Considering Military and Ethical Implications of Nanofactory-Level Nanotechnology

Brian Wang*

This essay looks at some existing trends in military capability and technology development, and considers the impact of nanofactory-level nanotechnology (NN). A nanofactory[1] is a proposed manufacturing system that could be built if molecularly precise manufacturing technology is developed. Current projections indicate that a nanofactory should be able to fabricate its own mass of advanced products—including duplicate nanofactories—in just a few hours.

Assumptions of this essay

The development of a nanofactory seems to be between five and fifteen years in the future. If there is a secret nanofactory development program, then nanofactories might be produced at an earlier date. The impact of an introduction of nanofactory capabilities will be considered for the 2011 to 2025 timeframe. Artificial intelligence with human or better performance across a broad range of functions could in theory speed development of nanotechnology, but this is assumed to come *after* the nanofactory, because it is assumed that nanofactory-level technology likely would be needed to successfully reverse engineer the human brain.

Safe leads, and who will get it first

Any non-US developer of a nanofactory will have to either develop systems that overcome the current US lead in conventional and non-conventional capabilities, or develop new tactics that circumvent those capabilities. NN could make large amounts of current weapons systems obsolete. For the US, superiority would have to be maintained by pressing ahead with nanotechnology development, because former advantages may be no longer be decisive. Although game-changing shifts in military technology advantage are historically infrequent, the costs and required technology base for developing NN are widely available in the world. It is not assured that any one country will reach game-changing capabilities first.

* E-mail: blwang@gmail.com.

1 Phoenix, Chris (2003) "Design of a Primitive Nanofactory" http://www.jetpress.org/volume13/Nanofactory.htm.

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Also, nanofactories are not a finish line for technology. Nanofactories could massively accelerate the pace of research and development.[2] Precise designs could be produced and tested in hours. The cost of production will be almost equal to the cost of generating a prototype. Currently the United States spends billions of dollars and takes about five years to create one prototype of a new fighter jet. In the first months of the project, there are multiple detailed fighter jet proposals, which are then reduced to the compromise that is developed. In the age of nanofactories, multiple design teams with superior computer assistance could generate many more detailed proposals, and all of them could be built for little additional cost and effort and compared in competitive showdowns. This change in the rate of development will enable leapfrogging shifts in capabilities.

Some existing and expected capabilities by 2025 even without nanotechnology

The following is a summary of existing and expected technologies. Many people do not fully understand the power of current technology or the pace of technological progress. Military technology, surveillance, computers, and other technologies are already very powerful and becoming more powerful. The capabilities listed in this section, which are projected to exist in the 2011–2025 timeframe, are those that currently are being funded and appear likely to be successful.

Precision-guided munitions provide one of the most important existing capabilities.[3] Precision munitions lets the military destroy whatever can be identified as an important target. This places importance on airspace domination to allow the munitions to be delivered. Accurate military intelligence and electronic sensing are needed to identify and locate targets in real-time. In World War II, an average of 9000 bombs were needed to destroy a specific target; now it usually takes only one or two. A month-long mission that used to require 30 sorties with 100 airplanes can now be accomplished with a cruise missile fired from 1500 miles away, and the target will be destroyed in three hours.

The United States has a $2 billion UAV (unmanned aerial vehicle) annual budget[4] and possesses a large and increasingly wide variety of UAVs. Some are as small as insects, but they can be as large as supersonic fighters and bombers. Unmanned aerial vehicles will enable their users to conduct more capable and flexible military operations that do not have the political risk of loss of military personnel. The trend towards unmanned military vehicles also is progressing in ground vehicles.

Standard computers should continue to follow Moore's law[5] for improvement and would be about 1000 times more powerful than today by 2020. The potential developments can be summarized as a tenfold increase in capability in most military systems and a thousandfold increase in computing capability.

[2] Phoenix, Chris (2005) "Fast Development of Nano-Manufactured Products" http://crnano.org/essays05.htm#7,July.

[3] Hallion, Richard P. (1995) "Precision Guided Munitions and the New Era of Warfare" http://www.fas.org/man/dod-101/sys/smart/docs/paper53.htm.

[4] http://www.military.com/features/0,15240,87318,00.html, The FY-07 budget request includes $1.7 billion for UAV buys and research programs and $9.9 billion between FY-08 and FY-11.

[5] http://en.wikipedia.org/wiki/Moore%27s_law, "Moore's Law" formalizes the empirical observation that, at the present and continuing rate of technological development, the complexity of an integrated circuit, with respect to minimum component cost, will double about every 18 months.

Production revolution and product performance in the age of nanotechnology

One product of a nanofactory is another nanofactory (though security restrictions may limit this capability in deployed versions). This enables exponential manufacturing. The first tiny lab-built device can be made to build a system with two integrated devices, which can work in parallel to build four, and in just a few months can build a full-sized nanofactory. Less than a month after that, millions of nanofactories could produce thousands of tons of products (including more nanofactories) per hour.

Products of nanofactories will be high performance: small precise machines are more powerful than large ones—perhaps a million times more powerful, when shrunk to the nanoscale—and precise materials may be a hundred times stronger than today's best.

Nanofactories will be capable of general-purpose manufacturing: because structures will be made additively from tiny precise building blocks under automated control, simply changing the program (blueprint) will change the product. A wide range of components and products will be possible, including computers, sensors, motors, and displays.

Automated nanofactories will reduce direct manufacturing costs drastically. Carbon-based feedstocks are inexpensive. Services, design work, and intellectual capital costs would become the main drivers of overall costs and pricing.

Nanofactory-level nanotechnology would bring 100 to 1 000 000-fold increases in militarily relevant capabilities. Systems could become both cheaper and more functional, to an extent that would make a game-changing difference. Sufficiently advanced systems could have an overwhelming advantage over less advanced systems; for example, an essentially unlimited manufacturing capacity combined with fully automated battlefield weapons implies near-certain destruction of all soldier-based forces.

Surveillance and data mining from now into the age of nanotechnology

Nanofactories will make computers millions of times faster and more powerful than traditional computers. What can you get with this capability? ECHELON[6] is a highly secretive world-wide signals intelligence and analysis network run by the UKUSA Community. It is estimated to intercept 3 billion communications per day. A similar nanotechnology-enhanced system would be able to intercept many more messages and perform more detailed analysis on the messages. Ten times more capability could be obtained for 100 000 times less money. Instead of a single billion-dollar project producing one machine, there could be thousands of $10 000 Echelon workstations and even $100 portable Echelons. Such a powerful state-run surveillance capability could profoundly impact civil rights.

Smart dust[7] is a hypothetical network of tiny wireless microelectromechanical sensors (MEMS), robots, or other devices installed with wireless communications, which can detect

6 http://en.wikipedia.org/wiki/ECHELON, http://cryptome.org/echelon-nh.htm, ECHELON is a highly secretive worldwide signals intelligence and analysis network run by the UKUSA Community. ECHELON can capture radio and satellite communications, telephone calls, faxes and e-mails nearly anywhere in the world and includes computer-automated analysis and sorting of intercepts. ECHELON is estimated to intercept up to three billion communications every day.

7 http://en.wikipedia.org/wiki/Smart_dust.

anything from light and temperature to vibrations. Work on smart dust is ongoing at the University of California. Nanofactory-level nanotechnology would enable smart dust that is orders of magnitude more compact and with vastly improved functionality.[8] The improved sensing ability of nanotechnology-enabled smart dust and nanotechnology-enabled UAVs will revolutionize the military ability to identify and locate valuable opposing assets in real time. An arms race to make stealthy smart dust, smart dust detectors, and smart dust hunter-killers may be inevitable. One thousand times cheaper smart dust of similar capability would be the expectation from Moore's law. Today, a smart dust device costs about five dollars and has 32 000 bytes of memory. In 2025, standard advancement would provide the same device for half a cent. Four hundred million smart dust devices, one for every person in the United States, would cost just $2 million. Each device could record 80 bytes of information every day for a year.

Nanofactories could increase capabilities by a million times *beyond* that. The gain could be split between lower cost and higher performance: devices could be a thousand times cheaper and a thousand times more capable. The same $2 million referred to above could buy 400 *billion* devices. These could be distributed: two on each person in the world, eight for different locations that the person goes to or vehicles in which they travel, and 40 on different objects or animals that they possess. The improved devices would have 32 MB of memory and correspondingly more processing power and sensors. They could record video, audio, act as biosensors, and use better processing to discard redundant information. Information could be pooled to know which objects and people are together at different times. The history of any object or person could be tracked. Who and what were you with? What were you saying? How were your heart rate and blood pressure? Your mood? Your facial expressions and gestures? What was the weather? Did you have your dog, your wallet, your car keys, a gun hidden in your clothes? Did you swallow a balloon filled with contraband? Detailed records of 1600 bytes could be recorded every half hour for a year or every six seconds for a day.

Nano-enhanced smart dust also could be weaponized. A person who offended any of the 100 different groups using smart dust to track them could be killed when the smart dust was activated to release a toxin. Even without nano, a future smart dust could have this capability, but the nano-version would be some combination of cheaper, more flexible, and more capable, enabling those who control the smart dust to eliminate or control exactly whom they want under precise parameters. This could be part of a system of super-oppression.

Destroying the world in the age of nanotechnology: offense is stronger

A 100 kg nanofactory-built combat drone could be supersonic[9] and have the destructive capability of a modern fighter jet. Nanofactories could produce billions of these drones in a few months. Several could be targeted at every person on the opposing side of a military conflict. Genocide will become cheaper and easier. Image processing and sensors could also allow a more selective targeting.

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8 "Sensor networks for Dummies" *MIT Technology Review,* March 17, 2006 http://www.technologyreview.com/InfoTech/wtr_16607,300,p1.html.

9 http://www.post-gazette.com/pg/06038/651627.stm, One small step for drones: Lockheed leaps into unmanned plane market, Feb 2006. (Falcon is a conceptual drone bomber that would fly at Mach 9 near the edge of the atmosphere.)

It appears that offensive military capabilities will improve faster than defensive capabilities, especially since nanofactories would revolutionize access to space and the ability to utilize space-based resources.[10] Nanofactory-built launch systems with widespread use of diamond and carbon nanotube material would enable $1-10/kg launch costs by reducing the mass and construction cost of vehicle and systems.[11] Nanofactories could create space vehicles with ion drives with 700 kWe/kg specific power, 1000 km/s exhaust velocity and 10 m/s^2 acceleration. This would be an early capability provided by very significantly enhancing current designs with better materials and molecularly-precise construction.

The enhanced space systems that nanofactories can create will provide ease of movement in and around the solar system. For military purposes, space vehicles could divert and accelerate asteroids and comets at the earth and other targets.

These vehicles could position themselves near a space rock (1 000 000 tons or more) for months or years and divert large ones that would have passed near the earth so that they impact the earth. Even huge killer comets could be diverted.[12] This comet-diverting capability would have power orders of magnitude in the attacker's favor. It could be used as a second strike capability[13] for mutually assured world-destroying capability.

The defender would need a comet shield[14] that works even if there are intelligent forces actively working to make the defense fail. Most plans for comet defense depend on detecting a comet that will hit the earth early enough to nudge it out of the way. Second strike crews deliberately nudging whatever they can onto earth collision courses would makes defense a lot more difficult. Attackers with space rocks have a huge advantage.

Large-scale space bombardment with large objects could be considered a doomsday response. This could actually be stabilizing: if certain powers have doomsday options, their enemies might back off from attempting to wipe them out. This does not address small-scale conflicts that do not trigger a doomsday response. It is unclear whether smaller incoming objects could be deflected or destroyed; objects too small will be destroyed in the high atmosphere, and it may not be possible to accelerate intermediate-sized objects to sufficient speed to evade destruction. If intermediate-scale space bombardment turns out to be a feasible offensive technology, it could deliver energies comparable to thermonuclear warheads.

Nations and alliances either possessing or on a path to develop significant space programs are the United States, China, Europe, Japan, Russia and India. Nanofactories would greatly enhance space capabilities.

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[10] McKendree, T. L (2001) "A Technical and Operational Assessment of Molecular Nanotechnology for Space Operations," Ph.D. Dissertation, Industrial and Systems Engineering Dept., University of Southern California.

[11] http://www.zyvex.com/nanotech/nano4/mckendreePaper.html, Implications of Molecular Nanotechnology Technical Performance Parameters on Previously Defined Space System Architectures.

[12] Hammerschlag, Michael "It's the End of the World as We Know It" http://members.surfbest.net/mikehammer/endword2.htm.

[13] http://en.wikipedia.org/wiki/Second_strike, In nuclear strategy, second strike capability is a country's assured ability to respond to a nuclear attack with powerful nuclear retaliation against the attacker.

[14] http://spacewatch.lpl.arizona.edu/faq.html; http://en.wikipedia.org/wiki/Asteroid_deflection_strategies.

On deterrence

The maximum deterrence you can have is the ability to kill all of your enemies and destroy everything they care about. (Enemies who do not care about dying may not be deterred even by this.) Deterrence does not require this ultimate level of harm; deterrence of a rational opponent requires only being able to cause more damage to them than their gain from attacking you. China has relied upon that level of deterrent for the last 30 years. Useful discussions of deterrence levels can be found at various websites.[15]

Being weaker than an opponent that is evil can be a very dangerous position. A surprisingly small advantage can be exploited for genocide. The Hutus, armed with machetes and guns, killed 937 000 Tutsis and moderate Hutus. However, an imbalance of power does not mean that war or genocide is inevitable. One side or the other will always have an advantage. Motivation is a key determiner of conflict, and, as described in the following section, advanced nanotechnology can reduce incentives for war.

Deterrence may not work if one side miscalculates the effectiveness of the deterrence of the other side. If an aggressor underestimates an opponent's defenses or willingness to resist, they could mistakenly start a more costly conflict than intended. More accurate knowledge may prevent such miscalculation between rational opponents. However, a strategy of providing misinformation and confusing information could be followed by a weaker power to confuse an opponent who needs good information and a clearer cost-benefit calculation before acting.

Ethics, shifting motivations, and rational calculations in the age of nanotechnology

The powerful technologies that are being developed could rapidly shift military balances of power. Nations cannot assume that their existing weapons inventory provides assured security. A lead in current technology, even current nanotechnologies, does not guarantee a lead with molecular manufacturing. The future balance of power will be determined by a nation's level of development with advanced nanotechnology, as well as space capabilities and other new technologies that will be augmented by nanofactory technology. Nations without a molecular manufacturing capability will be at the mercy of opponents with the technology.

Nanotechnology can shift the motivations and rational calculation for war. For example, if nanotechnology makes a nation's economy grow at 25% per year, then in three years that nation will have twice as much stuff; they would have less incentive to attack an equal size opponent and try to take their stuff. Attacking an opponent brings in elements of risk and cost. With such large gains in the near future, rational groups should not want or need to engage in violent conflict for economic gain. Other differences between groups that lead to conflict need to be addressed to prevent violent conflict.

Genocide and super-oppression become technically easier with nanotechnology. Therefore, it is more important than ever for all people to work together toward peaceful resolution of differences and to keep those who would try to initiate atrocities in check. The economic bounty and other benefits[16] that nanotechnology could provide should be used by farsighted nations to reduce the motivations for conflict.

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15 http://en.wikipedia.org/wiki/Category:Nuclear_strategies.

16 Center for Responsible Nanotechnology (2003) "Benefits of Molecular Manufacturing" http://www.crnano.org/benefits.htm.

About the author:

Brian Wang has a degree in computer science and an MBA and has worked in the information technology industry for 20 years. He created and ran his own professional services computer consulting company with offices in Canada and the United States, and with clients in the USA and Europe. In addition to being a CRN Task Force participant, Brian has been a Foresight Nanotechnology Institute senior associate since 1997. He is also on the advisory board of the Nanoethics Group.