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Nano and Micro Drones

Nanotechnology in Warfare - Some Ethical Concerns
The greatest investment in nanotechnology is being made by the military. Is there anything good that can be said about the future of defence where nanotechnology is playing a major role?

A Comprehensive Guide to Biologically Inspired Micro and Nano Air Vehicles
Mechanical birds, insects, spiders and snakes – How scientists are copying nature to create the drone army of the future

The Tools of Nanomedicine
The new tools and techniques which are helping understand the causes of disease at the cellular level, leading to vastly improved treatments

Plus the latest news about nano for medicine, society and industry

NANO AND THE MILITARY

Resources channelled into military research is not always considered the most palatable way to spend money, when there are many societal ills that are in desperate need of solutions, and where most things military tend to create many more problems than they solve.

Ottilia Saxl, Director, NANO Magazine

In this issue, Daniel Moore, as well as working as a research scientist with IBM, is Director of the Nanoethics Group and Fellow of the Hybrid Reality Institute, so he comes to the nanoworld from a position of knowledge. In this issue, he discusses the **ethical issues in relation to the deployment of nanotechnology** as another weapon in the science arsenal of the military. He argues that of course the intended outcome of all military engagements are death and destruction, but also there is the possibility that nanotechnology can make soldiers safer, because of targeting, can reduce collateral damage and using smart techniques to disable systems, lessen the time to returning vital services such as water supplies back to normal.

Much in evidence in the news over the last few weeks and months is the development of a variety of smaller and more versatile **micro and nano unmanned robotic machines**. These have been in the main funded for their military potential – small unobtrusive objects that can gather intelligence in many situations regarding troop deployment, sense potentially toxic environments and even whether an enemy lurks unseen behind a doorway. The burgeoning of these small machines – not limited to being airborne - as scientists have emulated spiders, snakes and beetles in their quest to create miniature controllable battalions. Much work has also been focused on 'arming' living creatures with sensors and cameras. Recent developments in the field of these micro and nano 'vehicles' is reviewed at length in this issue. There is a peace dividend in this fascinating work, as unmanned miniature robots will have many applications in saving lives where there has been some natural or other catastrophe, for example, in finding people buried in earthquake zones, or trapped in house or forest fires.

Developments in nanomedicine are always of interest, but these new developments are not possible without the latest tools and techniques for investigating the early manifestations of disease. We include an article on the **mechanics of nanomedicine**, which reviews the many exciting tools that are revolutionising the study of living cells, and through a better understanding of disease are enabling many new therapies.

Finally, we also have a short article reviewing the benefits that nanotechnology offers the **packaging industry**, and why that industry and its customers are more accepting of arguably what is a controversial new technology.

A huge amount is happening in the nano world, and NANO magazine is seeking news and articles that would be of interest to a broad community of readers.

Contact us at editor@nanomagazine.co.uk if you believe that some nano breakthrough, innovation or development deserves a wider audience.

Nanotech in Warfare

Some Ethical Concerns

Daniel F. Moore, Ph.D.

Warfare and military development have always been wrought with ethical concerns. The most obvious and familiar example of this is the introduction of atomic weapons; where the ethical debates continues to rage even now, more than sixty years after the invention of nuclear weapons and their deployment.

This debate has not limited itself to nuclear weapons, but has also extended to other forms of nuclear technology. In the US, nuclear concerns have led to a very strong antipathy towards building nuclear energy facilities, despite their ability to provide electricity free of oil or coal. To some, these concerns were played out in the disaster at the Fukushima Daiichi nuclear reactor following the earthquake and tsunami in March, 2011.

In this article I will examine some of the broader questions related to the ethics of another emerging and possibly as threatening technology, nanotechnology, in relation to military applications and its implications for society.

Looking back at the history of military technological introduction, it is possible to examine at what effect the introduction of new technologies has had on warfare and the military and draw some lessons for what may come with the introduction of various nanotechnologies. The first lesson is that a sudden, complete overturning of the current world system of states (with several non-state actors) is unlikely. The other end of the spectrum is equally unlikely. This camp says that nanotechnology will bring about an end to fights about resources, food, and other things that states go to war over and, thus, bring about peace. However, with this, it would be wise to remember the words of former international relations professor Hedley Bull, who said that although states at peace is thought of as the alternative to states at war, the typical alternative is "more ubiquitous violence."[1] Bull's warning was written in 1977, and history before and since tends to confirm this statement.

It is useful then to look at what impact new nanotechnologies might have on these acts of violence, whether by a state or not. Many of the technologies are protective in their nature, such as toxic atmosphere sensors, improved body armour and pharmaceutical delivery systems, etc.; they help reduce death rates in combatant sand occasionally civilians. Other nanotechnologies make precision guidance of weapons more accurate leading to higher fatalities.

What these add up to is quite interesting. New technologies, of which nanotechnology leads the way, can make war and violence easier, more remote and less costly to participate in from an offensive point of view. Fewer soldiers die because of advance in protective and medical technologies. Arguably, fewer civilians might be injured because of population-wide protection. A lower percentage of individuals is involved in the military because more precise and destructive weapons require less ground troops. Because of the higher precision of the weapons, the costs could possibly

be less on the defending side as well. So-called "collateral damage," from which states tend to shy away, can be minimized. Weapons can be made that strike only one building and do it with accuracy and precision, though reduction in collateral damage is unfortunately not always an objective. So, war-like acts are easier to inflict on enemies from a nanotechnologically-enabled society.

it easier and therefore more likely to enter wars and conflicts, given that technological superiority will reduce casualties on the technologically superior side, i.e., make war more risk free.[3] Taking a strong stance against these technological advancements would rule out not only the introduction of new weapons but possibly also incremental improvements in, say, personnel armour

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However, it has also happened that the societies in which the vast majority of nanotechnology research and development is being done have a low tolerance for casualties in military actions. With nanotechnological developments making it easier to protect, defend, and otherwise shield soldiers and populations from taking casualties (and making casualties more rare), this tolerance might become even lower. This lessens the likelihood that long, drawn out, high-casualty military actions will be tolerable to the population of a nanotechnologically advanced nation. By its nature, prognostication is imperfect, but combining these last two probabilities, it seems likely that "small wars" in which technologically advanced nations perform "police actions" on less-developed regimes could become more and more frequent, because of nanotechnology.

This, then, raises challenges to the Just War tradition, that entering and fighting a war is morally justified only under certain conditions, such as in self-defence and when combatants can be discriminated from non-combatants (which rules out weapons of mass destruction, nano-enabled or otherwise).[2] Specifically, and as noted by other ethicists but in the context of other technologies, innovations such as nanotechnology may make

and even better battlefield medicine. Offensive or defensive tools could also not be improved upon, because they would make it easier, politically if not also economically, to engage in armed conflict, and this is presumably undesirable. On the other hand, if armed conflict is an inevitable fact of the human condition, then it is difficult to blame defence organizations for developing new strategies, tactics, and tools that minimize civilian and combatant lives.

Even if nanotechnology systems for military use are developed for purely defensive reasons, this can have a destabilizing impact on relations between great powers. In recent history, there are examples of the development of apparently 'purely' defensive systems causing much concern to another nation. An example of this can be seen in Russia's (previously as the Soviet Union) desire to stop the development of a missile shield by the United States and other western powers. An increase in 'defensive' weapons upsets the status quo between states and, as such, they become objectionable to the powers that are using the technologies rendered obsolescent by them. In much the same way that new 'offensive' weapons that render 'defensive' technologies obsolete can upset a security balance, so too can new 'defensive' technologies that render 'offensive' weapons obsolete upset a security balance. Changing the balance of power of weaponry can have wide reaching implications in international relations, even when it is towards the defensive end. More powerful defensive weaponry can protect a citizenry from attacks, but an enemy that finds itself extremely resistant to attacks will feel at greater liberty to act in a belligerent manner.

The international stage is not the only impact that a nanotechnological revolution in the military will have on society. It seems likely that the amount of health and mental care needed to be provided to members of the armed services will increase. As nanotechnology allows for stark increases in the ability to save a life, injuries that once were life-threatening or led to a certain death become treatable. Illnesses and chemical attacks become less threatening. Further, a much higher percentage of soldiers will live through military actions and will, as such, be in some need of psychiatric care. Furthermore, it seems likely that as medical nanotechnology is able to fix more problems, more, newer problems will be manifest and be in need of treatment. Tailoring each treatment to individual patients based on their DNA and their environment again increases the actual care (though perhaps not the time) that each patient needs. Another issue that needs to be considered is that of a population that has an increasing amount of members who volunteered to serve in the military. When the chances of death are lessened on one side, the idea of military service becomes more attractive and a greater percentage of the population will have an interest in military training.

In conclusion, nanotechnology offers significant opportunities to revolutionize warfare in many different ways, both offensively and defensively. These changes, as with all technological changes, will have a wide ranging impact on warfighting and provide opportunities to reconsider many ethics of war and international relations issues that depend on underlying technology. I have considered a few of those wide-reaching issues here and a method rooted in historical examination that can be used to provide a sense of the challenges and promise that the world will face.

Nano-enabled Defence Systems

Defence and protection of its citizens from undue harm are, ostensibly, primary functions of any government. Nanotechnology in defence and protection spans a wide range of applications, not just for individuals, but for societies as a whole. One aspect of defence is border protection. Border protection includes not only standing guard at borders and regulating which individuals may enter into a particular country, but also controlling ports and scanning cargo to make sure that harmful chemical or biological species are prevented from entering. It involves quarantining possible contagious diseases, which means effective testing, and it involves performing these tasks with minimal interruption to the commercial and personal interests of the citizenry.

Defence also involves protection from other threats against the populace. This is not limited to invasions by foreign armies. Threats can be as simple as anthrax powder delivered through the mail or a radiologically-enhanced "dirty bomb" exploded from inside of a suitcase. These threats are not always foretold by a warning and they require diligence and constant monitoring. In an open and free society, it is also required that this monitoring occur with minimal disturbance to the populace and with minimal invasion into individual privacies and liberties.

Nanotechnology can provide this capability with technologically advanced environmental, chemical, and biological sensing. The smaller size of nanomaterials allows for a faster response time and greater sensitivity, due to the increased surface-to-volume ratio of nanomaterials. Furthermore, the unobtrusive size of nanoscale sensors also allows for their placement in unique locations without significant disruption. In theory, a sensing network could easily be placed, for example, on traffic signals or lampposts throughout a city, and capable of communicating a chemical fingerprint of locations throughout the city. With proper monitoring, this information could be used to detect real time chemical and biological threats. Furthermore, it could be used to provide first responders to chemical and biological attacks with the information that they need to properly outfit themselves. With the threat of biological, chemical, or "dirty" bomb attack, this type of technology can provide for quicker detection of harmful species and, therefore, a much quicker and more effective response.

Public infrastructure protection is another major sphere of homeland defence. For example, water treatment centres are a potential "weak link" in the homeland defence system. As has been noted, they represent a significant target for dispersing harmful chemical species. Nanoscale sensors and filters that allow only "desired" chemical and biological species through provide a possible solution to this problem. This can be accomplished in a number of ways. First, magnetic nanoparticles could be functionalized to adhere to certain harmful chemical species. The magnetic nanoparticles could be placed early in the filtration system and then removed later with a magnet, thus removing the chemical threat. Another way of achieving more effecting filtering would be to use nanoporous materials. These are materials that act as sieves, filtering out harmful molecules.

Nanotechnology can also offer greater defence in the field of electronics. The danger of an electromagnetic pulse (EMP) is one that is very difficult to shield against completely. Most shielding that provides some protection for electronics also results in a significant loss in performance of what is protected. However, there is reason to believe that optical computing, DNA computing, and other nanotechnology-based computing options are more naturally resistant to EMPs. All-optical computing has the added benefit of being of being less sensitive to electronic eavesdropping. Because the optical signal is confined to a fibre more tightly than an electronic signal is truly confined to a wire, it is more difficult to eavesdrop using external equipment.

"Nanotechnology can provide this capability with technologically advanced environmental, chemical, and biological sensing."

References

1. Hedley Bull, The Anarchical Society (New York: Columbia University Press, 1977), p. 179.

2. See, for example, Michael Walzer, Just and Unjust Wars: A Moral Argument with Historical Illustrations, 3rd ed. (New York: Basic Books, 2000).

3. See, for example, Rob Sparrow, "Killer Robots", Journal of Applied Philosophy, Vol. 24, No. 1 (2007), pp. 62-77.