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The 4th Industrial Revolution, Military-Civil Fusion, and the Next RMA

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ABSTRACT *The technologies embedded in the emerging 4th industrial revolution (4IR) –and artificial intelligence (AI) in particular– promise to constitute a disruptive paradigm shift in the future nature and conduct of warfare. These technologies will likely also have a major impact on the competitions between great powers, countries that aspire to be leading regional players or nations that see technology as a critical force multiplier. It is important to understand what new and emerging critical technologies are challenging the traditional warfighting paradigm and how militaries might access and leverage these innovations. This entails an examination of the potential military-technical impact of technologies embedded in the 4IR, as well as the means –generally described as 'military-civil fusion'– for exploiting those technologies for military capability and advantage.*

Keywords: Military-Technological Innovation, Defense Industries, Military Modernization, Fourth Industrial Revolution, Military-Civil Fusion

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Michael Raska notes that there have been five major waves of military innovation –that is, Revolutions in Military Affairs (RMAs)– since the late 1980s. These are: first, the initial theorizing and development of the concept of a Military-Technical Revolution (MTR) in the Soviet Union, based on "reconnaissance-strike complexes" (1980s); second, the study and refinement of MTR concepts by the U.S. military (early 1990s); third, the development of the Information Technologies-led RMA (IT-RMA) in the U.S. military (mid-to late-1990s); fourth, limited implementation of the IT-RMA under the guise of Defense Secretary Donald Rumsfeld's "defense transformation" efforts (early 2000s); and, fifth, a growing questioning of the overall RMA concept (mid-2000s onward).[1]

Raska now asserts that we are on the cusp of a sixth RMA wave, based on a 4th Industrial Revolution (4IR) and particularly on developments in artificial intelligence (AI). This new AI-RMA differs radically from previous RMAs in that 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 organizational force structures."[2]

The 4IR is driving this new RMA wave, and AI is particularly viewed as a key force multiplier. As the U.S. National Security Commission on Artificial Intelligence (NSCAI) puts it:

> A new warfighting paradigm is emerging because of AI…called "algorithmic" or "mosaic" warfare; China's theorists have called it "intelligentized" war. All these terms capture, in various ways, how a new era of conflict will be dominated by AI and pit algorithms against algorithms. Advantage will be determined by the amount and quality of a military's data, the algorithms it develops, the AI-enabled networks it connects, the AI-enabled weapons it fields, and the AI-enabled operating concepts it embraces to create new ways of war.[3]

The Commission goes on to state that:

> AI will transform the way war is conducted in every domain from undersea to outer space, as well as in cyberspace and along the electromagnetic spectrum. It will impact strategic decision-making, operational concepts and planning, tactical maneuvers in the field, and back-office support.[4]

How exactly the 4IR –and particularly AI– will transform future warfare is still undetermined. Few chores are more difficult than predicting the future. The past is littered with failed predictions, and so it is easy to become jaded and cynical. Yet, when it comes to envisaging future advances in military capabilities –and, subsequently, future areas of military advantage– few requirements are more critical. We care about RMAs because we ignore them at our peril. It is doubly difficult when we realize that we are not only attempting to predict RMAs but to actualize them as well.

RMAs are, of course, much more than 'mere' technology. As Cheung, Mahnken, and Ross put it: "Technology is the most visible dimension of military innovation, but military innovation is not to be equated with, or reduced to, technological innovation…the organizational and doctrinal components of military innovation are no less significant than its technological component."[5] RMAs entail "innovative operational concepts" and "organizational adaptation," done in such a way as to "fundamentally alter the character and conduct of a conflict," and produce "a dramatic increase…in the combat potential and military effectiveness of armed forces."[6] And yet technology and technological innovation are what we always come back to. Mostly this is because technological advances are central to implementing the organizational and operational aspects of the RMA. Without the requisite technology, the RMA cannot be imagined or implemented, and this is what makes the 4IR so relevant.

Still, technology is perhaps the most crucial determinant when it comes to military innovation, effectiveness, and advantage. Even Cheung, Mahnken, and Ross agree that "technology, in the form of weapons and weapon systems, serves as the source of the hardware dimension of military innovation and its concrete products."[7] Furthermore, Keith Krause argues that "the possession of modern weapons is a key element in determining the international hierarchy of power."[8] In other words, the possession of cutting-edge militarily relevant technologies equals more effective weapons systems, which in turn results in greater military power, which in turn translates into greater geopolitical power.

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Technology is still one of the most critical enablers of defense transformation, and the transnational diffusion of military-related technologies is an important factor affecting the distribution of power in international politics. Consequently, the global dissemination of advanced, militarily relevant technologies should be as great a security concern as the spread of weapons systems themselves.

Complicating this predicament, we live in a time when 'militarily relevant technologies' are becoming harder and harder to identify and classify. Technological advances, especially in the area of military systems, are a continuous, dynamic process; breakthroughs are always occurring, and their impact on military effectiveness and comparative advantage could be both significant and hard to predict at their nascent stages. In particular, advanced technologies –many of which are embedded in commercial, rather than military-industrial sectors– offer new and potentially

Soldiers are using drone for scouting during military operation in the desert.

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significant opportunities for defense applications and, in turn, for increasing one's military edge over potential rivals. Finally, such technologies and resulting capabilities rarely spread themselves evenly across geopolitical lines. Around the world, the diffusion of new and potentially powerful militarily relevant technologies –as well as the ability of militaries to exploit potential– varies widely across the region. This unequal distribution will, in turn, naturally affect how these technologies and capabilities may impact regional security and stability. Consequently, it is critical to understand what new and emerging critical technologies are challenging the traditional warfighting paradigm and how militaries might access and leverage these innovations. This entails an examination of the potential military-technical impact of technologies embedded in the 4IR, as well as the means –generally described as 'military-civil fusion'– for exploiting those technologies for military capability and advantage.

Enter the 4th Industrial Revolution

Military acquisitions around the world over the past 25 years or so have been noteworthy in at least three respects: the procurement of larger and/or more versatile platforms, the parallel purchase of more and improved stand-off precision-strike systems, and the acquisition of modern, advanced infrastructures for command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR). This global arms build-up has been more than 'mere' military modernization;

rather, these new types of armaments and pieces of military equipment have significantly upgraded the concepts and conduct of modern warfare. In general, militaries around the world are acquiring greater lethality and accuracy at greater ranges, improved battlefield knowledge with command and control, and increased operational maneuver and speed. Stand-off precision-strike weapons, such as cruise and ballistic missiles, terminal-homing (such as GPS or electro-optical) guided munitions, and particularly the proliferation of armed drones, have all greatly increased the combat firepower and effectiveness of modern militaries (witness Ukraine's ability to blunt invading Russian tank forces with relatively cheap Turkish drones). The addition of modern submarines and surface combatants, amphibious assault ships, air-refueled combat aircraft, and transport aircraft have extended many militaries' theoretical range of action, while advanced reconnaissance and surveillance platforms have considerably expanded the capacities to 'look out' over the horizon and in all three dimensions. At the same time, many of these forces are increasingly equipped with state-of-the-art sensors, combat management systems, and communications. Finally, through the increased use of stealth and active defenses (such as missile defense and longer-range air-to-air missiles), militaries are significantly adding to their survivability and operational capabilities. Overall, therefore, modern militaries are increasingly better at projecting power further out into their nearby ground, maritime, and air spaces, thus expanding their operational footprint. Warfare is becoming faster, more long-range, and yet more precise, and more lethal in its effect.

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In this regard, the 4IR promises to create a new set of promises and challenges in the decades to come when it comes to identifying what are new and significant military capabilities, as well as how these capabilities will create military advantages and therefore political leverage. The 1st industrial revolution began in the late 18th century, and it was an age of steam and iron, exemplified by the first mechanized industry –textiles– and the birth of the railroads. This was superseded in the late 19th century by the 2nd industrial revolution, the age of steel, oil, electricity, the internal combustion engine, and heavier-than-air flight. The 3rd industrial revolution –the digital revolution in which we exist and operate today– began in the 1950s with the invention of the transistor and integrated circuits, which subsequently led to the ubiquity of computers, digital telecommunications, and the internet.

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Now we supposedly stand on the cusp of a 4IR, characterized by AI, machine-learning, man-machine interfacing, automation and robotics, quantum computing, and the "internet of things" (IoT). To this, we may also add other emerging technologies, such as additive manufacturing (i.e., 3D printing), the militarization of the cyber realm, hypersonics, directed-energy weapons, electromagnetic rail guns, and stealth.[9]

Technologies like AI, along with cloud computing, quantum computing, and the IoT, are enabling computers to collect and process vast amounts of data faster than ever before, and then store this data and permit it to be accessed at any time, from anywhere, by someone with internet access. Above all, therefore, the 4IR is about 'connectivity:' permitting the user to retrieve information from a shared and constantly updated network of multi-sourced data processed by artificial intelligence.[10]

Consequently, the 4IR promises to affect military capabilities in several ways. AI could greatly assist humans when it comes to collecting, processing, and interpreting the large amounts of data being collected by these new and more capable sensors in order to help produce actionable intelligence and aid in decision-making. According to Kirchberger, AI and quantum computing could provide the "immense computing power" necessary to interpret large amounts of data coming in from a wide variety of sensors and other resources, as well as enhancing datalinks that would "provide connectivity between disparate units to allow a shared situational awareness –ideally, in real-time or near-real-time."[11]

The 4IR will likely also have a dramatic impact on operational warfighting capabilities. According to Diego Ruiz Palmer, "advances in precision location, targeting and strike, navigation, large data transmission and discrimination, and weapon-system range and maneuverability, as well as the growing importance of the outer space and cyber domains" are collectively altering "the spatial dimensions" of warfare.[12] The 4IR could also enable the development of increasingly autonomous offensive combat systems, particularly armed robotic systems –air, sea, or land-based– outfitted with advanced sensors and driven by AI-enabled decision-making algorithms. Human involvement in such systems' programming might only be required when the use of lethal force needs to be permitted. In addition, AI-controlled drones could operate in large swarms, remotely controlled "by a single soldier using improved man-machine interfaces."[13]

Exploiting the 4IR through Military-Civil Fusion

The advantages of acquiring such advanced military technologies are self-evident. At this juncture, it is critical to note that most research and development (R&D) in the area of 4IR technologies –and therefore the source of most innovation– is overwhelmingly embedded in the commercial high-tech sector. This includes corporate engineering centers, start-up firms, research parks, and private software companies. This trend is particularly apparent in the broad field of information technologies, where critical breakthroughs are primarily made in civilian high-tech industries, including artificial intelligence, advanced computing, big data, robotics, wireless and cellular communications, the internet, and the like. In addition, the vast bulk of all contemporary R&D spending is basically oriented toward civilian applications, and global commercial R&D is around ten times greater than military R&D.[14]

More and more, advanced militarily relevant technologies are increasingly found in the commercial sector. The appeal of such technologies –that is, dual-use civilian-based technologies that have potentially significant applications for military systems– has only grown in recent years. In the first place, they can permit expanded access to new and cutting-edge innovations outside the defense technology and industrial base. They can also expand the prospective national innovation base for military systems, thereby lowering costs for military R&D and better-leveraging R&D funding. Moreover, the successful exploitation of dual-use technologies in the defense sector can help create an "integrated national industrial base" that would inject greater competition into defense contracting, thereby promoting innovation while reducing procurements costs, life-cycle costs, and acquisition times. Finally, they may also provide improved surge capacities (i.e., the ability to ramp up armaments production in times of emergency) and greater overall national economic competitiveness.[15]

Understandably, therefore, there is a growing interest on the part of militaries and governments around the world in harvesting emerging critical 'commercial' technologies –and particularly those technologies embedded in the 4IR– for their military potential. By piggybacking on huge leaps in the commercial high-tech sector, many countries around the globe are actively exploring the militarization of 4IR technologies, especially AI. As such, the value of technologies is no longer simply a matter of their immediate (i.e., commercial) end-use but all their 'potential' uses.[16]

As a result, militaries and governments around the world are increasingly focused on how and where advanced commercial technologies, innovations, and breakthroughs might create new capacities for military power, advantage, and leverage. This process of exploiting such civilian-based advanced technologies for military use is increasingly known

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as military-civil fusion (MCF). Since advanced militarily relevant technologies are increasingly found in the civilian high-tech sector, MCF offers 21st century militaries an essential path to securing a military-technological advantage over their competitors and adversaries. Proponents of MCF, in fact, frequently assert that the "dynamic of innovation" has shifted from the military to the civilian/commercial sector. The 'combination' of MCF and the 4IR, therefore, promises to create a new set of opportunities when it comes to identifying what are novel and significant military-related technologies, how these technologies might create unanticipated, innovative military capabilities and advantages in the decades to come, and how they might be best absorbed in military R&D and armaments production.

MCF differs from traditional concepts of civil-military integration (CMI). Traditional CMI essentially entailed the transfer of commercially developed technologies to military use. One of the best examples is the emergence in the 1960s of a vibrant civilian-based microelectronics industry, generating such innovations as integrated circuits, microprocessors, business, and home computers, commercial software, wireless communications, and the like –advances that were subsequently spun onto military products. MCF, on the other hand, emphasizes the fusion of cutting-edge technologies into military products through joint, civil-military technological collaboration, starting at the earliest stages of products' R&D. The outcomes of these efforts occasionally find their way back to the civilian market after being adapted to the civilian market's needs. In this regard, MCF should be viewed as creating a common "technology well" to which both the military and civilian R&D bases contribute and from which both can draw.[17]

Countries have only recently begun to explore the value of using MCF as a means to 'militarize' the 4IR. The U.S. Department of Defense (DoD), for example, has established several initiatives to exploit MCF, including the creation of a Defense Innovation Unit (DIU), which has the goal of accelerating the U.S. military's early adoption of commercial technology; the DoD has also established the Joint Artificial Intelligence Center (JAIC), whose mission is to accelerate "the delivery and adoption of AI" via a "holistic approach" that includes partnerships with large established technology firms, small startups, and academia.[18] China in 2017 issued its 13th 5-Year Special Plan for Science and Technology MCF Development,

The Kargu rotary-wing striker unmanned aerial vehicle system, was used against Haftar's forces in Libya.

Defense Industry Presidency /AA

which "detailed the establishment of an integrated system to conduct basic cutting-edge R&D in AI, biotech, advanced electronics, quantum, advanced energy, advanced manufacturing, future networks [and] new materials," in order "to capture commanding heights of international competition."[19] At the same time, Beijing created the "Central Commission for Integrated Military and Civilian Development," a new powerful body for overseeing MCF strategy and implementation. For its part, the Israeli Ministry of Defense is especially keen to expand its links to the country's hundreds of start-up companies pursuing 4IR technologies (particularly AI), through government-run authorities (such as the Israel Innovation Authority and MATIMOP, the Israeli Industry Center for R&D), and through informal ties formed by service in the Israel Defense Forces.[20]

Conclusions: The Futurist's Caveats

As 4IR technologies become one of the central paths to military modernization, the ability of states to implement MCF will likely factor more and more in how militaries gain comparative advantages over their rivals. Indeed, the major powers (that is, the U.S., Russia, and China), countries that aspire to be great powers or leading regional powers (such as India, Iran, or Türkiye), and nations that see technology as a critical force multiplier (such as Israel and Singapore) are increasingly interested in assim-

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ilating 4IR technologies into their armed forces. Concurrently, since the early 21st century some of these countries have adopted various measures to promote MCF, which they increasingly regard as an essential means to achieve this goal.

The U.S. is particularly driven by its strategic competition with China (and to a lesser extent with Russia) to embrace the AI-RMA. According to a 2021 report issued by the U.S. National Security Council on Artificial Intelligence, "China is a competitor possessing the might, talent, and ambition to challenge America's technological leadership, military superiority, and its broader position in the world," adding that "AI is deepening the threat posed by cyber-attacks and disinformation campaigns that Russia, China, and other state and non-state actors are using to infiltrate our society, steal our data, and interfere in our democracy. The limited uses of AI-enabled attacks to date are the tip of the iceberg."[21] The Council goes on to argue that "if China's firms win these competitions, it will not only disadvantage U.S. commercial firms, it will also create the digital foundation for a geopolitical challenge to the U.S. and its allies."[22]

At the same time, due to their complexity, some kinds of 4IR technologies, such as highly autonomous armed drones, are unlikely to proliferate widely, at least not in the foreseeable future. The application of the 4th industrial revolution, particularly AI, may turn out to be much slower and more narrowly applied than some might think. Despite the ubiquity of 4IR technologies found in the commercial sector, the challenges to adopting such technologies to military use will likely be much less or take longer than anticipated. One should not expect the 4IR to create revolutionary, 'game-changing' weaponry or military systems that will quickly affect regional or strategic military balances. The 4IR does promise some dramatic new platforms and systems, and developments in AI or autonomous systems could eventually constitute mind-boggling breakthroughs, but these will likely take decades for their impacts to be felt.

In addition, the barriers to the widespread development, diffusion, and exploitation of many 4IR technologies will remain high, especially for smaller or less-financed militaries. In the first place, technologies tend to distribute themselves unequally, depending upon a country's ability to access, absorb, and leverage such know-how. At the same time, there still exists high barriers to spin-on, especially in countries with weak military R&D infrastructures. In fact, many militaries around the world are still stuck in the "metal-bashing" 2nd industrial revolution, and even the digital revolution of the 3rd industrial revolution eludes them. No one should expect the 4IR to quickly affect these countries' military capabilities. The ability to develop and integrate 4IR technologies could therefore remain more or less the purview of larger, more technologically advanced countries. Like the information technologies-driven RMA of the 1990s and 2000s, the AI-RMA could easily become a 'big boys' club comprising just a few countries with both the technology base and the resources sufficient to undertake such a transformative effort.

Nevertheless, less technologically advanced militaries are not necessarily doomed to permanent inferiority. There are many discrete 4IR technologies –such as simple robots, AI, and offensive cyber systems– that could be successfully (and relatively cheaply) plugged into the existing force structures of many small states. Systems such as Unmanned Aerial Vehicles (UAVs) are already being increasingly used to complement or replace manned reconnaissance platforms; and while more innovative types of unmanned systems are so far limited in their deployment, the situation is dynamic and likely to change. Some smaller countries, for example, are already developing indigenous UAVs and experimenting with limited swarming concepts.[23]

In sum, the AI-RMA, powered by the 4IR, promises to be a real paradigm shift in the nature and conduct of future warfare. Consequently, the process of MCF should grow in importance and value as a facilitator of military modernization efforts. This, in turn, means that the traditional configuration of national military-industrial complexes being largely segregated from the rest of the economy is becoming increasingly untenable and even counterproductive. If the technological vanguard is increasingly found in the high-tech commercial sector, then militaries and their traditional arms suppliers will have to adapt. Otherwise, they risk losing access to emerging critical technologies that, in the future, could be the most important determining factors of military power and advantage.

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