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ARTICLE

The sixth RMA wave: Disruption in Military Affairs?

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ABSTRACT

The Revolution in Military Affairs, its concepts, processes, and debates, have evolved in five 'IT-RMA waves' since the 1980s. None of them, however, have fully achieved their intended outcomes as their ambitious premises have exceeded available technologies, budgetary resources, and operational capabilities of a given era. This paper argues that a new 'artificial intelligence-driven RMA' wave differs in the political, strategic, technological, and operational diffusion paths and patterns. While the AI-RMA may affect select countries and regions disproportionately, its technological advances coupled with an ongoing strategic competition is sufficiently broad to stipulate significant military changes across geopolitical lines.

KEYWORDS Revolution in Military Affairs; military innovation; future warfare; emerging technologies; disruptive defence innovation; strategic competition; East Asia

Introduction

After nearly three decades of debating the Revolution in Military Affairs (RMA), security studies is once again reflecting narratives of a 'disruptive' or significant military change brought by the convergence of emerging 'next-frontier' technologies, novel operational concepts and organisational force structures.[1] In particular, the application of advanced machine-learning algorithms in select areas of warfare promises to enable unprecedented capabilities concerning the speed of information and data processing, automation for weapons platforms and surveillance systems, and ultimately, decision-making.[2] For example, advanced sensor technologies such as hyperspectral imagery, computational photography, and compact sensor design, promise

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[1]Andrew James, 'Emerging Technologies and Military Capability', in Richard Bitzinger (ed.), *Emerging Critical Technologies and Security in the Asia-Pacific* (London: Palgrave Macmillan 2016), 6–21.

[2]Zachary Davis, 'Artificial Intelligence on the Battlefield', *PRISM* 8/2 (2019), 114–131; M. L. Cummings, ''Artificial Intelligence and the Future of Warfare', *Chatham House Research Paper*, 26 January 2017; Paul Scharre and Michael C. Horowitz, 'An Introduction to Autonomy in Weapon Systems', Center for a New American Security, 13 February 2015; Michael Horowitz, 'The Promise and Peril of Military Applications of Artificial Intelligence', *Bulletin of the Atomic Scientists*, 23 April 2018; Greg Allen and Taniel Chan, 'Artificial Intelligence and National Security', *Belfer Center for Science and International Affairs*, 6 July 2017.

to significantly improve target detection, recognition, and tracking capabilities and overcome traditional line-of-sight interference.[3] State-of-the-art materials, including composites, ceramics, and nanomaterials with adaptive properties, promise to make military equipment lighter but more resistant to the environment.[4] Emerging photonics technologies, including high-power lasers and optoelectronic devices, may provide new levels of secure communications based on quantum computing and quantum cryptography.[5] Moreover, the convergence of these technologies with artificial intelligence (AI) systems, robotics, additive manufacturing (or 3D printing), quantum computing, directed energy, unmanned systems and other 'disruptive' technologies of the 4th Industrial Revolution (4IR), are increasingly synonymous with sources of strategic and operational advantages in future warfare.[6]

While the strategic context differs, the diffusion of these technologies has prompted theoretical and policy-prescriptive questions similar to those posed in security studies since the early 1990s: Does the diffusion of emerging technologies signify a 'disruptive' shift in warfare or is it a mere evolutionary change? If emerging technologies stipulate a disruptive shift in warfare, what are defence resource allocation imperatives, including force structure and weapons procurement requirements? How can military organisations exploit emerging technologies to their advantage? Furthermore, how effective are emerging technologies to counter security threats and challenges of the 21st century, characterised by volatility, uncertainty, complexity, and ambiguity?

In this context, this paper positions its argument along two main lines: First, RMA conceptions and debates on the impending major change in warfare have progressively evolved over the past three decades. In 2006, Colin Gray briefly mentioned five stages or 'RMA waves' that have guided both theoretical and policy-oriented debates in strategic studies: (1) the intellectual discovery in the Soviet strategic thought in the 1980s, (2) the conceptual adoption and adaptation in the United States military in the early 1990s, (3) the culminating point of the RMA debate in mid-to-late 1990s, (4) the shift toward 'defence transformation' in the early 2000s, and (5) critical reversal questioning the RMA thesis from 2005 onwards.[7] This paper argues that since the mid-2010s, with the accelerating research and development of

[3]Sara Freitas, Hugo Silva, José Almeida & Eduardo Silva, 'Hyperspectral Imaging for Real-Time Unmanned Aerial Vehicle Maritime Target Detection', *Journal of Intelligent and Robotic Systems* 90 (2018), 551–570.
[4]Mark Burnett, et. al., 'Advanced Materials and Manufacturing – Implications for Defence to 2040 ', *Defence Science and Technology Group Report*, Australia Department of Defence (2018), https://www.dst.defence.gov.au/sites/default/files/publications/documents/DST-Group-GD-1022.pdf.
[5]International Institute for Strategic Studies, 'Quantum Computing and Defence', in IISS, *The Military Balance 2019* (London: Routledge 2019), 18–20.
[6]DARPA, 'Strategic Technology Office Outlines Vision for Mosaic Warfare', *DARPA News*, 4 August 2017, https://www.darpa.mil/news-events/2017-08-04.
[7]Colin Gray, *Strategy and History: Essays on Theory and Practice* (London: Routledge 2006), 113; Michael Raska, *Military Innovation and Small States: Creating a Reverse Asymmetry* (London: Routledge 2016), 30.

novel technologies such as artificial intelligence and autonomous systems, a new AI-driven RMA wave has already emerged (See Figure 1).

Second, notwithstanding significant advances in military technologies and the use of force in the initial five RMA waves, these trends have not been fully implemented relative to their envisioned conceptions. Their varying and often ambitious premises have generally exceeded available technological capabilities, financial resources, and operational requirements of a given era. Moreover, Gray's 'Five RMA' waves have actually been subsets of one comprehensive 'information technologies RMA,' or IT-RMA, which focused on integrating digital technologies into existing conventional weapons platforms and systems. The new AI-enabled RMA wave, however, differs from the past IT-RMA waves in several ways. Firstly, for the first time in decades, the US faces a strategic peer-competitor, China, capable of pursuing and implementing its own AI-RMA that can potentially negate strategic and operational advantages of the US military across geopolitical lines, particularly in East Asia. Secondly, advanced military-industrial sectors are no longer the primary drivers of technological innovation; instead, advanced technologies with a dual-use potential are being developed in the commercial sectors, including those of small states and middle powers, and then being 'spun on' to military applications. Finally, the diffusion of autonomous and AI-enabled weapons systems, coupled with novel operational constructs and force structures, challenge the direction and character of human involvement in future warfare.

Accordingly, the main question is not whether the AI-RMA wave is 'the one' that will bring about a fundamental discontinuity in warfare, and if so, how and why? Instead, it is whether the US AI-RMA can be nullified – or at least weakened – by a corresponding *Chinese* AI-RMA? Consequently, how will the global diffusion of emerging technologies affect strategic stability, alliance relationships, arms control, ethics and governance, and nearly all aspects of international security? These questions will arguably shape the next decade of debates in security studies with diverse theoretical and policy-oriented viewpoints, interpretations, and arguments. To advance these debates, however, it is essential to reflect on the intellectual history of the five IT-RMA waves, critically pointing out their failures to fully achieve their intended conceptual visions, while highlighting the differences in the strategic contours of the AI-RMA wave. As this paper shows, the IT-RMA waves trace their conceptual roots to Russian strategic thought, followed by varying experimentation and implementation paths in the US military, while the AI-RMA wave is a global phenomenon. It is embedded in the growing US-China systemic rivalry and their varying 'techno-nationalist' visions and approaches to dominate in areas of disruptive technologies of the 4IR.[8] At the same time, its diffusion paths and patterns are shaped by defence

[8]Paul Evans, 'Techno-Nationalism in China-US Relations: Implications for Universities', *EAI Background Brief*, 30 April 1527, 2020.

	1980's	1990-95	1995-2000	2000-2005	2005- 2010	2010- present
Wave	Intellectual Discovery	Early Adaptation in the West	IT-RMA Technophilia	Shift to Defence Transformation	Second & Third Thoughts	AI-Enabled RMA
Type	IT-RMA					4IR
Term	Military-Technical Revolution	Military Revolutions vs RMAs	Revolution in Military Affairs	Defence Transformation	Modernisation 'Plus'	Disruptive Defence Innovation
Country	Soviet Union	US	US	US	US / NATO	US China Russia Israel / Others
Warfare	Electronic Warfare	Information Warfare		Digitised Warfare	Hybrid Warfare	Automated Warfare
Operational Concepts (Examples)	Reconnaissance-Strike Complexes Operational Manoeuvre Groups	Dominant Battlespace Knowledge	Network-Centric Warfare	Effects-Based Operations Network-Centric Warfare	COIN Dynamics Network-Centric Warfare	Multi-Domain Operations PLA Intelligentised Warfare
Impetus	Technology/ Military Innovation	Technology/ Military Innovation	Technology/ Military Innovation	Technology / Defence Innovation / Low-Intensity Conflicts	Technology / Defence Innovation/ Low-Intensity Conflicts	Strategic Competition/ Emerging Technologies/ Civil-Military Convergence
Strategic Competition	Yes	No	No	No	No	Yes
Implementation	No	Limited	Limited	Partial	Partial	Ongoing

Figure 1. Overview of the six RMA waves. **Source**: Author; Adapted from Raska (2016).

innovation trajectories of select advanced small states and middle powers such as Australia, France, Israel, Singapore, South Korea, United Kingdom, and others. These states seek to leverage advanced technologies such as AI systems not only to alleviate their traditional defence constraints but also to advance their power and influence in the international arena.[9]

First RMA wave: Electronic warfare & military-technical revolution (MTR)

In the early 1980s, Soviet strategic forecasters debated the first-generation of RMA theories under the conceptual umbrella of the Military-Technical Revolution (MTR).[10] As Dima Adamsky noted, the Soviet MTR debate focused on two aspects: (1) the implications of scientific progress on the direction and character of future military operations; and (2) responding to Western doctrinal and technological innovations, notably the 1982 US AirLand Battle (ALB) and NATO's Follow-on Forces Attack (FOFA).[11] Indeed, following the Yom Kippur War in 1973, Russian analysts interpreted US advances in precision-guided munitions, advanced C3I systems, electronic warfare, and computer simulation as strategically detrimental to their baseline principles, methods, and forms of waging wars.[12] Lessons learned in the wars between Israel and Soviet-backed Arab neighbours showed that radar detection and precision firepower combined with new electronic warfare systems produced high attrition rates.[13] The ALB doctrine – attacking deep in the rear through a combination of stand-off precision fire, interdiction, and ground offensive operations - threatened Soviet operational-tactical and operational-strategic art based on large strategic formations and concepts of echelonment.[14]

In 1984, Gorbachev's call for 'new thinking' in defence and national security affairs opened a dialogue between Russian military-technical analysts and civilian social scientists on the challenges imposed by the MTR.[15] Leading military theorists such as General of the Army Makhmut Akhmetovich Gareev, then Deputy Chief of the Soviet General Staff and Chief of the Directorate for

[9]Itai Barsade and Michael Horowitz, 'Artificial Intelligence Beyond the Superpowers,' *Bulletin of the Atomic Scientists*, 16 August 2018.
[10]Raska, *Military Innovation and Small States: Creating a Reverse Asymmetry*, 30.
[11]Dima Adamsky, 'Through the Looking Glass: The Soviet Military-Technical Revolution and the American Revolution in Military Affairs', *Journal of Strategic Studies* 31/2 (2008), 257–94.
[12]Jacob Kipp, 'The Russian Military and the Revolution in Military Affairs: A Case of the Oracle of Delphi or Cassandra?', *US Foreign Military Studies Office Paper* (1995), 3; Williamson Murray and MacGregor Knox, 'Thinking about Revolutions in Warfare', in MacGregor Knox and Williamson Murray (eds.), *The Dynamics of Military Revolution, 1300–2050* (Cambridge: Cambridge University Press 2001), 3.
[13]Keith Shimko, *The Iraq Wars and America's Military Revolution* (Cambridge: Cambridge University Press 2010), 6.
[14]Murray and Knox, 'Thinking about Revolutions in Warfare', 3; Philip Petersen, 'The Soviet Conceptual Framework for the Application of Military Power', *Naval War College Review* 34/3 (1981), 21; Department of the Army HQ, *The Soviet Army: Operations and Tactics – Field Manual 100-2-1* (Washington DC: Department of Defence 1984), 1–12.
[15]Kipp, 'The Russian Military and the Revolution in Military Affairs: A Case of the Oracle of Delphi or Cassandra?', 6.

Military Science, and Marshal Nikolai V. Ogarkov, chief of the Soviet general staff from 1977 to 1984, conceptualised the MTR through the evolutionary lens of Marxist-Leninist dialectics in the continuity and change of military art. For example, Gareev argued that varying political, geostrategic, and economic limitations, such as the cost of modern military technologies, impose limitations to the MTR, while novel technological innovations such as information processing bring revolutionary aspects in new types of weapons.[16]

Similarly, following his ousting from the general staff in 1984, Ogarkov published in professional periodicals and monographs, examining the impact of emerging technologies on Soviet ways and means of warfare. He cautioned that the diffusion of precision-guided munitions coupled with enhanced sensors would result in qualitatively new and incomparably more destructive forms of warfare than ever before.[17] In future warfare, he argued, the integration of unmanned systems, space-based systems, and automated detection systems in a 'network of networks' would enable a near-simultaneous engagement of an entire array of targets at greater distances, precision, lethality, and speed. As such, Soviet conceptions of military effectiveness based on quantity as a source of military advantage, would be outweighed by quality.[18]

In this context, Soviet military thought at that time focused on the development of two interrelated operational concepts: (1) Reconnaissance-Strike Complexes (RSC) and (2) Operational Manoeuvre Groups (OMG).[19] Both concepts reflected Soviet adaptations of 'deep battle' by mobile groups using novel forms of weapons technologies, capable of engaging 'an array of targets at extended ranges with a high degree of accuracy and lethality'.[20] However, as the political and socio-economic conditions in the Soviet Union started to deteriorate from the early 1980s, while the Red Army was both entrenched and overextended in a protracted war of attrition in Afghanistan – the military lacked the technological means, financial resources, and organisational flexibility to implement these concepts. Intellectually, however, Russian conceptions on the MTR during this period provided greater analytical and critical depth than comparable writings in the West. Thus, the intellectual discovery and initial analysis of the MTR is credited to Russian strategic and military discourse.[21]

[16] *Ibid*., 20.
[17] Philip Petersen, 'The Modernization of Soviet Armed Forces', *NATO's 16 Nations* 31/4 (1984), 34.
[18] Nikolai Ogarkov, *Istoriya Uchit Bditelnosti* (*History Teaches Vigilance*) (Moscow: Voenizdat 1985); Dusko Doder, 'Ousted Soviet Chief of Staff Returns to Scene as Author', *The Washington Post*, 10 June 1985.
[19] *Ibid.*
[20] Andrew Krepinevich, *The Military-Technical Revolution: A Preliminary Assessment* (Washington DC: Office of Net Assessment 1992), 6.; Barry, Watts, 'What is the Revolution in Military Affairs?', *Northrop Grumman Analysis Center*351 (1995), 2.
[21] Dima Adamsky, *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the US, and Israel* (Palo Alto, CA: Stanford University Press 2010); Shimon Naveh, *In Pursuit of Military Excellence: The Evolution of Operational Theory* (London: Frank Cass 1996), 236.

Second RMA wave: Conceptual adaptation in the US military

Throughout the 1980s, US intelligence monitored changes in Russian military thinking.[22] The CIA, for example, published National Intelligence Estimates (NIE) that identified trends and developments in Soviet weaponry coupled with the emergence of RSC and OMG operational concepts.[23] However, these assessments underestimated the strategic significance of the MTR, and characterised it in terms of incremental military modernisation efforts, conditioned by Soviet technological, manpower, and resource limitations.[24] Some also argued that the MTR was only 'propagandistic hyperbole'.[25] In the early 1990s, however, the Office of Net Assessment (ONA) in the Office of the US Secretary of Defence (OSD) began investigating Soviet writings about the MTR as part of its mission of assessing military balances, which stipulated understanding Soviet conceptions of modern warfare. Headed by Andrew Marshall, the ONA began to expand its focus to explore the hypothesis that an MTR was underway. In 1990, for example, the ONA conducted a major review of the Soviet MTR literature to determine its validity and resulting policy imperatives, resulting in the 1992 publication: *Military-Technical Revolution: A Preliminary Assessment*. The report viewed the MTR as a fundamental discontinuity in warfare – not only in the technical aspects of the speed in which change takes place, but rather in the *magnitude* of the change itself, which 'at some point … will invalidate former conceptual frameworks by bringing about a fundamental change in the nature of warfare and, thus, in our definitions and measurement of military effectiveness'.[26]

However, the ONA report argued that Soviet MTR conceptions were confined to the technological dimension while mitigating the significance of organisational, operational, and human drivers of change. With this assumption, the term MTR evolved into the Revolution in Military Affairs (RMA) concept and its widely quoted definition – 'the application of new technologies into military systems combined with innovative operational concepts and organisational adaptation that alters the character and conduct of military operations'.[27] In doing so, RMA combined four key drivers of a major military change: (1) technological change; (2) military systems development; (3) operational innovation; and (4) organisational innovation. 'When (and only when) these elements are combined', the report argued,

[22]Raska, *Military Innovation and Small States: Creating a Reverse Asymmetry*, 33.
[23]Adamsky, 'Through the Looking Glass: The Soviet Military-Technical Revolution and the American Revolution in Military Affairs', 257–94.
[24]Office of Soviet Analysis, 'Trends and Developments in Warsaw Pact Theater Forces 1985–2000, *National Intelligence Estimate* No. 11–14 (1985).
[25]James Blaker, *Understanding the Revolution in Military Affairs: A Guide to America's 21st Century Defence* (Washington DC: Progressive Policy Institute 1997), 5.
[26]Krepinevich, *The Military-Technical Revolution: A Preliminary Assessment*, 3.
[27]*Ibid*., 3.

'dramatic improvement in military effectiveness and combat potential would take place'.[28]

During this period, the strategic studies literature focused on the lessons from the first Gulf War (1991), pointing to the emergence of novel military technologies, particularly precision-guided munitions, as a proof of the US military superiority embracing the RMA in the post-Cold War era.[29] Specifically, RMA studies reflected four key themes: (1) historical assessments of technology as a contributor of military effectiveness in war; (2) the sources and nature of military innovation; (3) the interpretations of processes of change brought by the Information Revolution; and (4) policy implications linked with short-and-long-term consequences of the RMA for military organisations.[30] In the varying debates, two terms began to appear (often interchangeably): *Military Revolutions (MR)* and *Revolutions in Military Affairs (RMA)*.[31] The MR implied a broader *socio-political and military* paradigm shift in the ways and means society, the state, and military organisations prepare and conduct war.[32] In other words, MRs would signify a grand-strategic dimension of a major military change beyond the battlefield and military organisations. In contrast, within or alongside the major MRs would be varying RMAs, characterised by Murray and Knox as 'periods of innovation in which armed forces develop novel concepts involving changes in doctrine, tactics, procedures, and technology … RMAs [also] take place almost exclusively at the operational level of war. They rarely affect the strategic level, except in so far as operational success can determine the large strategic equation. RMAs always occur within the context of politics and strategy–and that context is everything'.[33]

The conceptual adaptation phase focusing on the origins and character of MRs *vis-à-vis* RMAs began to shape defence policy planning, particularly in the US military. As Jeffrey Cooper noted, the RMA debate in the early 1990s divided US policymakers into two contending camps: (1) those who focused on the external perspective of the RMA as a means of attaining strategic objectives in the post-Cold War era; and (2) those viewing the RMA through internal processes as an organising principle or a tool to shape and determine future policy, acquisition programs, resource allocation, and bureaucratic relationships.[34] In retrospect, the early adaptation of the RMA in Western

[28] *Ibid*., 3.
[29] George and Meredith Friedman, *The Future of War: Power, Technology, and American Dominance in the 21st Century* (New York: Crown 1996); Max Boot, *War Made New Technology: Warfare and the Course of History, 1500 to Today* (New York: Gotham Books 2006).
[30] Raska, *Military Innovation and Small States: Creating a Reverse Asymmetry*, 35.
[31] Geoffrey Parker, 'Military Revolution 1560–1660–A Myth?' *Journal of Modern History* 48/2 (1976), 196–214.
[32] Murray and Knox, 'Thinking about Revolutions in Warfare', 7.
[33] *Ibid*., 12.
[34] Jeffrey Cooper, 'Another View of the Revolution in Military Affairs,' in John Arquilla and David Ronfeldt (eds.), *Athena's Camp: Preparing for Conflict in the Information Age* (Santa Monica, CA: RAND 1994), 99.

strategic thought during 1990–94 showed both streams of the debate – a broader search for a new strategic paradigm that would reflect the underlying geopolitical shift of the world order into a post-Cold-War era, while recognising the potential of emerging information technologies on the future of warfare. However, the output of US and European RMA studies at that time was not comprehensive and as a result 'offered only limited or broad policy choices'.[35]

Third RMA wave: Information warfare and IT-RMA technophilia

Starting in the mid-1990s, the RMA became the 'acronym of choice'[36] in the US defence planning and strategic studies community, 'arousing tremendous excitement among American defence planners'.[37] Historical analyses of MRs and RMAs were superseded by a plethora of studies focusing on the varying policy aspects, i.e. how to increase military effectiveness with new technologies at a reduced cost.[38] For example, key questions included how does the RMA impact defence planning and management, what are the critical changes needed to implement the RMA in organisations, and perhaps most importantly, how to implement the RMA at the operational level. In 1996, for example, Admiral William Owens, then Vice Chairman of the Joint Chiefs of Staff, conceptualised the *System-of-Systems* approach as the overarching operational vision for the RMA.[39] This concept focused on linking existing (and in some ways overlapping) inter-service platforms and systems – particularly, command, control, computers, communications, and information (C4I) systems coupled with intelligence, surveillance, and reconnaissance (ISR) systems into one interoperable network. By networking the varying C4I architectures and ISR information systems, the military would attain novel situational awareness capabilities – defined as 'Dominant Battlespace Knowledge' (DBK), across a large area of operations (200-by-200-mile boxes). DBK, in theory, would enable speeding up of decision-making processes, and allow directing 'precision force in action and results'.[40] In this context, Owens argued that the US military should accelerate the pursuit of RMA by embracing substantial technological, organisational, structural, and doctrinal changes.

It should be noted that before Owens' appointment as the Vice Chairman of the Joint Chiefs of Staff in 1994, the US military services did not widely perceive the RMA as a major military change, but rather as an evolving continuation of existing military-technological development. In other words, a phenomenon

[35]Steven Metz and James Kievit, *Strategy and the Revolution in Military Affairs: From Theory to Policy* (Carlisle: Strategic Studies Institute 1995), 1.
[36]Williamson Murray, 'Thinking About Revolutions in Military Affairs', *Joint Forces Quarterly* 16 (Summer 1997), 69.
[37]Metz and Kievit, *Strategy and the Revolution in Military Affairs: From Theory to Policy*, 1.
[38]Raska, *Military Innovation and Small States: Creating a Reverse Asymmetry*, 39.
[39]William Owens, 'The Emerging US System-of-Systems', *Strategic Forum* 63. (1996), 1–6.
[40]*Ibid*., 1.

more of modernisation than a revolution.[41] Owens' System-of-Systems vision, however, challenged these perspectives by projecting a future of unprecedented technological and operational inter-service compatibility. At the same time, it defined a set of new procurement priorities toward select military technologies that would enable better connectivity, interoperability, and jointness coupled with precision firepower. As a result, the US military accelerated the institutional adoption and adaptation of the RMA, as seen in the official publications such as the 1996 *Joint Vision 2010* and the 1997 *Quadrennial Strategy Review*. In particular, the *Joint Vision 2010* published by the Office of the Joint Chiefs of Staff, provided a template for translating Owens' system-of-systems concept into a joint operational framework.[42] However, its critics argued that despite two decades of military-technological advances and operationally focused thinking in the US military, the JV2010 would still represent a linear extension of the previous strategic context, existing technologies, and operational doctrines such as the AirLand Battle.[43] Therefore, in order to represent a paradigm shift that would account for information revolution in the new strategic context of the post-Cold War era, a radically different approach would be required. This idea is evident, for example, in the 1997 publication of the National Defence Panel's (NDP) report titled *Transforming Defence: National Security in the 21st century*. The report argued that the security environment of the 21st century will be 'quantitatively and qualitatively different from those of the Cold War and will require a fundamental change to US national security institutions, military strategy and defence posture'.[44]

Fourth RMA wave: Digitised warfare & defence transformation

While military-technological aspects remained an essential driver in the RMA debate in the early 2000s, the varying narratives increasingly reflected also changes in the global and regional security environment such as the rise of non-state actors, terrorism, and asymmetric warfare threats and challenges.[45] With the changing strategic impetus, the RMA debate in the US shifted toward the concept of defence transformation, which further extended the scope of envisioned military change.[46] Following the 9/11 terrorist attacks,

[41] *Ibid*., 7.
[42] Office of the Joint Chiefs of Staff, 'Joint Vision 2010, US Department of Defence, July 1996.
[43] Paul Mitchell, *Network Centric Warfare and Coalition Operations: The New Military Operating System* (London: Routledge 2009), 34.
[44] National Defence Panel, *Transforming Defence: National Security in the 21st Century* (Washington DC: US Department of Defence 1997), 3.
[45] Ronald O'Rourke, 'Defence Transformation: Background and Oversight Issues for Congress', *CRS Report* for Congress 322,238 (2007).
[46] Steven Metz, 'America's Defence Transformation: A Conceptual and Political History', *Defence Studies* 6/1 (2006), 1–25.; Thomas Adams, *The Army After Next: The First Postindustrial Army* (Westport, CT: Praeger 2006); Thomas Mahnken and James Fitzsimonds, 'Tread-Heads or Technophiles Army Officer Attitudes Toward Transformation', *Parameters* 34/2 (2004), 57–72.

defence transformation became an 'all-encompassing umbrella for multifaceted initiatives'.[47] These would embrace strategic and operational imperatives to fundamentally restructure US forces and that of its allies by radically transforming defence planning, organisational force structures, and operational conduct.[48] In the words of Richard Bitzinger, 'the transformation of the US armed forces was initially promoted as nothing less than a fundamental shift in the way wars would be fought in the future. Nothing was sacred: every piece of defence dogma was on the table for debate and discussion – force structure, organisation, equipment, budgets, doctrine, and strategy'.[49]

In October 2001, Donald Rumsfeld, then the Secretary of Defence, established the Office of Force Transformation (OFT), led by Vice Admiral Arthur K. Cebrowski, tasked with coordinating the implementation of various transformation visions, plans, and programmes across the US military services. These included a plethora of transformation-related documents and roadmaps.[50] For example, the 2003 *Transformation Planning Guidance* (TPG) defined defence transformation as a 'process that shapes the changing nature of military competition and cooperation through new combinations of concepts, capabilities, people and organisations that exploit our nation's advantages and protect against our asymmetric vulnerabilities to sustain our strategic position, which helps underpin peace and stability in the world'.[51] Other notable policy documents included *Elements of Defence Transformation* (2004), *National Defence Strategy* (2005), and *the Quadrennial Defence Review* (2006). At the same time, US military services published their select transformation plans and visions. For example, under the *Navy Sea Power 21* strategy (2004), the US Navy (USN) would transform by conducting more flexible and expeditionary deployments in littoral (i.e. near-shore) waters, relying on new platforms such as multi-mission destroyers and cruisers, new types of modular mission-ships with smaller crews.[52] Similarly, the *Air Force Transformation Flight Plan* (2003), envisioned more expeditionary character for future missions of the US Air Force (USAF), which would be transformed into a 'global reconnaissance and strike force' dominating air, space, and cyberspace.

[47] Raska, *Military Innovation and Small States: Creating a Reverse Asymmetry*, 42.
[48] Peter Dombrowski and Andrew Ross, 'The Revolution in Military Affairs: Transformation and the Defence Industry', *Security Challenges* 4/4 (2008), 13.
[49] Richard Bitzinger, *Transforming the US Military: Implications for the Asia-Pacific* (Barton: Australian Strategic Policy Institute 2006), 6.
[50] Office of the Joint Chiefs of Staff, '*Joint Vision 2020: America's Military – Preparing for Tomorrow*', US Department of Defence, June 2000.
[51] Office of the Secretary of Defence, 'Transformation Planning Guidance', US Department of Defence, April 2003, 3.
[52] Office of the Secretary of Navy, 'Sea Power 21: Projecting Decisive Joint Capabilities', US Department of the Navy, October 2002.

Meanwhile, the US Army would be reorganised into modular, brigade-sized forces called Units of Action, and deployed in more distant areas and adaptable to the needs of specific contingencies.[53] 'Digitised warfare' became the buzzword in the Army's Force XXI effort, and the 'Millennium Challenge' exercise.[54] The idea was that greater digitisation and more networks would significantly improve situational awareness and precision-strike capabilities, and enable small units to be more lethal in future conflicts. The US Army subsequently rolled out the FBCB2 (Force XXI Battle Command Brigade and Below), Blue Force Tracker, and started to replace its tactical network capabilities. Tactical and operational-level Unmanned Aerial Vehicles (UAVs) became more ubiquitous during this period as well.[55]

At the operational level, US military innovation efforts focused on the experimentation and implementation of two key concepts: *Network-Centric Warfare* (NCW) and *Effects-Based Operations* (EBO). Both concepts essentially aimed at exploiting emerging military technologies in order to attain novel 'information-superiority' and precision-firepower capabilities. However, their ambitious visions stirred a new wave of debates that questioned their validity, reliability, and applicability. In particular, after eight years of conceptual development, EBOs became the focal point of criticism for the complex terminology and fragmented templates that aimed to predict outcomes of actions in any operational environment.[56] Its critics argued that EBOs are impossible to implement in a dynamic security environment with an infinite number of variables – EBOs could never accurately anticipate nor measure reactions of complex systems (i.e. political systems), which are highly adaptive or have different strategic cultures and behavioural parameters. In 2008, the Joint Forces Command (JFCOM) headed by Marine Gen. James Mattis issued a memorandum discarding the concept.[57] Once again, notwithstanding the military-technological developments of the era, the ambitious strategic and operational objectives behind defence transformation have failed or have been only partially implemented.

Fifth RMA wave: Hybrid warfare & modernisation-plus

From the mid-to-late 2000s, the vision of defence transformation projected an ambitious and diversified agenda for a major military change, which

[53]William Donnelly, *Transforming an Army at War: Designing the Modular Force 1991–2005* (Washington DC: Center for Military History 2007), 27–63.
[54]Micah Zenko, 'Millennium Challenge: The Real Story of a Corrupted Military Exercise and its Legacy', *War on the Rocks Commentary*, 5 November 2015.
[55]John Sloan Brown, *Kevlar Legions: The Transformation of the United States Army 1989–2005* (Washington DC: United States Army, Center of Military History 2012), 1.
[56]Milan Vego, 'Effects-Bases Operations: A Critique', *Joint Forces Quarterly* 41/2 (2006), 51–57.
[57]James Mattis, 'USJFCOM Commander's Guidance for Effects-Based Operations', *Joint Forces Quarterly* 51 (2006), 106.

transcended available technological, financial, and organisational resources.[58] As Bitzinger summarised, 'the challenge for the US military has been translating the transformational vision into a credible and effective set of capabilities, strategies and organisations'.[59] In the following years, the ambitious narrative as a process of disruptive military change has culminated into a ubiquitous term, which in reality outpaced the actual implementation. Before that, there were a number of critics arguing that the RMA as a theory, process, and debate has no validity and that it has rapidly evolved 'from exposition to consideration for implementation as a US government policy' so quickly that it 'outpaced the ability of scholarship to examine its underlying premises and evidence'.[60] Defence transformation pushed these ideas further and amplified expectations in ways that far exceeded available capabilities. Accordingly, an increasing number of 'transformation critics' voiced the varying problems in the unfulfilled promises and ambiguities of an open-ended process, suggesting that the concept became an empty phrase. The rationale for 'new way of thinking and a new way of fighting' justifying virtually every defence initiative or proposal, whether RMA related or not, signalled disorientation rather than a clear strategy.[61] Transformation sceptics also cautioned about the flawed logic in solving complex strategic challenges through technology, while discarding the adaptive capacity of potential enemies or rivals. In short, defence transformation turned into a misguided idea, propelled by the military's budgetary requirements and unrealistic capability sets rather than actual policy requirements.[62]

Most importantly, however, defence transformation was challenged by the operational requirements and experiences in wars in Iraq and Afghanistan, which imposed increasing costs in the protracted counterinsurgency campaigns. These two conflicts shifted the resources, priorities and focus of the US military away from pursuing broad transformational ideas and in favour of fighting low-tech insurgents capable of inflicting significant damage. In other words, the US military became entrenched in the political, socio-economic challenges of a non-linear conflict that 'it was not prepared for, nor had it anticipated'.[63] As Robert Gates succeeded Donald Rumsfeld as Secretary of Defence in 2006, the transformation agenda, as well as the overall narrative, changed its tone from the ambitious paradigm shift to a 'shift in emphasis'.[64] This lexical turn also signalled the mounting costs of defence transformation

[58] *Military Innovation and Small States: Creating a Reverse Asymmetry*, 50.
[59] Bitzinger, *Transforming the US Military: Implications for the Asia-Pacific*, 12.
[60] Stephen Biddle, *The RMA and the Evidence: Assessing Theories of Future Warfare* (Alexandria, VA: Institute for Defence Analyses 1996).
[61] Lawrence Freedman, *The Transformation of Strategic Affairs* (London: International Institute of Strategic Studies 2006).
[62] Kevin Reynolds, *Defence Transformation: To What? For What*? (Carlisle: Strategic Studies Institute 2006).
[63] Shimko, *The Iraq Wars and America's Military Revolution*, 203.
[64] O'Rourke, 'Defence Transformation: Background and Oversight Issues for Congress', 7.

programmes, such as the Future Combat System (FSC) concept, which envisioned distributed and networked forces being able to coordinate and mass fires from dispersed positions on the battlefield. However, the technology was simply not developed at that time, and the funding was not available due to the ongoing Global War on Terror.[65] Taken together, as Peter Dombrowski and Andrew Ross argued, the institutionalisation and actual substance behind defence transformation visions, plans, and programs within the US military establishment reflected more of an *evolutionary change* or 'modernisation plus,' rather than a discontinuous, disruptive innovation.[66]

It is important to note, however, that the transformation narrative during this period diffused beyond the US military, and it had a profound impact on military modernisation trajectories elsewhere. Studies of RMA adoption and adaptation paths outside the US began to emerge in the late 2000s in the European (NATO) states, China, Russia, Israel, Australia, and other countries. At the same time, RMA studies focused on its impact on the global defence industry.[67] However, actual RMA-oriented adaptations, such as the Systemic Operational Design in the Israel Defence Forces in the mid-2000s, were arguably not fully implemented into the use of force, i.e. in the Second Lebanon War.[68] Many European/NATO countries also faced a range of organisational, technological, and (especially) budgetary challenges when it came to implementing network-enabled capabilities by connecting post-Cold War armament platforms.[69] Consequently, the failures to implement the IT-RMA by 2010 has diminished its importance in the military concepts development and defence planning processes, particularly in the US/NATO militaries.

Sixth AI-RMA wave: Automated warfare and strategic competition

From the early 2010s, however, the narrative of an impending 'disruptive' military-technological paradigm shift in warfare began a subtle revival, propelled by three key drivers: (1) the accelerating strategic competition for political, economic, and military-technological supremacy between world's major powers – the US, China, and to a lesser degree Russia; (2) the changing dynamics of military-technological innovation brought by the convergence of varying science and technology areas such as synthetic biology and artificial intelligence, human-machine learning and cognitive manipulation, and

[65] Anthony Cordesman and Paul Fredericksen, *Is Defence Transformation Affordable? Cost Escalation of Major Weapons Programs* (Washington DC: Center for Strategic and International Studies 2006).
[66] Dombrowski and Ross, 'The Revolution in Military Affairs: Transformation and the Defence Industry', 23.
[67] Richard Bitzinger, 'The Revolution in Military Affairs and the Global Defence Industry: Reactions and Interactions', *Security Challenges* 4/4 (2008), 1–12.
[68] Avi Kober, 'The Israel Defence Forces in the Second Lebanon War: Why the Poor Performance?', *Journal of Strategic Studies* 31/1 (2008), 3–40.
[69] Juha Kai Mattila, 'Engaging a Moving Organisation – Modelling a Military Enterprise with Architecture Tools', PhD Dissertation, Aalto University School of Science and Technology (2020).

between cyber and artificial intelligence; and (3) the resulting diffusion of dual-use emerging technologies, particularly autonomous and AI-enabled systems in warfare – not only in the arsenals of great powers but also in select advanced small states and middle powers. The confluence of these drivers has signalled the emergence of a new, unique AI-enabled RMA wave, i.e., the AI-RMA.

Contrary to previous IT-RMA waves, which, admittedly, utilised *some* dual-use technologies in the development of major weapons platforms and systems, the current AI-RMA wave differs in the magnitude and impact of the commercial-technological innovation as the source of military innovation.[70] In particular, the AI-RMA wave is evident in the varying 'techno-nationalist' approaches, embedded in the strategic competition between the US and China, which is conditioned by economic interdependencies as well as strategic challenges simultaneously.[71] For example, the quest for disruptive technologies found as AI systems clearly underpins China's strategy of 'military-civil fusion', which views technological innovation as the central element in generating economic competitiveness, political legitimacy, military power, and international influence. This strategy has progressively evolved over the past four decades, from Chinese defence companies engaging in civilian production to overcome resource limitations in the 1980s and 1990s, to creating and leveraging synergies between defence-commercial developments and supply chains in the 2010s and 2020s.[72]

In doing so, China's concepts of 'indigenous innovation' and 'independent innovation' have aimed to identify, absorb, digest, and reinvent technology transfers from global commercial high-technology R&D sectors to the military.[73] The strategy has accelerated the People's Liberation Army (PLA) dual-track military modernisation trajectory. On the one hand, the PLA has invested in continuous upgrades of existing or legacy weapons platforms, while simultaneously experimenting with novel technologies in the so-called domains of 'new military rivalry': outer space, near-space, cyberspace and underwater.[74] The prioritisation of these domains has led

[70]Michael Raska, 'Strategic Competition for Emerging Military Technologies: Comparative Paths and Patterns,' *PRISM* 8/3 (2020), 64–81.

[71]Office of the Secretary of Defence, The National Defence Strategy 2018 (Washington DC:, Department of Defence 2018); Office of the President of the US, The National Security Strategy 2017 (Washington DC: The White House 2017); Thomas Mahnken, 'A Framework for Examining Long-Term Strategic Competition Between Major Powers', *SITC Research Brief*, January 2017; Aaron L. Friedberg, 'Competing with China', *Survival* 60/3 (2018), 7–64.

[72]Mel Gurtov, 'Swords into Market Shares: China's Conversion of Military Industry to Civilian Production', *The China Quarterly* 134 (1993), 213–241; Elsa Kania, 'Innovation in the new Era of Chinese Military Power', *The Diplomat*, 25 July 2019.

[73]Tai Ming Cheung, 'Innovation in China's Defence Technology Base: Foreign Technology and Military Capabilities', *Journal of Strategic Studies* 39/5–6 (2016), 728–761.

[74]Michael Raska and Richard Bitzinger, 'Strategic Contours of China's Arms Transfers', *Strategic Studies Quarterly* 14/1 (2020), 92.

the PLA to field novel military technologies such as new ballistic missiles, hypersonic weapons, unmanned underwater drones, and many other systems and platforms designed to negate strategic and operational advantages of the US military presence in East Asia, namely 'power projection, forward presence, freedom of action'.[75] Indeed, since the late 1990s, the PLA has shifted its strategic direction and operational requirements away from a continental/territorial defence and toward projecting power in China's maritime periphery or the 'three seas' – i.e., the Yellow, East China, and South China Seas – under the narrative of protecting 'China's national sovereignty, security, and territorial integrity'.[76] Since 2016, the PLA also embarked on a series of major organisational reforms, aimed to complement PLA's ongoing military-technological transformation toward 'Intelligentised' form of warfare.[77]

In this context, the key questions in the AI-RMA debate is, firstly, whether China will be able to attain technological capabilities to project military power in the Indo-Pacific region sufficient to disrupt or degrade US forward presence, and, secondly, how the United States and its key allies, in unison with other regional powers, will respond to such changes.[78] Moreover, can the US military sustain a long-term deterrence, project power in contested areas, and mitigate escalatory risks amid growing anti-access/area denial (A2/AD) challenges, and, if so, how?[79]

While PLA analysts in the US have closely followed developments in the Chinese strategic thought and military-technological advances during the 1990s, the realisation that the US could be facing a peer competitor became apparent to its political and military leadership only after two decades of fighting counterinsurgency campaigns in Iraq and Afghanistan. In July 2009, for example, then-Secretary of Defence Robert Gates instructed military planners to explore options to 'preserve the US ability to project power and maintain freedom of action in the global commons'.[80] One of the initial attempts was the development of the Air-Sea Battle (ASB) concept,

[75]Taylor Fravel, 'China's New Military Strategy: Winning Informationized Local Wars,' *China Brief*, 15/13, 2 July 2015.

[76]Andrew Erickson, 'China's Modernization of its Naval and Air Power Capabilities', in Ashley Tellis and Travis Tanner (eds.) *Strategic Asia 2012–13: China's Military Challenge* (Washington DC: The National Bureau of Asian Research 2012), 60–125; Michael Chase, Jeffrey Engstrom, Tai Ming Cheung, Kristen Gunness, Scott Warren Harold, Susan Puska and Samuel Berkowitz, *China's Incomplete Military Transformation: Assessing the Weaknesses of the People's Liberation Army* (Santa Monica, CA: RAND Corporation 2015), 26.

[77]Phillip C. Saunders and Joel Wuthnow, 'China's Goldwater-Nichols? Assessing PLA Organizational Reforms', *Joint Forces Quarterly* 82, July 2016; Michael Dahm, 'Chinese Debates on the Military Utility of Artificial Intelligence', *War on the Rocks*, 5 June 2020.

[78]Chung Min Lee, *Fault Lines in a Rising Asia* (Washington DC: Carnegie Endowment for International Peace 2016), 190.

[79]Aaron Friedberg, *Beyond Air-Sea Battle: The Debate over US Military Strategy in Asia* (London: International Institute for Strategic Studies 2014), 74.

[80]Michael E. Hutchens (et.al.), 'Joint Concept for Access and Maneuver in the Global Commons: A New Joint Operational Concept', *Joint Forces Quarterly* 84, 27 January 2017.

coordinated by the joint Air-Sea Battle Office (ASBO) in the US Department of Defence.[81] The ASB concept, however, became highly controversial as it envisioned air and naval strikes on early warning and missile bases located in mainland China (designated 'Networked, Integrated Attacks-in-Depth'), which led to debates on its escalatory risks and potential outcomes for US allies.[82] In February 2015, the DOD then renamed ASB into the 'Joint Concept for Access and Manoeuvre in the Global Commons' (JAM-GC). It later shifted its development into varying inter-service 'Multi-Domain Operations' concepts – joint operations across the air, land, sea, cyber, and space domains, and the electromagnetic spectrum.[83]

However, the operational-tactical ASB debate initiated a much broader search for novel strategies, organisational and operational concepts that would exploit emerging technologies such as AI-enabled systems and autonomous weapons and ensure strategic advantages in future warfare. In 2014, for example, the US DOD launched the *Defence Innovation Initiative* (DII) as a comprehensive strategy to accelerate the absorption of emerging breakthrough technologies, primarily from the commercial sector into the military.[84] The DII called for the need to 'identify a third offset strategy that puts the competitive advantage firmly in the hands of American power projection over the coming decades.'[85] The Third Offset (3O) strategy, developed under former Deputy Secretary of Defence Robert Work, then became one of the central constructs for integrating the varying 4IR technologies into the US armed forces.[86] Its analogy followed the First and Second Offset strategies during the Cold War, designed to counter Soviet quantitative military superiority – the first through the development of nuclear weapons and delivery means, and the second through qualitative leaps in conventional military capabilities.[87] The Third Offset, in turn, aimed at extending the margin of US military-technological superiority in a strategic competition with China and Russia.

At present, the US military is experimenting with select command and control and weapons systems with varying levels of autonomous functions, while rethinking ways and means to exploit commercially driven innovation.

[81]Norton Schwartz, 'Remarks to the National Defence University Distinguished Lecture Program,' 15 December 2010.
[82]Friedberg, *Beyond Air-Sea Battle: The Debate over US Military Strategy in Asia*, 80–90.
[83]Tom Greenwood and Pat Savage, 'In Search of a 21st-Century Joint Warfighting Concept', *War on the Rocks Commentary*, 12 September 2019.
[84]Timothy Walton, 'Security the Third Offset Strategy – Priorities for the Next Secretary of Defence', *Joint Forces Quarterly* 82/3 (2016), 6–15.
[85]Chuck Hagel, 'Memorandum – The Defence Innovation Initiative', Office of the Secretary of Defence, 15 November 2014.
[86]Cheryl Pellerin, 'Deputy Secretary Discusses Third Offset, First Organisational Construct,' *Department of Defence News*, 21 September 2016, http://www.defence.gov/News/Article/Article/951689.
[87]Robert Martinage, *Toward a New Offset Strategy: Exploiting US Long-Term Advantages to Restore US Global Power Projection Capability* (Washington DC: Center for Strategic and Budgetary Assessments 2014).

Notwithstanding the classified nature of many of these programmes, select priority research and development areas have been noted in published official budgetary statements, including the development of AI-systems and autonomous weapons in various human-machine type collaborations – i.e. AI-enabled early warning systems and command and control networks, space and electronic warfare systems, cyber capabilities, lethal autonomous weapons systems, and others.[88] These technologies have also gradually permeated into future warfare experimentation and capability development programmes, including DARPA's Mosaic Warfare, Army Futures Command, Air Force Warfighting Integration Capability, Office of Naval Research, and Joint Artificial Intelligence Centre.[89]

At the same time, the diffusion of AI-enabled RMA technologies, including additive manufacturing (3D printing), nanotechnology, space and space-like capabilities, artificial intelligence, and drones, are not confined solely to the great powers.[90] The AI-RMA wave is also reflected in defence innovation trajectories of select advanced small states and middle powers, such as Australia, France, United Kingdom, Singapore, Israel, South Korea and others.[91] These states seek to develop niche 4IR technologies to advance not only their defence capabilities but also economic competitiveness, political influence and status in the international arena.[92] Singapore is a prime example of a small state actively pursuing the research and development of AI-enabled systems in defence through strategic collaborations with leading research entities on global defence industries, as well as local small and medium enterprises. Facing a widening spectrum of threats coupled with increasing demographic and manpower limitations, the 'next-generation Singapore Armed Forces (SAF)' transformation efforts envision leveraging 4IR technologies in nearly all aspects of military operations and planning. Some of the ongoing programmes include using data analytics for servicing the Republic of Singapore Air Force's fleet of fighter jets, battlefield instrumentation analytics systems for the Army, autonomous underwater vehicles for mine detection in shallow waters, development of unmanned watchtowers for

[88]Cheryl Pellerin, 'Work: Human-Machine Teaming Represents Defence Technology Future,' *Department of Defence News*, 8 November 2015, http://www.defence.gov/News/Article/Article/628154/work-human-machine-teaming-represents-defence-technology-future.

[89]Benjamin Jensen and John Paschkewitz, 'Mosaic Warfare: Small and Scalable are Beautiful', *War on the Rocks*, 23 December 2019. Sydney J. Freedberg Jr., 'Inside Army Futures Command: CFT Chiefs Take Charge,' *Breaking Defence*, 14 August 2018; Arnold W. Bunch Jr and Jerry Harris Jr, 'Presentation to the House Armed Services Committee: Air Force, Force Structure and Modernization Programs,' Department of the Air Force, 12 April 2018, 14.

[90]T.X. Hammes, 'Technologies Converge and Power Diffuses: The Evolution of Small, Smart, and Cheap Weapons', *CATO Institute Policy Analysis* 786, 27 January 2016.

[91]Andreas Krieg and Jean-Marc Rickli, *Surrogate Warfare: The Transformation of War in the Twenty-First Century* (Washington DC: Georgetown University Press 2019), 85–116.

[92]Itai Barsade and Michael Horowitz, 'Artificial Intelligence Beyond the Superpowers,' *Bulletin of the Atomic Scientists*, 16 August 2018.

naval and coastal surveillance, and many other programmes.[93] How militaries such as the SAF interact with commercial science and technology ecosystems, while adopting and adapting novel technologies in their defence innovation trajectories, has become another critical feature in the ongoing AI-RMA wave.

Conclusion

From the Military-Technical Revolution conceptions by Soviet strategic theorists in the 1980s, IT-RMA narratives and debates have evolved over five consecutive waves, primarily in the strategic and operational context of the US military modernisation trajectory. These initial five waves focused mainly on integrating digital technologies into existing conventional weapon systems and organisational force structures to achieve an 'order of magnitude' change in military effectiveness. While many military innovations during this era, such as concepts of Network-Centric Warfare, have matured, the ambitious narratives of impending 'transformation' have nearly always surpassed available technological, organisational, and budgetary capabilities. In contrast, the current (sixth) AI-driven RMA wave is progressing along multiple lines simultaneously, albeit in varying paths and patterns: in the strategic competition between China, Russia and the US, which abbreviates the margins of US military-technological superiority; in the 4IR technological breakthroughs that occur primarily in the commercial arena and that inspire militaries to leverage their military potential; and along the niche defence innovation trajectories of advanced small states and middle powers that see opportunities to offset their strategic challenges and constraints through novel technologies. The AI-RMA wave also differs in the magnitude and impact of human-machine interactions in warfare, in which algorithms increasingly shape human decision-making, and future combat is envisioned in the use of AI-enabled autonomous weapons systems.

Consequently, the AI-RMA wave does not reflect a mere continuation of '*modernisation-plus*' wave; it signifies a real disruptive shift in warfare – in the framework of new or different instruments (technology), practices (doctrines and operational concepts), to the formation of new organisational force structures.[94] While the AI-RMA wave may affect select countries and regions disproportionately, its technological reach coupled with an ongoing strategic competition is sufficiently broad to require a rethinking of weapons development and R&D, defence budgetary processes, defence contractors as well as tip of the spear of operational and warfighting domains and

[93]Michael Raska, 'Singapore's Next-Frontier Defence Innovations', *The Straits Times*, 27 June 2018.
[94]Tai Ming Cheung, Thomas Mahnken, Andrew Ross, 'Frameworks for Analysing Chinese Defence and Military Innovation,' *SITC Policy Brief* 27 (2011), 1–4.

concepts, alliances and strategic partnerships. In doing so, the AI-RMA reflects novel strategic and operational challenges, particularly in the deployment of automated and autonomous systems and human-machine teaming, that propel new questions and debates ranging from future military budget priorities to issues of AI governance and ethics. Ultimately, the ramifications of the AI-RMA marks new opportunities and risks for international cooperation by exposing limitations of established paradigms in the ways and means of using force.

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