles; I cannot defend, nor am I tasked to defend, against a hypersonic glide vehicle attack.”⁷⁹ A primary reason for this inability to defend against the Chinese weapon is that the July 2021 test revealed that China now had a Fractional Orbital Bombardment System (FOBS)

⁷⁶ Smith, *Hypersonic Missiles are Unstoppable*, 5.

⁷⁷ North American Aerospace Defense Command, “About NORAD”, last accessed 16 April 2022, <https://www.norad.mil/About-NORAD/>.

⁷⁸ CTV News, “North America vulnerable to Russian and Chinese hypersonic weapons: NORAD commander,” last accessed 16 April 2022, <https://www.ctvnews.ca/canada/north-america-vulnerable-to-russian-and-chinese-hypersonic-weapons-norad-commander-1.5825995>.

⁷⁹ House of Representatives, House Armed Services Committee, *Statement of General Vanherck*, 16.

capability.⁸⁰ A FOBS, given it has the ability to orbit the globe, can approach a target area from any direction. Therefore, this nullifies, or at the very least reduces the effectiveness of, the NORAD surveillance capabilities given they are situated to look towards the Arctic.⁸¹ Furthermore, the Democratic People's Republic of Korea (DPRK) is also exploring hypersonic weapons capabilities, which includes a reported successful weapons test in January 2022.⁸² If the DPRK perfect hypersonic weapon systems that have the capability of striking the continental US, this will further challenge NORAD until it is able to detect threats coming from all directions.

Additionally, the flight profile of a regular hypersonic weapon system, especially the hypersonic glide vehicles, creates problems for the current ballistic missile defence systems. This is because hypersonic weapons approach targets at altitudes that are “roughly 12 to 50 miles above the surface of the earth.”⁸³ At this altitude, the incoming hypersonic weapons are not within the typical field of view of the current ballistic missile detection systems.⁸⁴ Therefore, this renders those detection systems and the overall missile defence capability impotent or ineffective.⁸⁵ This failure to detect incoming hypersonic weapons supports the NORAD Commander's statement to the House Armed Service Committee, and his urgent request for “advanced space-based sensors.”⁸⁶ Without an effective detection system, it is impossible to defend against hypersonic weapon

⁸⁰ Bugos, *China Tested Hypersonic Capability*, 20; Futter, *Disruptive Technologies*, 103-104.

⁸¹ *Behind Murky Claim*; Bugos, *China Tested Hypersonic Capability*, 20.

⁸² Congressional Research Service, *Hypersonic Weapons*, 19; BBC News, “North Korea says Kim Jong-un oversaw third hypersonic missile test,” last accessed 17 April 2022, <https://www.bbc.com/news/world-asia-59958664>.

⁸³ Smith, *Hypersonic Missiles are Unstoppable*, 5.

⁸⁴ Congressional Research Service, *Hypersonic Weapons*, 2; House of Representatives, House Armed Services Committee, *Statement of General Vanherck*, 5.

⁸⁵ Smith, *Hypersonic Missiles are Unstoppable*, 5.

⁸⁶ House of Representatives, House Armed Services Committee, *Statement of General Vanherck*, 16.

systems, and this can affect international security by changing the extant offence-defence balance. This change in balance may cause nations to upgrade their military capabilities, thereby creating a situation where an arms race may start. For example unless NORAD obtains improved surveillance capabilities, with respect to hypersonic weapon systems, it illustrates that the thesis of this paper is correct as they have rendered the NORAD capability obsolete and weakened deterrence measures.

From a purely defensive point of view – and until the fielding of effective detection and intercept systems occurs – the perceived best method of defence is to strike an adversary’s hypersonic weapons prior to launch.⁸⁷ In order to do this in a timely fashion, the pre-emptive strike is therefore likely to be executed with hypersonic weapons – requiring enough hypersonic weapons to destroy the adversary’s hypersonic caches. In line with the assertions of Herz and the paper’s thesis, this will likely start an arms race.⁸⁸ Each nation will seek to increase its weapon numbers, to ensure it has the means to maintain the desired balance of power, or the ability to launch a counterstrike.

A component of an arms race is the corresponding technology race to support R&D, and eventual capability introduction.⁸⁹ Hypersonic weapons programs, including countering them, are costly ventures in which there is potential to expend, and sometimes waste, significant resources. The US DoD has been engaged in escalatory R&D on hypersonic technologies for approximately 20 years.⁹⁰ Typically, the expenditure on hypersonic technologies, up until Financial Year (FY) 2021, has been in the region of

⁸⁷ Sherman, *Hypersonic Arms Race Heats Up*, 3.

⁸⁸ Herz, *Idealist Internationalism and the Security Dilemma*, 157.

⁸⁹ Crimmins, *Cognitive Enhancement*, 45, 46.

⁹⁰ Congressional Research Service, *Conventional Prompt Global Strike*, 1-2.

\$100-200 million per year.⁹¹ However, FY 2021 and 2022 has seen the DoD's budget increase to \$3.2 and \$3.8 billion, respectively.⁹² This reflects the strategic priority of hypersonic weapon systems to the US, and the amount of funding required when introducing an effective capability into service.⁹³ A further indication of the required levels of funding to develop hypersonic weapon systems is a 2017 flight of a test vehicle for the US Navy. This one test activity cost US\$160 million; fortunately, resources were not wasted given the test was a success.⁹⁴ At the time of writing however, the US DoD still does not have a fielded hypersonic weapon system.

There also exists the need for R&D to address shortfalls related to the identification of methods and capabilities to defend against hypersonic weapon systems. As noted earlier, the US is allocating \$3.8 billion to developing hypersonic weapon systems, whereas the budget for hypersonic defence is only around \$250 million for the current FY.⁹⁵ Currently the US counter-hypersonic weapons effort is conducting R&D into an integrated solution of: space based sensors; high-performance interceptors; and directed energy weapons.⁹⁶ However, should any of these prove successful, it is likely it will accelerate the arms race given that Russia and China will feel that they need to ensure they have their desired offence-defence balance.⁹⁷

⁹¹ Congressional Research Service, *Conventional Prompt Global Strike*, 23-25.

⁹² Congressional Research Service, *Hypersonic Weapons*, 21.

⁹³ Smith, *Hypersonic Missiles are Unstoppable*, 1; Congressional Research Service, *Conventional Prompt Global Strike*, 1.

⁹⁴ Congressional Research Service, *Conventional Prompt Global Strike*, 22.

⁹⁵ Congressional Research Service, *Hypersonic Weapons*, 21.

⁹⁶ Congressional Research Service, 21 House of Representatives, House Armed Services Committee, *Statement of General Vanherck*, 13, 16; Jeffress and AIR WAR COLL MAXWELL AFB AL United States, *Hypersonic Threats*, 5.

⁹⁷ Smith, *Hypersonic Missiles are Unstoppable*, 6.

One way to avoid this imbalance is to consider a treaty that is akin to the Anti-Ballistic Missile Treaty that the US withdrew from in 2002.⁹⁸ Russian President Vladimir Putin intimated that Russia “started its hypersonics program to ensure it could get around any American ballistic missile defences.”⁹⁹ This suggests that had the US not withdrawn from the treaty, and subsequently strengthened its anti-ballistic missile capabilities, Russia would not have pursued hypersonic weapon systems to achieve a game-changing capability.

The final concept that this paper will use to demonstrate how hypersonic weapon systems can influence international security is the three-pillar security framework of the international relations scholars Buzan and Hansen.¹⁰⁰ The *Complementary* pillar is influenced by: strategy; deterrence and containment. The discussion on hypersonic weapon systems has shown that all three are likely to be affected. The arrival of these weapon systems has been shown to force nation states to change their national and military strategies to counter their effects. Hypersonic weapon systems are challenging extant deterrence measures, given the latter are now targetable or obsolete. The global reach of the hypersonic weapon systems in development influences the containment sub-element. Nation states that have these capabilities will no longer need to position weapon capabilities in close proximity to their adversaries to strike them.

The *Parallel* pillar considers power, sovereignty and identity. While there may be affects against all three, power would be the element influenced the most by hypersonic

⁹⁸ Smith, *Hypersonic Missiles are Unstoppable*, 7; Congressional Research Service, *Hypersonic Weapons*, 12.

⁹⁹ Smith, *Hypersonic Missiles are Unstoppable*, 6-7; Congressional Research Service, *Hypersonic Weapons*, 13; Radio Free Europe – Radio Liberty, “‘Listen To Us Now’: Putin Unveils Weapons, Vows To Raise Living Standards In Fiery Annual Address,” last accessed 18 April 2022, <https://www.rferl.org/a/putin-set-give-annual-address-amid-presidential-election-campaign/29069948.html>.

¹⁰⁰ Buzan and Hansen, *Evolution of International Security Studies*, 14.

weapon systems. This is due to the fact that hypersonic weapon systems allow a nation state to strike and counter-strike an adversary using their military, and the military is an instrument of national power when using the Diplomatic, Information, Military and Economic model.¹⁰¹

The last component of the security framework is *Oppositional* and it consists of peace and risk, and hypersonic weapon systems influence both. Peace is heavily impacted given these weapons would likely cause a nation state to pre-emptively use their hypersonic weapon systems as a first strike capability against an adversary's centres of gravity – deterrence weapons; hypersonic capabilities; key leadership; and command and control infrastructure. Hypersonic weapons systems will affect risk, given adversaries and other nation states need to consider the ambiguity of the incoming weapon within a very short timeframe. Is it a nuclear ICBM? Is that hypersonic weapon system carrying a nuclear or conventional warhead? Is that weapon targeting my nation, and if it is, what is the target? The above analysis illustrates that hypersonic weapon systems affect all three elements of the Buzan and Hansen security framework. Therefore, this demonstrates that disruptive technologies can influence international security and supports this paper's thesis.

The aim of this paper was to show that disruptive technologies have the potential to influence and shape international security given they can introduce game changing effects to the military environment. The thesis statement of the paper offered that disruptive technologies, such as hypersonic weapon systems, can provide a military advantage that can: render an opponent's defences impotent; nullify deterrence measures;

¹⁰¹ Andrea Lane, "DS569 SCO LE-2 Power as a Concept" (lecture, Canadian Forces College, Toronto, ON, 07 September 2021), with permission; *Proliferation of Weapons- and Dual-use Technologies*, 2.

force a change in national and military strategies; and can force nations to expend significant resources to counter the ensuing arms and technology races. To support this thesis statement, the paper first defined the disruptive technology concept and showed that it was applicable to the military environment. The paper then defined international security and selected an applicable framework to analyse the impacts of disruptive technologies. It then discussed the history, technology and capabilities of hypersonic weapon systems to understand their impacts on international security, through their influences upon the military environment. This illustrated that hypersonic weapon systems have produced a dilemma for nations potentially targeted with these capabilities, forcing them to review strategies, increase capability levels, and enter arms and technology races. The latter is to ensure the military can meet the needs of its nation by having the desired capability states, offence-defence balances, and deterrence posture. Lastly, the paper used the Buzan and Hansen International Security Framework and the contents of the previous discussion to ascertain if hypersonic weapon systems are an influence upon international security. The results of this analysis supported the thesis statement of the paper, that disruptive technologies – using hypersonic weapon systems as an example – can influence international security. In conclusion, any disruptive technology delivering a game changing capability to an actor, be they nation state or terrorist organisation, has the potential to change the status quo and affect international security. The nation state needs to consider its use and introduction of disruptive technologies to ensure it aligns with the strategic goals of the nation and is not a catalyst for undesirable international security changes.

BIBLIOGRAPHY

- Australian Strategic Policy Institute. “*Special Report – Projecting National Power: Reconceiving Australian air power strategy for an age of high contest*”, 2019. Last accessed 16 April 2022. https://ad-aspi.s3.ap-southeast-2.amazonaws.com/2019-08/SR%20142%20Projecting%20national%20power.pdf?VersionId=QeRRGJoyHVP0x2SH_8p.527emrIPIxaa.
- Behind Murky Claim of a New Hypersonic Missile Test, there Lies a very Real Arms Race*. Washington, D.C: NPR, 2021.
- BBC News. “*North Korea says Kim Jong-un oversaw third hypersonic missile test.*” Last accessed 17 April 2022. <https://www.bbc.com/news/world-asia-59958664>.
- Bower, Joseph L. and Clayton M. Christensen. "Disruptive Technologies: Catching the Wave." *Harvard Business Review* 73, no. 1 (1995): 43-53.
- Bryen, Stephen. “Major Powers Starting to Deploy Hypersonic Weapons.” *United States Air Force Center for Unconventional Weapons Studies – Outreach Journal* 1313 (4 May 2018): 35-38. Last accessed 17 April 2022. https://media.defense.gov/2019/Jun/13/2002144791/-1/-1/0/CUWS_OUTREACH1313.PDF.
- Bugos, Shannon. "China Tested Hypersonic Capability, U.S. Says." *Arms Control Today* 51, no. 9 (2021): 19-20.
- Buzan, Barry and Lene Hansen. *The Evolution of International Security Studies*. Cambridge: Cambridge University Press, 2009; 2012;. doi:10.1017/CBO9780511817762.
- Cheung, Tai Ming. "A Conceptual Framework of Defence Innovation." *Journal of Strategic Studies* (2021): 1-27.
- Congressional Research Service. *Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues*. CRS Report, 2021.
- Congressional Research Service. *Hypersonic Weapons: Background and Issues for Congress*. CRS Report, 2022.
- Crimmins, Denise M. "Cognitive Enhancement, the Super Soldier and Beyond: Expanding Discourse Over Emerging Disruptive Technology." ProQuest Dissertations Publishing, 2019.
- CTV News. “North America vulnerable to Russian and Chinese hypersonic weapons: NORAD commander.” Last accessed 16 April 2022.

<https://www.ctvnews.ca/canada/north-america-vulnerable-to-russian-and-chinese-hypersonic-weapons-norad-commander-1.5825995>.

EXECUTIVE OFFICE OF THE PRESIDENT WASHINGTON DC. *National Security Strategy 2015*.

Frühling, Stephan and Andrew O'Neil. *Alliances, Nuclear Weapons and Escalation: Managing Deterrence in the 21st Century*, edited by STEPHAN FRÜHLING, ANDREW O'NEIL. 1st ed. Canberra: ANU Press, 2021.
doi:10.2307/j.ctv25m8dp0.

Futter, Andrew. "Disruptive Technologies and Nuclear Risks: What's New and what Matters." *Survival* (London) 64, no. 1 (2022): 99-120.

Goure, Dan. "A Real Missile Gap Is Looming In Hypersonic Weapons." *United States Air Force Center for Unconventional Weapons Studies – Outreach Journal* 1313 (4 May 2018): 34-35. https://media.defense.gov/2019/Jun/13/2002144791/-1/-1/0/CUWS_OUTREACH1313.PDF.

Herz, John H. "Idealist Internationalism and the Security Dilemma." *World Politics* 2, no. 2 (1950): 157-180.

Jeffress, Henry III R. and AIR WAR COLL MAXWELL AFB AL MAXWELL AFB United States. *Hypersonic Threats to the Homeland* 2017.

Karako, Tom and Masao Dahlgren. *Complex Air Defense: Countering the Hypersonic Missile Threat*. Center for Strategic and International Studies, 2022.

Kenny, Noni. "Meta-level Terrorism Futures: Constructing and deconstructing using Causal Layered Analysis," Doctor's thesis, Queensland University of Technology, 2013.

Kosal, Margaret E. *Proliferation of Weapons- and Dual-use Technologies: Diplomatic, Information, Military, and Economic Approaches*. Cham: Springer International Publishing AG, 2021.

Kosal, Margaret E., Springer ebook, and Springer Link. *Disruptive and Game Changing Technologies in Modern Warfare: Development, use, and Proliferation*. Cham, Switzerland: Springer, 2020; 2019.

Lane, Andrea. "DS569 SCO LE-2 Power as a Concept." Lecture, Canadian Forces College, Toronto, ON, 07 September 2021, with permission.

Lele, Ajey. *Disruptive Technologies for the Militaries and Security*. Vol. 132; Singapore: Springer, 2019; 2018.

- Limba, Tadas, Andrius Stankevičius, and Antanas Andrulevičius. "Industry 4.0 and National Security: The Phenomenon of Disruptive Technology." *Entrepreneurship and Sustainability Issues* 6, no. 3 (2019): 1528-1535.
- Mattis, Jim and Department of Defense Washington United States. *Summary of the 2018 National Defense Strategy of the United States of America* 2018.
- Missile Threat – CSIS Missile Defense Project. "*Kh-47M2 Kinzhal*". Last accessed 19 April 2022. <https://missilethreat.csis.org/missile/kinzhal/>.
- Missile Threat – CSIS Missile Defense Project. "*Standard Missile-6 (SM-6)*". Last accessed 19 April 2022. <https://missilethreat.csis.org/defsys/sm-6/>.
- North American Aerospace Defense Command. "About NORAD." Last accessed 16 April 2022. <https://www.norad.mil/About-NORAD/>.
- North Atlantic Treaty Organisation. *Science and Technology Trends 2020-2040: Exploring the S&T Edge*. Brussels: NATO, 2020.
- NPR. "*To Find America's Nuclear Missiles, Try Google Maps*." Last accessed 16 April 2022. <https://www.npr.org/sections/thetwo-way/2014/07/31/336847318/to-find-america-s-nukes-try-google-maps>.
- Radio Free Europe – Radio Liberty. "*'Listen To Us Now': Putin Unveils Weapons, Vows To Raise Living Standards In Fiery Annual Address*". Last accessed 18 April 2022. <https://www.rferl.org/a/putin-set-give-annual-address-amid-presidential-election-campaign/29069948.html>.
- Reus-Smit, Christian and Duncan Snidal. *The Oxford Handbook of International Relations*, edited by Snidal, Duncan, Christian Reus-Smit. 1st ed. New York; Oxford;: Oxford University Press, 2008.
- Sherman, Jason L. "The Hypersonic Arms Race Heats Up: The U.S. Military Executes what it Says was a 'Successful' Mach 5 Weapon Test Over the Pacific. Have Russia and China had Even Greater Success?" *The Daily Beast*, 2017.
- Smith, R. Jeffrey. "Hypersonic Missiles are Unstoppable. And They're Starting a New Global Arms Race: Feature." *New York Times* (Online), 2019.
- Sutyagin, Igor, Justin Bronk, and Royal United Services Institute for Defence Studies. *Russia's New Ground Forces: Capabilities, Limitations and Implications for International Security*. 1st ed. Vol. 89. Milton Park, Abingdon: Published on behalf of the Royal United Services Institute for Defence and Security Studies by Routledge Journals, 2017.

"The Center for Strategic and International Studies Holds a Conference on Assessing the Third Offset Strategy, Panel on Defining the Offset Strategy." *Political Transcript Wire*, 2016.

The Diplomat. "*A Tale of Two Offset Strategies*". Last accessed 16 April 2022.
<https://thediplomat.com/2014/11/a-tale-of-two-offset-strategies/>.

Tzu, Sun. "The Art of War." *New England Review* (1990) 23, no. 3 (2002).

United Nations. "*General Assembly Overwhelmingly Adopts Resolution Demanding Russian Federation Immediately End Illegal Use of Force in Ukraine, Withdraw All Troops*". Last accessed 16 April 2022.
<https://www.un.org/press/en/2022/ga12407.doc.htm>.

"U.S. Military Lags on Disruptive Technology." *Signal* 69, no. 2 (2014): 10.

Wrigley, C., G. Mosely, M. Gill, J. Reid. "*Air Force by Design: Applying Design for Transient Capability Advantages*", 2020. Last accessed 16 April 2022.
https://www.researchgate.net/publication/338902280_Air_Force_by_Design_Applying_Design_for_Transient_Capability_Advantages.

Wrigley, Cara, Genevieve Mosely, and Michael Mosely. "Defining Military Design Thinking: An Extensive, Critical Literature Review." *She Ji: The Journal of Design, Economics, and Innovation* 7, no. 1 (2021): 104-143.

Wrigley, Cara, Erez Nusem, and Karla Straker. "Implementing Design Thinking: Understanding Organizational Conditions." *California Management Review* 62, no. 2 (2020): 125-143.