Do Advances in Synthetic Biology have the Potential to Transform the Future of Warfare?

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This essay will argue that while advances in synthetic biology may have the limited potential to transform the future of warfare, these technologies do not operate in a vacuum and their use will be constrained and shaped by contextual and political factors. As such, they are less than likely to lead to transformation. This case will be made largely in relation to the body of work surrounding Revolution in Military Affairs (RMA) theory, however, before discussing this proposition in more depth, some qualification of terms is necessitated in order to delineate the boundaries and underlying assumptions of the argument being forwarded. Firstly, regarding warfare, this paper only considers it in relation to more conventionally held notions of the concept – as the means and methods by which war is fought between two organised state military forces. Consequently, this is a much narrower scope of analysis than if one was to adopt even a Clausewitzian definition of war and warfare; importantly, this excludes terrorism from this analysis.[1] Secondly, with regards to the 'future', in order to provide cogent and empirical analysis, the scope of this investigation will be limited to biotechnologies that either exist today or are known to be in development and theoretically feasible.

With the above established, this paper will progress, as follows; firstly, a look RMA theory and how it can be used as a framework to assess if new technologies are potentially 'transformative' will be briefly outlined. Next, a brief definition of synthetic biology will be offered, which will then compliment a discussion relating to how certain exemplar technologies under the synthetic biology umbrella, such as CRISPR and germ line editing, may have utility in warfare. This will then be examined in relation to the wider RMA framework to show that while there may be some novel elements to synthetic biological approaches to biowarfare, there is a need for much scepticism regarding its potential transformative effects on the conduct of future war.

To begin by briefly outlining RMA theory, it is in essence the notion that throughout history, numerous periods of rapid innovations have occurred that have manifestly and irreversibly changed the character of warfare.[2] A classically given (though my no means uncontested), example of such a revolution is the US military's use of precision guided munitions and coordinated fires during the 1991 Gulf War to handily defeat the Iraqi military.[3] This, according to RMA theorists, represented a clear and fundamental shift in how regular armed conflicts are fought.[4] As defined by Krepinevich an RMA, 'Is what occurs when the application of new technologies into a significant number of military systems combines with innovative operational concepts and organizational adaptations in a way that fundamentally alters the character and conduct of conflict.'[5] There are thus three key elements that can be identified to suggest that we may have entered a period of RMA: new technology that has the potential for novel utility, doctrinal and organisational development, and lastly the political will to facilitate and drive changes – these will consequently be grounds on which synthetic biology is assessed.[6] There are however some clear challenges and limitations in adopting an RMA approach that it is important to note.

Firstly, there is the inherent risk of techno-determinism, wherein one places undue weight in the transformative power of technology alone without due consideration of the surrounding doctrinal, political, and social factors.[7] Not all RMAs are driven primarily by technology, Gray for example highlights how there is great difficulty in finding a new technology which drove the RMA that occurred during the Napoleonic Wars.[8] Further, the appearance of new technology does not inherently mean that a RMA will occur, there may well be a time lag or indeed no true RMA at all.

For example, the machine gun existed decades before it played a major role in the RMA of the First World War – again the social, political, and operational environment within which technology exists is crucial in shaping its potential impact on warfare.[9] Lastly, one might rightly question why transformation should be considered via a revolutionary framing and not instead as something more incremental and marked more by continuity than change, as suggested by Biddle.[10] While there is certainly merit to such an argument, it is contended here that an RMA framing provides a good impetus to asses any elements of discontinuity that may emerge as a result of advancements in synthetic biology – rather than focusing on areas of continuity. Moreover, it remains a dominant way of theorising about future transformations in warfare, hence so long as one is mindful of the aforementioned trap of techno-determinism, there is certainly value in continuing to consider synthetic biology under the same light.[11]

With the framework of analysis outlined, the potential ability of synthetic biology to transform warfare can be assessed against the criteria outlined above. To contextualise such an assessment by first briefly outlining what synthetic biology is, while there is no universally agreed upon definition, put simply it is the use of biotechnology to systematically modify or create biological organisms.[12] Alternatively, synthetic biology can be considered to be a series of approaches and tools developed with the aim of making 'the engineering of biology easier and more predictable.'[13] Synthetic biology technologies have numerous applications in medicine and other industries, such as the production of synthetic anti-malaria drugs that can be produced at scale far more easily than their naturally derived counterparts.[14] However, as is the case with traditional biowarfare, the techniques, the knowledge and equipment used in peaceful applications of synthetic biology are dual-use and can also therefore be used for malicious and offensive ends.[15] CRISPR is perhaps one of the most widely known synthetic biotechnologies in general discourse and is a genome editing tool that allows one to make targeted changes to an organisms genome.[16] It serves at a good example of the state of synthetic biology today, for not only has CRISPR undergone rapid development over the last ten years, but has also raised significant biosecurity and ethical concerns regarding the genetic modification of humans.[17]

To then look at the potential military applications of synthetic biology, it is clear that there is without question some possible novel applications and cases where the use of synthetic biology appears to convey advantages over natural biological approaches. Nonetheless, it can for the most part be argued that these technologies augment and amplify existing characteristics of biological, as well as in some cases conventional, warfare. The potential effects of synthetic biotechnologies can be categorised as those that effect the traditional biowarfare landscape as it stands today and those that fall outside of this paradigm which thus can be considered to be more novel. Starting with the more traditional aspect, multiple areas exist where synthetic biology appears to convey advantages over natural biological approaches, namely in predictability, specificity of targeting, potential destructive impact, and greater difficulties associated with defence.[18] Yet, the question remains as to whether or not such advantages substantially change biowarfare? They may certainly make biological programs more effective and as suggested by Petro and others, more attractive to actors.[19] Still, this doesn't mean that the technology on its own necessarily heralds a paradigm shift that completely transforms biowarfare. Taking the hypothetical creation of a new pathogen as an example, if used as a weapon it could in theory be more deadly, cause unusual or novel symptoms and create huge difficulties in post-dissemination mitigation for a defender when compared to a 'conventional' bioweapon.[20] However, the fact remains that if the USSR was to have employed its offensive biological weapons program, it's bioagents still would likely have been highly deadly and hard to mitigate against – the latter particularly true given its focus on producing antibiotic resistant strains.[21] In such a sense, the strategic implications and utility appears unchanged. Further, even the use of modified pathogens that are designed to target certain ethnic genetic markers aren't entirely without historical precedent; in the 1700s, British colonisers deliberately targeted Native Americans, who didn't possess the same levels of immunity as the Europeans, to Smallpox.[22] As such, although undoubtedly adding new capabilities into the contemporary biowarfare landscape, to an extent the potential to develop such pathogens opens up the ability to readopt older biowarfare strategies that were rendered redundant due a more globalised and interconnected world. Notwithstanding, the capabilities outlined here cannot be said to dramatically change or transform the existing character of biowarfare.

However, synthetic biology also has the potential to be utilised outside of the existing biowarfare paradigm which may have transformative impacts on warfare. Specifically, synthetic biology may in future allow for the direct modification of the human physiology and genetic makeup.[23] As Heslop and Macintyre note, the use of CRISPR to edit germ

line cells could have offensive utility but also bring advantages for one's own armed forces.[24] On the offensive side, if operationalizable there is the potential to introduce subtle 'sleeper' genetic modifications into an enemy's population that can be passed on in a hereditary fashion.[25] These modifications could be used to conceivably achieve long-term strategic effects such as introducing ecological weaknesses into enemy populations.[26] This vector of attack is notably different from the use of traditional bioagents given the longer temporal element and that it may be significantly more difficult to identify that an attack has occurred in the first place. Regarding one's own military forces, military advantages could be gained by introducing genetic modifications that seek to improve the performance of one's personnel by making them more resilient to environmental conditions, stronger, more attentive and so forth.[27] This potential application of germ line modification could have implications for warfare writ large, rather than solely biowarfare, given that it may grant qualitative advantages over an enemy unenhanced force and hence increase the likelihood of tactical battlefield successes.

To summarise then, not all synthetic biotechnologies are equal in regard to their potential transformative value. Those which largely interact with the existing biowarfare paradigm, while seemingly increasing the effectivity of biowarfare, do not on their own appear to substantially alter the existing character of warfare but instead augment it. On the other hand, technologies that allow activities like germ line editing, which may be used outside of the existing paradigm, may have identifiable unorthodox strategic utility. However, as highlighted above, technology alone doesn't determine the transformation of warfare and isn't sufficient alone to constitute an RMA. Considering how these technologies are being integrated and used (and importantly if they will actually be used) is vital in answering the question of their potential to revolutionise future warfare. CRISPR and germ line editing for instance have become highly controversial and subject to huge ethical debates, so there may well be political and social limits imposed on its military use and development going forward.[28] Consequently, it is necessary to now consider the other two elements inherent to a successful RMA and the more political elements inherent to the transformation of warfare.

Accordingly, on the topic of doctrinal development, there is very little that can currently be identified across the world's major militaries. There is some suggestion that China sees 'biological dominance' playing a key role in future warfare but it isn't clear what exactly this entails or if indeed the claim is authoritative of its wider strategic positioning.[29] This isn't to say that doctrinal and organisational changes are not occurring or won't be undertake in the future however, given the fact that historically the bioweapons programs of major powers have been incredibly secretive and can be kept so due to the dual-use nature of the technologies involved.[30] The USSR was able to keep its Biopreparat program secret throughout the Cold War by disguising it in civilian attire for instance.[31] As such, there is very little to empirically draw from on this front. What this may suggest is that we are not currently experiencing an RMA – but not that one won't come in the future.

Nevertheless, with the above being said while there may not be any clear indications of doctrinal development to support it, there is clear, current, and sustained interest and investment across the world in researching the military utility of synthetic biotechnologies – these however may not be for offensive biowarfare purposes. As noted by Malet, the US Department of Defense did not only establish in 2014 a Biological Technologies Division at the Defense Advanced Research Projects Agency (DARPA) but in 2002 pushed for looser regulations surrounding the deployment of experimental biotechnologies on the battlefield.[32] China as well appears to have placed significant emphasis on biotechnological development, particularly into continued research into CRISPR and the viability of genetic biowarfare agents.[33] Resultantly, it is clear that there is substantial investment is building biotechnology capabilities from the world's major military actors. Hence, it is not outlandish to suggest that given the obvious interest, the possibility for an RMA to occur does potentially exist. This is however contingent on state actors actually choosing to adopt offensive bioweapon programs.

Lastly then, to consider the political element, it is vitally important to highlight that possessing a capability isn't the same as using it. Despite the long history of biowarfare and weaknesses inherent within the Biological Weapons Convention, there is an international norm against the use of biological agents in war.[34] There is no question that states have engaged in biowarfare over the last century – during the Sino-Japanese conflict Japan deliberately spread the plague in China.[35] Despite this, the norm at least against the use, though not development, of bioweapons established by the US abandonment of its bioweapons program has held over the course of the Cold War and 'has become near universally accepted'.[36] As contented by Cross and Klotz, despite the clear potential of

emerging technologies to allow for the augmentation of biowarfare capabilities, there doesn't appear to be any clear current intent for actors to contravene these norms.[37] Should the norm hold strong into the future as currently appears likely, the use of synthetic biology in offensive biowarfare applications appears to be constrained.. It may be the case that non-offensive technologies such as human bio-enhancement via germ line editing have a greater chance of impact, though this remains difficult to judge given these approaches remain in their infancy.[38] It could therefore be considered that a real transformation in future warfare would occur because of an erosion of norms, not because of advances synthetic biology. As such, transformation in this case is not contingent on developing technologies, but instead very much in the continued international salience of the political boundaries around the deployment of *all* offensive bioweapon technologies – new or old.

To conclude, this essay has shown that while certain advances in synthetic biology may have the potential to become part of a future RMA and thus transform the character of warfare – this is by no means concrete or the most likely scenario. Firstly, not all the effects synthetic biology will have on biowarfare when considered on their own are transformative or novel; the creation of more virulent virus doesn't completely transform the threat. While some aspects of genetic engineering have been identified as potentially having novel strategic utility, these technologies are still in early development, and it is not yet clear how or if they will be employed. Moreover, while there may be significant interest and investment into biotechnological research by major military powers, ultimately the norms constraining the use of biological agents in war – should the hold into the future – will to a great extent limit the use of any offensive capabilities' states do come to possess going forward.

End Notes

[1] Carl von Clausewitz, *On War*, trans. Michael Howard and Peter Paret (Princeton, Princeton University Press, 2007), p. 60.

[2] Colin S. Gray, *Another Bloody Century* (London, Weidenfield & Nicolson, 2005), p. 122.

[3] Stephen Biddle, 'The Past as a Prologue: Assessing Theories of Future Warfare', *Security Studies* (8:1, 1998), p. 1.

[4] *Ibid*.

[5] Andrew F. Krepinevich, 'Cavalry to Computer: The Pattern of Military Revolutions', *The National Interest* (37, 1994), p. 30.

[6] Gray, *Another Bloody Century*, pp. 113-114.

[7] *Ibid*, p. 153.

[8] *Ibid*, p. 122.

[9] Andrew L. Liaropoulos, 'Revolutions in Warfare: Theoretical Paradigms and Historical Evidence', *The Journal of Military History* (70:2, 2006), p. 380.

[10] Biddle, 'The Past as a Prologue', p. 11.

[11] Gray, *Another Bloody Century*, pp. 151-153.

[12] The National Academies of Sciences, Engineering & Medicine, *Biodefense in the Age of Synthetic Biology* (Washington DC, The National Academies Press, 2018), https://www.ncbi.nlm.nih.gov/books/NBK535877/ (Accessed 10/10/21), p. 11.

[13] Royal Academy of Engineering, *Synthetic Biology: Scope, Applications and Implications*, (London, Royal

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[14] *Ibid*.

[15] James Petro, Theodore Plasse and Jack McNulty, 'Biotechnology: Impact on Biological Warfare and Biodefence', *Biosecurity and Bioterrorism* (1:3, 2003), p. 161.

[16] The National Academies, *Biodefense in The Age of Synthetic Biology*, p. 18.

[17] D. J. Heslop and C. R. Macintyre, 'Germ Line Genome Editing and the Emerging Struggle for Supremacy in the Chemical, Biological and Radiological (CBR) Balance of Power, *Global Biosecurity* (1:1, 2019), p. 169.

[18] Petro and others, 'Biotechnology', p. 164.

[19] *Ibid*.

[20] The National Academies, *Biodefense in The Age of Synthetic Biology*, p. 56.

[21] John Hart, 'The Soviet Biological Weapons Program' in M. Wheelis and others (eds), *Deadly Cultures: Biological Weapons Since 1945* (Cambridge, Harvard University Press, 2006), p. 143.

[22] Filippa Lentzos, *Biological Threats in the 21st Century* (London, Imperial College Press, 2016), p. 4.

[23] The National Academies, *Biodefense in The Age of Synthetic Biology*, p. 4.

[24] Heslop and Macintyre, 'Germ Line Genome Editing and the Emerging Struggle for Supremacy', pp. 170-171.

[25] *Ibid*, p. 171.

[26] *Ibid*.

[27] *Ibid*.

[28] David Cyranoski, 'The CRISPR-Baby Scandal: What's Next for Human Gene-Editing', *Nature* (26/02/2019), https://www.chicagomanualofstyle.org/tools_citationguide/citation-guide-1.html (Accessed 26/11/2021).

[29] Elsa Kania and Wilson VornDick, 'China's New Military Biotech Frontier: CRISPR, Military-Civil Fusion, and the New Revolution in Military Affairs', *Jamestown China Brief* (19:18, 08/10/19), https://jamestown.org/program/chinas-military-biotech-frontier-crispr-military-civil-fusion-and-the-new-revolution-in-military-affairs/ (Accessed 24/11/2021).

[30] Matteo Habian, 'A Threat Assessment of Biological Weapons', in James Grow and others (eds),*Routledge Handbook of War, Law and Technology* (Milton Park, Taylor & Francis Group, 2019), p. 237.

[31] *Ibid*.

[32] David Malet, 'Captain America in International Relations: The Biotech Revolution in Military Affairs',*Defence Studies* (15:4, 2015), p. 322.

[33] Kania and VornDick, 'China's New Military Biotech Frontier'.

[34] Habian, 'A Threat Assessment of biological Weapons', p. 237.

[35] Friedrich Frischknecht, 'The History of Biological Warfare', *EMBO Reports* (4:1, 2003), pp. 47-48.

[36] Glen Cross and Lynn Klotz, 'Twenty-First Century Perspectives on the Biological Weapon Convention: Continued Relevance or Toothless Paper Tiger', *Bulletin of the Atomic Scientists* (76:4, 2020), p. 185.

[37] *Ibid*.

[38] Malet, 'Captain America in International Relations', p. 332.

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