Molecular Nanotechnology and the World System

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Introduction

The fate of the world is determined by our actions and decisions, and many of the most profound decisions and actions are made by the largest of actors: states. The range of possible behaviors for states is partly delineated by the relations among them, as each state must always act in a world of other states. Kingdoms, republics and empires have risen and fallen over the millennia, their fortunes determined at all points by their store of power (1), and by their ability to use it in the world in which they acted. There are many sources of power, and the relative value of those sources to a nation has fluctuated historically. At one time, a nation's army may have been her most valuable asset. At other times, her store of gold, her population, her navy, her factories and technology and even her religion may have been determining factors in her relative standing in the world.

Molecular nanotechnology (MNT) is an emerging technology that has the potential to redefine the sources of power in the world and to change the structure of the international system, thus influencing the business of states, from how they live and trade to how they conduct war. It is therefore prudent for us to examine this new technology, and study its potential to reshape the world around us.

On a global level, MNT poses a serious challenge to decision-makers and ordinary citizens alike. On the one hand are the enormous benefits that the technology may produce, from personal and national wealth that nearly exceed our ability to imagine, to possibly final cures to the aging and diseases that have plagued us for our entire history. On the other hand are the dangers, hard to visualize at this point, but all stemming from the radical power of this new tool. Whether superweapons of unspeakable destructiveness or home-made attempts at genocide, at least some of the potential products of an advanced molecular manufacturing ability give us pause, making us wonder if the heralded "Age of Nanotechnology" will be nothing more than a finely engineered disaster.

The argument presented in these pages follows the usual argument about molecular nanotechnology to a certain extent; there are indeed both opportunities and dangers that the advent of this technology will force us to manage, and these will be addressed. But where these pages will leave the path of established thought on this subject is on the point of precisely what those dangers (2) and opportunities are, for it will argue that the dangers are different and more likely than previously imagined, and that in the midst of these dangers, an opportunity may emerge to purge our world of its most dreaded feature: war.

The Loss of Conflict

One of the highest hopes one can have for molecular manufacturing is that it will remove some of the causes of war, and contribute to a generally safer and more stable global environment. On the surface, there is cause to believe it will make the world safer, as there is a wide variety of conflicts that will be eased or even eliminated entirely by an advanced breed of this technology.

Conflicts come in many different forms, but it is possible to narrow them down to a few general types. Some conflicts are the result of simple misunderstandings. Those misunderstandings may be misinterpreted military activity or accidentally threatening actions (such as the accidental firing of a gun at a stand-off), or they may be a result of a fundamental inability of different cultures to communicate well. This kind of conflict is generally resolvable, given the proper effort and time. At the other end of the spectrum, many conflicts are a matter of pure, unreasoning hostility between groups. These

conflicts may be based on religious or ethnic differences, or they may be built on a tradition of hostility, the ancient origins of which are no longer clear. These conflicts are often without possible resolution, save for the complete elimination of one of the groups. (The Arab-Israeli conflict may be an example of this unresolvable, interminable conflict, as may the ethnic strife in the former Yugoslavia.)

We should not hope that any new technology will have the ability to resolve differences that are the result of human decisions or errors. However, there are some conflicts that may be amenable to technological resolution. One of the most common contributing factors to war among states is access to resources. There is a wide variety of resources that are important to states; natural resources, such as land, gold and oil, have a long history of being something states felt to be worth fighting over. There is also historical precedence for new technologies causing a decline in the value of some resources, so there is reason to think it is possible to happen again.

History is littered with examples of wars fought over resources. Wars were fought between European countries over the vast stores of gold and other treasures that were thought to exist in the New World. In our own century, Japan drew the United States into the Second World War when she attacked that country out of fear that a slow strangulation by lack of oil and other resources would happen otherwise. (3) Millions were killed in a brutal war that was in part started over the issue of access to resources, and it was not to be the last time. Tens of thousands more would be killed in the Gulf War of 1991, which was fought at least partially to defend the industrial states' access to oil.

More wars over resources loom, most notably in the South China Sea, where a small group of islands known as the Spatleys sits atop a potentially vast cache of oil and other valuable resources. 5 states claim sovereignty over this region, including China, which has approximately 3 million men in uniform. The Republic of China on Taiwan, which has had hostile relations with China since her government was forced off the mainland by the Communist revolution of 1949, also claims parts of the disputed area, as do Vietnam, the Philippines, and Malaysia. The prognosis for a peaceful resolution of these conflicting claims is not promising. The stakes are high, and Asian states have been arming themselves steadily during the last decade.

MNT may help to alleviate, and perhaps entirely resolve, the issue of access to certain materials. Petroleum, for example, may go the way of whale oil in the early 20th Century, "eclipsed" by a new source of power (in this case, solar). MNT will not revive the solar power of the 1970's, with massive collectors that take up acre upon acre of desert space, nor will it require the ugly water-heaters that clutter so many rooftops today. Rather, by increasing the efficiency of solar energy collection while simultaneously lowering the power requirements of manufacturing, MNT may make solar power an unobtrusive, sufficient source of energy for both home and industrial use, thus creating a viable, even desirable alternative to fossil fuels. There is also the possibility that for some tasks, molecular manufacturing processes will produce energy, rather than consume it. (4)

Should such a situation become reality, the implications for reduced interstate conflict are significant. Solar radiation is readily accessible at some level to every state on the planet, and it is hard to conceive of a practical way that any state could restrict the access of another to it. Viable solar power could lead to energy independence for all, and that would leave the states of the world with one fewer vital interest to defend from each other, and thus one fewer reason to wage wars.

There are other resource areas where MNT might help contribute to a reduction in conflict between states. One of those is food. An example of the isolated, low intensity conflict over food that is becoming more common today occurred in1995, when Canada and Spain clashed over Spanish fisherman trolling for fish off the coast of Canada. As fish populations dwindle due to overfishing, we should expect an increase in aggressive fishing practices and a concomitant rise in conflict regarding sovereignty over fishing grounds. MNT, however, may allow the inexpensive generation of all the fish the human race can consume, without a man-hour spent fishing. Sovereignty over prime fishing waters would become a non-issue. This apparently trivial example is important because it illustrates that MNT may help alleviate conflict over material resources that are non-exclusive (that is, resources that can be consumed by many at the same time, such as food, water and mass-produced goods. An example of an exclusive resource would be the French Riviera; there is only one, and only France has it.)

Notes

(1)"Power can be thought of as the ability of an actor to get others to do something they otherwise would not do (and at an acceptable cost to the actor). Power can also be conceived in terms of control over outcomes." (Power and Interdependence, Keohane, Robert O., and Nye, Joseph S., HarperCollins, 1989, p. 11) Later in these pages, a distinction will be made between the potential for power as described above, and power that is realized or made actual.

(2)The "established thought" on nanotechnology is that its greatest danger is its abuse. "The chief danger of nanotechnology isn't accidents, but abuse." (Unbounding the Future, Drexler, K. Eric et al, William Morrow and Company, 1991, p. 521) Later in these pages it will be argued that the greatest danger of nanotechnology is neither accidents nor abuse, but rather its normal use as a tool of state power (as opposed to its use as a tool of madmen).

(3)"When the United States exploited Japanese vulnerability to economic embargo in 1940-41, Japan countered by attacking Pearl Harbor and the Philippines." (Keohane and Nye, p 16)

(4)"... [A] molecular manufacturing process can be driven by the chemical energy content of the feedstock materials, producing electrical energy as a byproduct... ." Nanosystems, p. 428-429. Also: "Using typical organic feedstocks, and assuming oxidation of surplus hydrogen, reasonably efficient molecular manufacturing processes are net energy producers... . At a typical price for electrical energy today, ~0.1 $/kWhr, the value of the by-product electrical energy would usually exceed the cost of the feedstock materials." Nanosystems, Drexler, K. Eric, John Wiley & Sons, Inc., 1992, p. 433.

Power: Relative and Absolute

MNT will change states from the inside out, altering their capabilities for industrial production, for military action, for power projection, for independent behavior. The capabilities of states that are thoroughly infused with advanced molecular manufacturing technology will be quite potent. But the changes that take place are not only meaningful in terms of absolute power. We must also take into account the changes in relative power both within and between states that may develop during the introduction of MNT into the world and during its spread.

The possibility of internal relative power changes may lead to some counter-intuitive results. Countries such as mainland China, which one would expect to pursue molecular nanotechnology, may try to suppress the development and/or introduction of the technology within their own borders, if it is seen as a threat to autocratic rule. The Soviets, after all, did an excellent job of keeping their telephone system in a mostly unusable condition in order to cripple internal dissent. Nanotechnology will have a far greater impact on the power of individuals and small groups than a simple telephone ever could have.

On the other hand, countries like China (that is, highly centralized countries) may be among the best able to exploit nanotechnology. All else being equal, dictatorships and other highly centralized societies have an advantage over democracies in that they are able to make decisions more quickly. Today, a decision to pursue a new kind of weapons technology, for example, would not have a militarily significant impact for years, and in this context, the few months' advantage in decision-making that autocracies enjoy is not terribly important. Democracies suffer little strategically because there is plenty of time in which to react to the actions of other states. But if a decision to double the number of fighter-aircraft can become reality in a matter of days, then those few months become crucial. That, combined with the fact that autocracies will find it easier to make a decision to actively develop nanotechnology in the first place, may outweigh the internal risks that go along with it, making it a more attractive option for them.

Although molecular manufacturing technology will give all states that possess it nearly identical power potential (since it is based on abundant resources and low energy requirements), it does not follow that all states will therefore be equal in the power they exercise. It is important to understand that there is a difference between potential power and realized power. Just possessing the technology does not mean that a given state will be able to use it to full advantage.

There are many factors we can identify that contribute to or subtract from efficiency in the process of converting potential power to realized power, chief among them the internal structure of the state. Clear examples of how states with nearly equal potential can possess vastly different levels of realized power are not hard to find. Perhaps the most stark is a comparison of the U.S. and the former Soviet Union. They both are large countries, with vast expanses of open, unexploited land and natural resources. They have large, educated populations, and have strong traditions of science and technology. Yet, their performance as superpowers shows that potential power does not always equate to realized power. The Soviet Union rates relatively poorly in all measures of performance that can be applied. In terms of military ability, the U.S.S.R. fell further and further behind the U.S. in both level of weapons technology and in the fighting ability of its forces towards the end of the 1980's. Its economy deteriorated for decades before the country finally collapsed in on itself, and that weak economy was a drag on the country's power in the international sphere. At the same time, the U.S. performed far better

with roughly the same resource base; its internal system was much more efficient at converting its potential power into actual power. As long as the internal structures of states differ, we should expect that there will be similar cases of some having greater realized power than others that possess the same level of potential power. (Note that while their power may differ in terms of what they can do with the potential they have, they may all be equal in power in one important respect, the ability to destroy each other, as will be discussed later. It is this fact that will have the greatest impact on how they relate to each other.)

A state's social structure will be important because it may affect not only the state's ability to use the technology, but also how it uses the technology. It may be the case that the industrial democracies, with their relative openness and diversity, will prove to be more fertile grounds for the interdisciplinary work that will be necessary to make nanotechnology a reality. Indeed, capitalist competition may be enough of an impetus in itself; the relative states of the American and the former Soviet electronics industries spoke volumes about centrally-planned economies. While this may sound reassuring, it also implies a potentially difficult problem. Over the past five to ten years, centrally-planned states have at last come to realize an important fact about the West: our wealth is due to extreme specialization and competition, and that arrangement rests on a foundation of openness and freedom. Tired of their pathetic living standards, they are adopting openness in order to enjoy the material benefits of capitalism. Nanotechnology, however, will require little specialization, since the entire material needs of a state can be met with only a very small amount of labor. This means that the temptation of material wealth, which was so effective in drawing most of the world's centrally-planned economies into the arms of freedom, will cease to be effective once molecular manufacturing technology is available. With advanced MNT, material wealth can be had without the social structure it now needs, and so some autocracies may adopt our nanotechnology (after we have developed it) but not our institutions, instead retaining the power and decision-making advantages that go along with one-man or one-party rule.

Perhaps some will dismiss the potential of countries like China to develop nanotechnology, but they need only be reminded of China's nuclear arsenal. Today, even countries as poor and undeveloped as Pakistan and Iraq are busy developing nuclear bombs, and those weapons require an internationally monitored, difficult to obtain, toxic material. Nanotechnology could emerge directly from the pharmaceutical industry, and may be far cheaper to develop than the bomb.

A nation's social structure will be important not just because it may affect a state's use of the technology, but also because the social structure may determine which state develops nanotechnology first. One can find in history numerous examples of uneven technological development affecting regional, and sometimes global, power structures. One of the best is the experience of Britain during the Industrial Revolution. In a matter of a century (from about 1750 to 1850), Britain went from a mostly agrarian society to a mostly industrial one, with farmland sprouting smoke-belching factories at an amazing rate. Britain urbanized, industrialized and "modernized" faster than any other state at that time, and as a result of a few years' head-start, Britain was able to dominate global politics for nearly a century. For a small, insular nation to "rule the waves" as Britain did, and to do it for so long, is both surprising, even in retrospect, and instructive.

Had all states at that time progressed at the same rate, there would have been a lower likelihood of conflict, as the power structure, which depends on relative differences in levels of power among actors, would not have changed. The danger of conflict arose when the differential in the various rates of

progress began to widen. There is, unfortunately, no reason to think that a similar set of events will not occur during the introduction of MNT. The reason for expecting different rates of progress is in ample evidence today. A survey of the world's states will show not only vast existing differences in present capabilities, but also vast differences in the ability to adopt and adapt to new technologies.

Some of the telltale signs of strength or weakness in this crucial area are easy to spot and easy to measure. Communications infrastructures, for instance, vary widely in terms of bandwidth and reliability all over the world. Western Europe, Japan and most of North America, as well as a few other locations, have first-rate infrastructures for many types of communication. Fax machines, telephones, televisions, computer networks and satellites combine to form an intricate web of contact among people in these areas, and cheap, instant contact with almost anyone is the norm. In this environment, collaboration and the rapid dissemination of ideas thrive, and contribute to a rate of technological growth that is far above what is found in states with incomplete, unreliable or outdated information infrastructures. (Consider the poor quality of the Soviet phone system, as mentioned above, and its impact on the progress of Soviet technology during the 1980s.)

The same is true of market infrastructures. Where they are in poor health, or even completely non-existent, there is a limited ability to innovate and adapt. Without market pressures for change, corporations and individuals can become complacent about their skills; isolated from incentives for constant advancement, they slow and even stop in terms of progress. Again, the Soviet Union is illustrative of this phenomenon, as are a few industries in the West, such as the German biotechnology industry, the American textile industry and the Japanese pharmaceutical industry.

Other factors that may limit the ability of a given state to adapt are numerous, but much more difficult to express succinctly and to measure accurately. For instance, the openness of a state to new ideas and new people (who often carry new ideas with them) can affect the rate at which a state may adapt to MNT and apply it quickly and effectively. The same can be said of a state's corporate management style; some, notably that of the U.S., are very open to innovation, and some nations also have a tradition of entrepreneurialism, which could be considered an extreme form of corporate acceptance of innovation. (1) Traditions of inventiveness and innovation and an expectation of progress are other cultural factors that may prove important during the years of transition to societies based on advanced MNT, and they vary greatly from country to country.

All the above factors will contribute to differing rates of progress as MNT becomes a widely used technology. As the industrial capabilities of some states expand more rapidly than others, the result will be changes in the relative power of states, and this will destabilize relations among those affected. The national differences outlined above may conspire to produce at least temporary shifts in the existing distribution of power in a given region, quickly creating large gaps in the abilities of some actors. This can only be destabilizing (although its impact may be diluted by diplomacy and negotiation), and should be a cause of concern, even before it happens (as just the threat of a power shift can also be destabilizing, since preemptive action is possible on the part of actors who think they will be on the losing end of a power redistribution).

To see the potential for a destabilizing power redistribution, one can look at South Asia. India, a giant both in size (3.3 million square kilometers) and especially in population (over 750 million), is bordered by two rivals: Pakistan to the west and China to the east. India has fought wars with both countries, and their rivalries continue unabated today. Looking more closely at India and China, we find two nations

that differ greatly in term of the factors outlined above. China is a closed society, one with a weak infrastructure (physical and information) and few real markets (although this is changing). China, as a Communist nation, also stifles dissent, change and innovation. India, on the other hand, is adjusting to some of the technologies of the late 20th Century at a faster pace. Indian programmers, for example, trained at U.S. universities, are behind the success of some of Silicon Valley's brightest stars in recent years, and many of them return to India (unlike many Chinese students, who remain overseas after study), where they are working to modernize their country. India also has a cultural advantage over China in that one of its official languages is English. As English is the most common language for international communication, Indians have easier access to the vast amount of technical information that is published each year, and this may make them more likely than the Chinese to take advantage of technical advances that occur outside their country.

If India does embrace and apply MNT before China, then we can expect a disruption of the regional power structure of South and East Asia. (2) A great disturbance in the relations between the two most populous nations in the world, who also happen to be nuclear powers and have a history of animosity and war that dates back centuries, should be a matter of concern, to say the least. This situation is illustrative of the sort of dangers that are inherent in the introduction of a radically different technology with such far-reaching consequences for the power of states, and it is especially unnerving because of the speed with which the technology may spread. The Industrial Revolution was difficult for Europe to endure, and it lasted over a hundred years (3); MNT may cause the same level of disruption in only a few short years, leaving much less time to adapt.

Power: Hard and Soft

The advent of MNT will not only cause disruption in power relationships by adding power to some states; it will also cause a loss of power for some. Not all power depends on military strength. Some is based on dependency, and that power can be utilized by either withholding what the dependent state needs, or by threatening to do so. This is usually referred to as "soft power," as opposed to the "hard power" of military action (or threat of it) (4). As an example of soft power, consider the U.S.-Japan trade relationship. Japan is dependent on the U.S. market, the largest single market in the world, as an outlet for its goods. Without access to that market, the prices for many of its goods would be too high (since the per unit cost would increase as the number of units produced decreased), and Japan would experience a lower standard of living and massive unemployment, at least in the short term. Thus, the potential to withhold something Japan wants gives the U.S. extra leverage in negotiations with that country. To be sure, the U.S. needs Japanese goods, but Japan would be hurt more by the closing of the American market to its goods than would the U.S., and it is this difference in relative dependency that gives the U.S. its advantage. (5) But should molecular manufacturing make trade obsolete (the reasons this may be the case will be presented later), then this advantage will vanish. Indeed, if MNT makes states more independent of each other (this will also be explored in detail later), then many other relationships based on dependency will change radically, making the soft power that is derived from manipulation of dependency less effective. The elimination of this source of power will change the power structure in many parts of the world in the same way that changes in absolute power will: by changing the relative levels of state power in the international system.

Other dependency relationships that might be changed by this technology are those that involve dependency on certain natural resources. Few resources are spread evenly around the globe, and the

differences in the natural endowments that each state enjoys is quite important to the structure of power in the world. The U.S. and Russia, for instance, have vast stores of natural resources, much of them unexploited. It is difficult to imagine either of them a great power without those resources. Other states are limited, rather than strengthened, by their natural resource base. Japan is a prime example of this situation. Japan is wealthy and industrially powerful, but virtually all of the raw materials that Japan's industries need are imported. Without those resources, Japan would be a poor, overcrowded nation of fishermen, and not much more.

We can expect wide-spread use of molecular manufacturing technology to reduce the need of industries around the world to require much in the way of raw materials, except for the few, common elements that are anticipated to be the key resources of the age of nanotechnology, which are found in abundance in every state on the planet (6). This will mean a great loss of power for many resource-exporting states, and a corresponding weakening of their relative power.

We can expect molecular nanotechnology to be opposed, whether openly or secretly, by any state that expects to suffer a loss of relative power. Perhaps no loss of relative power among states will be greater than that suffered by the oil-producing states of the Middle East. Molecular nanotechnology poses a challenge to the primacy of fossil fuel as an energy source on several fronts. For one thing, manufacturing on a molecular scale should be extremely efficient, without the wasteful processing associated with bulk manufacturing techniques. This alone would lower the value of oil by lowering energy requirements for manufacturing a given product. However, the efficiency of manufacturing has been increasing since oil started to become widely used in industry, and the world's appetite for energy has only continued to grow, so greater energy efficiency alone will not make oil obsolete. But what might do it is the fact that molecular nanotechnology may lower the level of energy need in manufacturing to a point low enough that solar power, even if collected by the inefficient cells we use today rather than a nanotechnological version, would be sufficient. If molecular nanotechnology can do this, and it appears likely that it can, then oil would no longer be in demand in any great quantity, and that would mean a great loss of power for the Middle East.

Again, it is not absolute power that is the only concern. Molecular nanotechnology, if adopted by Middle Eastern states, could make everyone in the region far richer than today's richest sheik, with choices that are not available today at any price, such as extremely long lifespans. Nonetheless, it may be actively opposed by many in the Middle East because it will lead to a loss of relative power, in this case control of the world's supply of energy. As OPEC demonstrated during the 1970s, this is an important lever to have one's hand on; by decreasing the supply of crude in 1973, the OPEC nations were able to throw the economies of all the industrialized world into deep recession, causing massive loss of jobs and lowered standards of living for millions of people. The dependency of North America, Japan, Europe and most of the rest of the world on a resource that is only found in abundance in one region of the planet and is controlled by a handful of decision-makers is an incredible weakness, and one that was easily exploited. Although OPEC is no longer a force, the dependency is real, and in some states (such as the U.S.) has even grown deeper. Dependency means vulnerability, vulnerability to the decisions of others, and it demands that attention be paid to a region of the world that otherwise would hold little significance. Were it not for oil, the Middle East would go mostly unnoticed by much of the world.

The oil-producing states are well aware of the source of their power, having already flexed their muscle once. Molecular nanotechnology is not likely to receive a warm welcome from these states, and many of

them (notably Iran, Iraq and Libya) are practitioners of the lowest form of violence: terrorism. The seriousness of an anti-nanotech terrorism, especially in a world where nuclear materials are becoming easier to obtain, should not be lost on anyone.

Notes

(1)Taiwan is an excellent example of entrepreneurialism as a way of life. Chinese immigrants from Taiwan usually carry the tradition with them abroad. In cities with high Taiwan-born populations, such as the Los Angeles and San Francisco areas of the United States, the immigrants tend to own their own small businesses.

(2)Note that this is only meant to illustrate some of the factors that could contribute to a power disruption, and how such a power disruption might occur. That India adopts MNT before China is not central to this argument; it could be China, or even Pakistan.

(3)In fact, there remain a few parts of Europe mostly untouched by the Industrial Revolution even today; Albania stands out as the largest example.

(4)There is a third kind of power, co-optive power, which is the ability to get others to want what you want. Nye describes it as "the ability of a nation to structure a situation so that other nations develop preferences or define their interests in ways consistent with one's own nation." Bound to Lead, Nye, Joseph S., Basic Books, 1991, p. 191. Co-optive power arises from cultural and ideological attraction, and from the rules and institutions of international regimes. An example of the former is the fact that American motion pictures occupy approximately 50% of world screen time, even though they are only about 6% of all movies made. (Nye, p. 194) An example of the latter is GATT, which embodies liberal, free-market/free-trade principles that match U.S. ideology and desires. This type of power may become relatively more important as soft power decreases in influence. However, its usefulness for resolving a particular conflict is extremely limited. "Politics takes place within the ground rules laid down by the regime, and generally it is directed toward small advantages, favorable adjustments, or exceptions to the rule." (Keohane and Nye, p 51) Thus, hard power will remain the key tool for conflict resolution.

(5)"It is asymmetries in dependence that are most likely to provide sources of influence for actors in their dealings with one another. Less dependent actors can often use the interdependent relationship as a source of power in bargaining over an issue and perhaps to affect other issues." (Keohane and Nye, p. 10-11)

(6)"...[T]he chief anticipated feedstock materials for molecular manufacturing (C, N, O, H) [Carbon, Nitrogen, Oxygen, Hydrogen] are available in bulk compounds for costs of ~0.1 $/kg " Nanosystems, p. 433.

War in the Age of Invisible Machines

MNT will change the nature of war in two fundamental ways. One of these is what one would normally expect from a technology that is so novel and powerful: it will make war far more dangerous and devastating than it has been at any time in the past, due to its ability to create weapons of extreme destructiveness. The other way is less obvious, but just as real: MNT will make war between states more likely in the present world system.

Weapons have a history of becoming more deadly over time. Much of the evolution of weapons has been driven by the need to overcome defenses built to counter a previous generation of offensive weapons; the crossbow, for instance, was developed to pierce the plate armour that had been invented to defend against arrows and swords. Other weapons have followed a different path, a path of growing destructiveness that aims for more "bang for the buck." The bomb is the clearest example of this type of weapon, and its history has a clear path from the bombs of the Second World War (the "Blockbuster") to the atomic bomb, the hydrogen bomb and finally today's breed of thermonuclear bombs that pack the equivalent of hundreds of Hiroshima bombs.

Nanoweapons will advance the state of the art in weaponry in both ways. Due to the small scale it works on, molecular manufacturing will allow for the creation of invisible weapons, dreadful and insidious in the same way as biological and chemical warfare. But nanoweapons will also be more precise than biological and chemical weapons because of how they are made. Nanoweapons will be made with an atomic precision that will allow the creation of actual robots smaller than the agents used in biological weapons, and as robots they will be programmable. This will mean weapons that can evade defenses and strike predetermined targets, much as cruise missiles do, but on an invisible scale.

Biological and chemical weapons have, and deserve, an ignominious reputation. It is hard to think of them as tools of honest warfare because they cannot be controlled once they are released. They travel with the wind, killing everything they come in contact with, soldier and citizen alike; one cannot surrender before them, and they take no prisoners. They do not even discriminate between "enemy" and "friend." They have only one purpose: to kill. Most other weapons can also be used to bring wars to end through means other than killing: factories can be shelled or bombed, tanks can be crippled, bridges can be brought down with dynamite, missile silos can be blown from the ground. But chemical and biological weapons reek of genocide, of wiping an enemy from existence rather than simply defeating him.

MNT may extend the capabilities of such "dirty" weapons, making total genocide a matter of programming, rather than favorable wind conditions. The possibilities for genocidal weapons are not hard to conceive. It may be possible, for example, to program a release of nanoweapons to move steadily from all sides of the border of an enemy country to the center (taking positional readings from Global Positioning satellites), killing everything they come in contact with, and thus effecting the elimination of an entire nation.

Of Swords and Plowshares

"...[D]evelopment of radically new weapons is always accompanied by a disruption of the rules by which international society is governed," (1) and as we saw above, that will be the case with molecular nanotechnology. Because molecular manufacturing technology will make weapons far more dangerous

than they are today, we can expect to see efforts to control them and their spread in one way or another. The most intuitive answer to the problem of a new weapon is to ban it, but this is as unworkable as it is obvious. No attempt to ban a weapon from existence has worked in the past, whether bows and arrows (The Second Lateran Council attempted that in 1159) or nuclear weapons (the U.N. General Assembly attempted that in 1946), and there is no reason to hope that this technology will depart from precedent.

Two somewhat more reasonable approaches remain: disarmament and arms control. Taking them in order of increasing feasibility, let us consider first the possibility of disarmament. Disarmament in recent years has focused on the elimination of nuclear weapons above all else. The desire for a world without them is understandable (2); present stockpiles of the the weapons can destroy all human life on the planet several times over. The nuclear disarmament movement failed to achieve its goal, but that does not mean that disarmament is not possible. There are historical examples of successful disarmament, and an examination of why disarmament has succeeded in the past but failed in the present is instructive. One of the most often cited examples of a disarmament that worked is the U.S./British disarmament of the Great Lakes in North America. This disarmament was a success because both sides felt that they would be secure from aggression by the other side, despite being unarmed. A lack of armaments did not invite aggression because there was no potential aggressor. In this case, peace had already been established, and weapons served no deterrent purpose. Peace, it seems, is the prerequisite for disarmament, and not the other way around; it follows naturally from the circumstance of peace. "Swords are not beaten into plowshares. They rust." (3)

While we have not seen nuclear disarmament, what we have seen to some degree is the second approach named above, arms control. Arms control has worked with both conventional weapons and nuclear ones, but in both cases has relied on something that cannot be hoped for in the age of invisible machines: the ability to detect weapons. Weapons today are detectable, often even against the will of a state that is trying to hide them. Although on-site inspections are an integral part of arm control agreements, the capability of detecting, identifying and counting weapons from space (through the use of "spy" satellites) is crucial. Many weapons built with nanotechnology will be virtually undetectable with anything but the most unacceptably invasive of investigative procedures, and this may prove to be an insurmountable barrier to arms control agreements. States cannot agree to limit what they cannot detect.

Clearly, the types of weapons described above will make warfare far more dangerous than it has ever been before. But the weapons themselves, though frightening, should not be our primary concern. Our primary concern should be the targets of these new weapons, because an advanced manufacturing capability based on nanotechnology will eliminate two of the traditional targets of military action, factories and weapons, leaving only one target: people.

The base of offensive military power today is manufacturing ability. It depends on the capacity of a state to produce the tools of war, to produce them in large quantity, and to produce them quickly and continuously in the case of protracted fighting. During the Second World War, it was the factories and workers of the United States that turned the tide against Germany and Japan in the end, not just the brave Allied soldiers. (Note that this is not necessarily the case with defensive power. This power is often derived from other sources, such as geography, as is the case with the U.S. and Switzerland. (4)) Manufacturing ability is embodied in factories, mines, and transportation infrastructures. These all make

for large, obvious and inviting targets in time of war, as was demonstrated by the Allied bombing campaign against German factories and bridges in the Second World War. And although thankfully never implemented, the strategic plans of the American and Soviet nuclear forces considered production centers to be valid and attractive targets for annihilation.

MNT will miniaturize not only many products, but most production facilities as well. Ugly grey buildings with tall, smoke-belching chimneys will become a thing of the past. So, too, will easy targets for strategic planners. Beyond this, even if the factories can be found, destroying them will be of little avail; with cheap and fast molecular manufacturing, factories will sprout like weeds. Raze a factory one day, it will grow back again soon after. Targeting production capability hardly seems a formula for success in nanotech-based warfare.

The other target of choice, one that is more tactical in nature, is the enemy's weapons. Destroy his planes, his tanks, his carriers and his bombers, annihilate his military forces and the war is won. But if the superweapons of the nano-age are invisible, then just like invisible factories, they may present no target at which to strike. (5) And like molecular factories, they can be replaced quickly and cheaply if they are destroyed.

Military planners will seek a target that is large enough to find and hit, and that cannot be easily replaced. The natural choice, given the circumstances, will be civilian populations. Targeting civilian populations is not a general characteristic of modern, Western warfare (although there have been instances). Returning again to the example of World War II, we find that when it has occurred, as in the German bombings of London, it was usually a choice made in desperation. So, too, will the future targeting of civilians be a choice of desperation, made by planners desperate for something they can find and destroy.

War in the "age of invisible machines," as we can see above, will be far more terrible than at any time in the past. Unfortunately, as these invisible machines make war more terrifying, they also make it more likely. (This point will be explained below in The State of Nature.)

Notes

(1)The Elements of International Strategy, Halle, Louis J., University Press of America, Inc., 1984, p. 78

(2)It is understandable, but it is also indicative of a radical misunderstanding of what nuclear weapons are used for. A bipolar system is inherently unstable. Without the threat of total annihilation in the event of hostilities, the U.S./U.S.S.R rivalry may have ended the same way that the Rome/Carthage rivalry did: with the destruction of one by the other. The nuclear deterrent of the Cold War worked, and it preserved the peace. Disarmament, had it taken place, may have open the door to war.

(3)Halle, p.97

(4)In the case of the U.S., there is an ocean on either side, which makes invasion much more difficult. Invasion is also difficult in Switzerland, which is nestled in a high mountain range.

(5)This will depend on what machines are used to detect and destroy them. Antibodies, for instance, are able to detect and destroy invisible invaders; "invisible" does not necessarily equate to "undetectable" or "indestructible." However, it is in general easier to hide a small thing than it is to find it.

Power: Military and State

MNT will be a very destabilizing technology, one that will change the relation that military power has to state power, and change the structural stability of the present world system. To address the first point, that the relation between military power and state power will be changed by MNT, we can start by considering one of the strangest aspects of the Cold War, which is the fact that it was cold. For over 40 years, the Soviet Union and the United States jockeyed for supremacy on the world stage. They armed themselves for eventual war with each other, they threatened each other, they pointed their nuclear weapons at each other. And yet, they never fought. But the decades of research and development, testing, practicing and manufacturing, not to mention the trillions of dollars spent, were not wasted. That is because one of the purposes of military forces is to deter attack, and deterrence works.

Deterrence works when one side convinces the other that it is both willing and able to to inflict unacceptable harm on the other. These two components are crucial for a successful deterrence; without either one, it will fail. Note, however, that neither has to be real. It is only necessary for the other side to believe it is so. Conversely, it may happen that one side is both willing and able to harm the other, but the other initiates hostilities anyway, unaware of this fact. The Korean War began for this reason. The U.S. did not make clear its intention to fight in the case of an invasion of South Korea, and in the mistaken belief that the U.S. would not fight, the North invaded, thus starting a war that cost many lives and accomplished virtually nothing. Deterrence depends on the potential aggressor's perception of the situation, and not on the reality of it.

Another purpose of military forces is to compel other states to do what they would not otherwise do by acting as a threat. Threatening military action is commonplace in the relations among states, and it need not be explicit to be effective. The belief that another state is more powerful may be enough to compel one state to bend to the will of the stronger, even though no open threat was ever made; implicit threat is present in obvious strength. Often, the demonstration of potential violence is the key ingredient in getting the most bargaining power out of military forces. This is why, for example, spy satellites are not completely unwelcome; they allow the enemy to see that one is not weak.

But a case can be made for just the opposite effect: that the existence of military forces and armaments provokes war, or at least contributes to hostility and suspicion. U.S. President George Washington said that "[t]o be prepared for war is one of the most effectual means of preserving peace." However, a later President, James Monroe, said that "[p]reparation for war is a constant stimulus to suspicion and ill-will," which would not do much for the cause of peace. Which one is correct? It appears that they are both correct, depending on the circumstances.

In a state of general peace and the absence of any imminent threat, a build-up of armaments by one state will almost certainly be interpreted by other states as a prelude to war, and thus be viewed as a threat. In this circumstance, Monroe would be correct in advising against war preparedness as a means of preserving peace, as threatening one's neighbors may bring the existing peace to an end. But in other circumstances, the build-up or maintenance of armaments may contribute directly to the continuation of peace by acting as a deterrent against aggression. Where peace does not exist (and the simple absence of actual fighting does not constitute complete peace, as the Cold War demonstrated), where

there is an implicit or explicit threat to a state, the deterrent effect of being ready for battle may dissuade a potential aggressor from initiating a hot war.

An unfortunate side-effect of molecular manufacturing is that it may contribute to the creation of a state of war regardless of the circumstances, whether they are ones of peace or of war. If MNT makes weapons invisible, and does the same for factories, then the ability of one side to measure the capabilities of the other will be severely hampered, and perhaps eliminated completely. This will be destabilizing in two ways. First, by making some weapons impossible to detect, it will prevent those weapons from fulfilling their role as deterrents in times when deterrents are needed, and thus will decrease the ability of states to dissuade potential aggressors from initiating military hostilities. (It may also put states in the unfortunate position of needing to advertise their military strength in non-passive ways. If allowing some of one's powerful weapons to be seen ceases to be possible, it may be necessary to make them felt, to demonstrate their destructiveness by using them to destroy.) Secondly, the lack of armaments, which is necessary for not projecting hostile intentions and arousing suspicions during peacetime, will be meaningless. The lack of detectable armaments will not in itself be reassuring to other states, and even the true absence of armaments will be inadequate proof of commitment to lasting peace, when the tools of war can be generated cheaply on a few days' notice, thanks to self-replicating factories (1). This will be destabilizing because knowledge of another state's capabilities is crucial to creating a threat profile, to knowing which states pose a threat and which do not. When a state cannot tell which states threaten it, then it will be prudent for that state to consider all states to be potential threats. "... [T]he primary and legitimate purpose of military forces is deterrence, not [defense], and it is only when deterrence fails that [defense] becomes necessary." (2) If deterrence becomes less effective in the age of invisible machines, then defense (i.e., warfare) may take primacy.

Self-replicating factories will also make war less "victory-oriented." The final stage of modern wars between states never ends with complete annihilation of the vanquished. Sometimes the offending state is disbanded, her territory swallowed up by neighbors (although these states often rise again after a few decades and another war), but usually the state is "set right" and allowed to continue its existence. The outcome of the Second World War illustrates this: Italy, Germany and Japan were occupied and allowed to continue to exist; today they are allies of most of their former enemies. After the First World War, Germany still existed, but was stripped of her industry. Victory in terms of total defeat (rather than annihilation) of the enemy will become much more difficult when industrial might can be rebuilt in a matter of days. Taking away an enemy's ability to wage war may become extremely difficult, and as a result, war will become more punitive in nature, in an attempt to make it too costly for an enemy to use his (indestructible) power to hurt others. This is why civilian populations will become the natural targets of military action; they will be one of the few remaining potential targets, and their destruction will be truly costly.

The State of Nature

To address the second point, that MNT will undermine the structural stability of the present world system, we need to look back almost 350 years to the publication of Thomas Hobbes' Leviathan, in 1651. In this work, Hobbes introduced his theory of the "state of nature," a description of a state of pure anarchy. This theory is important to our consideration of the impact of MNT on the world system, because states today exist in a state of anarchy, and Hobbes can shed light on the order in our anarchy, and give us a glimpse of its future.

The life of an individual in the state of nature, Hobbes says, is "solitary, poor, nasty, brutish and short," and it is no wonder, considering the circumstances he has to face. For one thing, there are no laws, and there is no one to enforce moral behavior. Each man must provide for himself all things, including defense. Each must fear for his life at all times, and even sleep, which is not optional for individuals, carries a risk of death. The individual can be killed, and he can be killed instantaneously. He is also capable of killing, and the strength of each is close enough that even the weakest can kill the strongest. This is the state of pure anarchy. Clearly, this situation is intolerable; one cannot even sleep without worrying about never waking up again. The solution, of course, is one we are all familiar with: the state. The state is necessary, Hobbes argued, because the state of nature will not accommodate a functioning society; government is the only alternative to a life that is "brutish and short."

States, too, exist in anarchy. There is no world government. And yet there is certainly a society of sorts. States know of each other's' existence, they communicate with each other and they negotiate. Society, Hobbes argues, is not possible in the state of nature, so if Hobbes is right, and his description of the state of nature makes this point a credible one, then modern states must exist in something other than a state of nature. A close examination of states shows that their situation is indeed different.

For one thing, states are extremely difficult to kill, especially today when the populations of many states number in the tens of millions. And they certainly cannot be killed instantaneously, which is part of the condition of Hobbes' solitary and poor man; states are, in a practical sense, immortal. Unlike individuals, states never sleep; they can be eternally vigilant if they choose. And also, unlike individuals, the weakest cannot kill the strongest (since states are so difficult to kill); in fact, most of the weakest can hardly hurt the strongest at all. Among states, there is an enormous difference in relative strength. Perhaps the only aspect of pure anarchy that the world system shares with Hobbes' vision is its general lawlessness. Although states can form alliances, sign treaties and agreements and such, there is no supreme authority to ensure that promises made are promises kept. There are no real laws to enforce, and there is no enforcer. But due to their lower vulnerability to death relative to the individual, states are able to function without a government where individuals would not be. There is order in the anarchy we find at the international level, a regularity that suggests stability, and this stability rests on the differences between states and individuals.

The advent of MNT seems likely to upset that stability because it will bring states closer to Hobbes' state of nature, thus changing the fundamentals of the international system, and increasing the probability of war at the time when states will target history's most horrific technology on civilian populations.

MNT will bring states closer to Hobbes' state of nature by making them more closely resemble individuals in their vulnerability, due to the impact that this new technology will have on the conduct of warfare. The terrifying power of nano-based weapons will make total annihilation of a state's population more possible, and this will make states approximate the key vulnerability of individuals: their mortality. And, as we saw above, MNT will not only make genocide possible, but, because of the fact that it will remove more traditional military targets, it will make genocide a more likely, even preferred, course of action in war.

MNT will also bring states closer to the condition of individuals in the state of nature by creating a general equality in destructive capacity. This is a process already underway today, in the proliferation of nuclear weapons technology. Since 1945, the nuclear club has grown from just one (the U.S.) to 7 (the US, Russia, China, France, Britain, India, and Israel). Several more nations are known or suspected to be

pursuing nuclear weapons development (North Korea, Pakistan, Iran), some have possessed them at one time (South Africa, Ukraine), and most likely others will join in the race. Nuclear technology is hard to contain, despite the fact that much of the equipment needed to produce bomb-grade material is expensive, specialized and heavy, making it difficult to purchase and transport secretly. If ensuring nuclear non-proliferation is proving difficult, then we can expect much more difficulty in containing the tools and knowledge necessary to implement a nanotechnology development program. This is especially true because of the high-level of dual-use technology that would make up a nanotechnology laboratory: Scanning Tunneling Microscopes (used in materials science and in the semiconductor industry), high-powered molecular modeling software and computers to run it on (used in scientific visualization and in pharmaceutical research), and common materials. As MNT spreads, so will the ability to create extremely powerful and deadly weapons, and the ability to rebuild an industrial base in a short time. These two consequences of the spread of MNT will make each state more of a threat to its neighbors by making it more deadly (due to the weapons) and more difficult to defeat (as opposed to destroy) in case of war (due to the self-replicating industrial base).

The third condition suffered by the individual in the state of nature already exists today, and that is the lack of authority. Just as individuals can rely on no one but themselves, so too are states dependent only on their own ability to defend themselves. (3) There is no "higher authority" to whom a state can appeal if it has been wronged, there is no international police force that will punish the offending state, and there is no global legislature to set the laws of state behavior. What is lacking is government, and in the past, this has not been as large a problem as it would be for individuals because of the special characteristics of states mentioned above. But if states become both mortal and equal in power due to the dissemination of MNT, then the lack of global authority will take on the same urgency that it has in the state of nature.

Notes

(1)"...[A] suitably designed and programmed molecular manufacturing system, built along the lines of the exemplar architecture, can be used to build objects that, when unfolded, are substantially identical to itself." Nanosystems, p. 427. Also, "A 1 kg system can build a 1 kg product object in ~ 1 hr ... . The range of products that can be produced is large, encompassing high-performance structures, massively-parallel supercomputers, and additional molecular manufacturing systems." p 441.

(2)Halle, p.25

(3)"States must rely ultimately on their own resources and must strive to maintain their relative positions in the system... ." (Keohane and Nye, p. 247)

The Conditions of Peace

For the provision of peace among different groups, there are certain "conditions of peace" that must be met (1), and they will be described here before we examine the practical question of how such a system might be brought into existence.

The foremost characteristic of a peaceful society is that despite the existence of separate and distinct groups within the society, they still think of themselves as one. Whatever the quarrels that internal groups have with each other, the issue of societal unity never arises. They consider themselves part of a single entity that will not divide over any issue; they have suprasectional loyalty to the society as a whole, and will subordinate their conflicts to it if necessary.

Without question, not all societies command this suprasectional loyalty from their members; these societies are not entirely at peace. Separatism is the most profound sign of this lack of domestic peace, and civil war is its most tragic expression. Separatism is quite common in the world today, and ranges from the generally peaceful movement of the Quebecois in Canada, to the terrorism of the IRA in Northern Ireland and the guerilla warfare of the Tamil Tigers in Sri Lanka. For a society to be at peace, it must have members who put their societal loyalty above their group loyalty.

To achieve this kind of loyalty from its members, a society must provide justice, or at least an illusion of justice or an expectation of justice. The issue of justice presents a problem in two ways. The first is the theoretical side, which is the matter of settling on a definition of justice. For the society to function peacefully, there must be a consensus on the abstract meaning of justice, of what it means to be treated fairly. This part of the problem of justice is the easier one, and for most societies, it does not pose any special difficulties. (Note, however, that what are states today are what would be members of the global society we are envisioning; reaching a global consensus on the meaning of justice would be a monumental task.) The second part of the problem of justice is much harder, and that is the application of justice in individual cases. It is easy for internal groups to see bias in any outcome that does not favor them; it is the role of government in this case to channel conflict and conflicting claims into peaceful means of resolution (such as a system of courts), while maintaining the appearance of a general neutrality toward those conflicting claims.

A necessary component of providing for justice is the ability to enforce it, and that is the third condition of peace: a monopoly on organized violence. This monopoly is indispensable (especially on the global scale), because anyone who can use violence will if the stakes appear to justify its use, and if the costs/risks are acceptable. Force (except for self-defense) must not be available for general use; it must be reserved for the tasks of preventing wrong-doing and dispensing justice.

The above conditions of peace must be provided for, or individuals (and the states that will come to resemble them due to MNT) will remain in the state of nature. The only way to meet those conditions and establish peace in a world crowded with equally deadly, equally mortal states is to establish a world government. While that statement may cheer some among the readership, it should not, for I am about to argue that no such "world state" is even remotely possible at this point, and that therefore peace under the present world system will become an impossibility with the advent of molecular nanotechnology.

E Pluribus Unum

To see why a "world state" is not yet possible, it will be helpful to start by asking what changes would be necessary for the creation of one. The present world system is one of many states, so in order to have a single state, these separate states must be combined into one. There are at least two ways for that to happen: either they can be formed into one (involuntarily), or they can unite (voluntarily). (2)

The former, for the states of the world to be coerced into a single state, is almost inconceivable. World conquest has never succeeded; the closest to total dominion over the world that has been accomplished was merely over the world known at the time of conquest, which was always much smaller than its true size. The Roman Empire was this type of incomplete "world state." Even at its peak, it occupied only a small portion of the world's surface. Conquest of every nation on earth would be incredibly difficult, not to mention dangerous, in today's world. It may become downright absurd once MNT has spread.

The latter way for a world state to come about, for the states of the world to unite into one, is also without precedence, at least on the global scale. Attempts have been made, but they have met with little success. The most significant attempts, the League of Nations and the United Nations, have special relevance because they both tried to create a world government in the our own century, which has been a particularly violent and divisive one.

On a regional scale, it would seem on the surface that attempts at uniting a group of states into a larger, single state have been more successful, and they have. Whether they have any relevance to similar operations on a global scale, however, is questionable. Let us first examine what is perhaps the most frequently sighted example of the "right way" to build a federation of many states: the United States of America.

Founded in 1776, the United States was formed from 13 states that united in a revolutionary war against their former colonial master, Great Britain. The war was won by the former colonies, and in 1787, work began on the writing and ratification of a constitution that would unite the 13 states into a single nation. After 3 years, the Constitution of the United States had been ratified by all 13, and a new state was created. There was no interstate warfare (at least not immediately), and each state made concessions in order to get the constitution ratified by all. It was an exemplar transition from many to one. (This accomplishment is commemorated on the national seal with the Latin phrase E Pluribus Unum: "From Many, One").

Were it possible for the world to unite in a fashion similar to this "American Model," the transition would be a smooth, peaceful one. It is unlikely, however, that such an approach will work anytime in the foreseeable future. The differences between the British colonies in North America in the 18th Century and the states of the world today are both numerous and profound. Perhaps the most significant is that the 13 American states had far more in common than do states today. After all, they were already part of the same country; their goal was not to replace their system with something terribly different. (Indeed, the quarrel with Britain began over the fact that the colonists felt they were not being treated as the British citizens they were, and the United States is not very dissimilar to Britain even now, over 200 years later.) The commonality the states shared was due to the fact that they were never really sovereign states; all they did in the end was to exchange one common government for another. Unlike the states of the world today, the 13 American states already shared a form of community, both in law (since they were colonies of the same nation) and in culture (since they were all British). The same

cannot be said of the world today. There is no common culture, no common language, no common religion, no common law; there is no community in any serious way, and this is the key difference.

Even with that pre-existing community, it still took the U.S. almost 100 years, and a Civil War (the bloodiest war in her history), to settle the issue of national unity for good. Community is the minimum pre-requisite for a voluntary state like the federal system we find in the U.S., and a global community will be the pre-requisite for a global state. (3) At present, that global community is nowhere in sight, and as we will see later, MNT may work against the formation of a world community by strengthening nationalism in a most surprising way.

Notes

(1)Politics Among Nations, Morgenthau, Hans J., McGraw-Hill, Inc., 1985, 526-531.

(2)Morgenthau, p 537

(3)"The community of the American people antedated the American state, as a world community must antedate a world state." Morgenthau, 541.

Engines of Autarky

The word autarky, which comes from the Greek words meaning "self-sufficiency," is used to describe the policy of being economically independent of other nations by having no trade with them. Autarky has many theoretical benefits that make it an attractive policy for a state that is contemplating its alternatives. The key benefit of autarky is that it provides an immense measure of independence from other states, since trade necessarily creates dependency in a state, both on imports (for products not produced domestically) and on exports (for foreign markets). (1) Alexander Hamilton articulated this desire well when he said that the U.S. should be "independent of foreign nations for military and other essential supplies" so that it may be "least dependent" on the foreign policies of other states. But this benefit has to date proven to be nothing but a deception, damaging nations more than it helps them. In our own century, there are many examples of semi- and completely autarkic practices being adopted by nations, only to be abandoned later. There are also examples of nations that are actively autarkic even today, and we can examine the experience of one to get a more clear idea of what autarky entails.

In Asia, we find that North Korea, a Communist nation since 1945 (and one of the few remaining nations committed to Communism), has practiced a semi-autarkic trade policy for decades and shows no signs of giving it up any time soon. North Korea trades mainly with Communist and former Communist nations, but the level of trade is low, and the traded goods are mostly raw materials, where the gains of specialization are minimal (because there is not much room for specialization, due to the fact that producing raw materials is mostly digging and chopping, rather than processing).

Hard numbers on the North Korean economy are difficult to generate because the nation is sealed off from the rest of the world, but anecdotal evidence based on the experiences of the few who have had the opportunity to enter the country paints a bleak picture of a dreary, colorless daily life, one devoid of any material comfort. North Korea's self-imposed autarky has come at a very high price. Their gain, however, is their independence of action, as they have displayed in their recent negotiations with the West over nuclear development within the country. Aside from military action against North Korea, there is little any other nation can do to influence her behavior (2). North Korea cannot be threatened with being ostracized from a world community she does not belong to, nor can she be threatened with trade sanctions when she does not trade. World public opinion is meaningless to a nation that does not allow in any news from the outside world or any form of contact between her citizens and those of other countries. Self-sufficiency has some very real benefits, and North Korea is willing to pay the price to have those benefits.

These are benefits that every state would like to have; after all, having power is a natural desire of any organism that has to fend for itself, as states do. More independence of action means less vulnerability to the desires of other states, and thus more power for the independent state. Avenues of action and types of behavior that would be unthinkable in a world of interdependent states become viable options with autarky. Were it not for its high cost, many more states, if not all, would consider autarky a reasonable and beneficial policy. Should autarky ever become more affordable in terms of what must be sacrificed in order to practice it, we can expect it to become much more common than it is today. As it turns out, molecular nanotechnology may remove many of the reasons for trade on an international scale, and may even have the same effect on much lower levels. This would pave the way for a world of autarkic states, which would create problems and opportunities that have never existed before.

The prospect of molecular nanotechnology reshaping our world into a more dangerous, more hostile one is as real as it is unfortunate. But the effects that MNT has on the international scene may not be all bad; indeed, it may be the case that certain aspects of the technology's effect on human societal organization offer a chance to end the scourge of war, and pave the way for a perpetual peace.

Economies of (Small) Scale

Since the earliest stages of industrial revolution, the root of material progress has been the division of labor. This mode of human organization is simple in principle: it is a type of sharing of work, but more importantly it is a division of work into discrete functions that workers can specialize in. (3) By dividing up work into separate tasks, workers can do just one thing and thus have the chance to learn to do it extremely well. It is the result of this specialization that there are people who make beer all day, so we can buy beer that is much better than anything we can brew at home in our spare time. It is also the result of specialization that we can consult a librarian who knows more about books than any of his patrons, or that we can find a doctor who studies and thinks about nothing but one particular part of the body for his whole career.

The benefits of this specialization are numerous. For one thing, there is the benefit of having workers who know and can perform their particular task better than a generalist ever could, as in the examples above. There is also a benefit that comes from specialization called economies of scale. Economies of scale are the savings that result from having a particular task done by fewer groups, or fewer companies, or in fewer places. For instance, rather than ship the raw materials for bread to 10,000 households, and having bread baking in 10,000 ovens and being tended by 10,000 amateur bakers, it is much more efficient to ship the raw materials to one factory (savings in shipping costs), and having it bake in only a few very large ovens (saving the costs of building 10,000 smaller ovens) and having it watched over by a few professional bakers (saving the huge amounts of time and effort of 10,000 people learning how to bake bread.) Many tasks can be consolidated into only a few, eliminating redundant factories, machinery and labor, and resulting in cheaper bread. And on top of all that, as professional bakers do nothing but bake all day, they tend to bake better bread.

Better products for less cost are the natural result of specialization, provided there is a way to coordinate the activities of all these specialists (i.e., a market based on money must exist). Before specialization, this problem did not exist; one simply made what one wanted, or what the family or tribe or village wanted. The benefits of the division of labor become truly profound only when the group of workers trading their goods and services becomes very large; the larger the market, the greater the degree of specialization that becomes possible, and as specialization increases, so do its benefits. Products become better and cheaper (all else being equal) as market size increases. It is no coincidence that the dramatic increase in world living standards that followed the end of the Second World War was concurrent with the dramatic increase in international trade made possible by the liberal post-war trading regime; improved standards of living are the result of more trade, because more trade has meant a greater division of labor and thus better, cheaper products and services.

With such compelling benefits, it is no wonder that many societies around the world are organized on the principles of markets, and that most others are starting to adopt markets as a central organizing principle. Trade is a win-win situation, one of the few that exist in this world. But any economist will verify that there is "no free lunch," and international trade, the logical extreme of the division of labor, comes with a hefty price tag. It is a cost that is not immediately apparent as such from a purely

economic viewpoint, but it is significant in terms of national strength. The cost is dependency on other nations, and it is becoming a significant problem today.

The Ties that Bind

In the past, the cost of depending on a product from another country was not a high one. Commodities were the usual stuff of international trade: cotton, wheat, spices, furs. These were things that were normally available from other sources, so being dependent on a foreign product did not necessarily mean being dependent on any one country for supply of that product. But as global markets expand and specialization increases, it is becoming the case that many products are available from only one country, and in some case from only one company in that country. The risks of dependency are becoming much greater, especially because many of these products are high-technology goods, and as such they are hard to begin producing domestically should the need ever arise. Whole industries may be brought to their knees without access to a crucial part. (The computer industry, for example, would be crippled, at least in the short term, if Intel were suddenly unable to produce any of its popular microprocessors.) Many important weapons systems in the U.S. military, including fighter planes and missiles, will not work without certain chips produced in Japan.

For states, depending on products from overseas in an age of increasing specialization is a considerable risk. Dependency is the opposite of independence, and dependency on foreign goods means a loss of the ability to act in a completely independent fashion, and that situation goes against the most basic self-preservation instincts of states. The benefits of trade are high, but the costs of it are rising. Molecular nanotechnology may hold the key to having our cake and eating it too: having the benefits of trade (better products at lower prices) without the cost (dependency). (4)

A world of autarkic states would present, first of all, a problem of organization, as each state would be able to pursue independent courses of action, without having to bend to outside, non-military pressure. The reason that this will be a central problem is that the "soft power" we examined above will be less effective; this is because soft power is based on dependency (that is, there must be some necessary thing for one state to threaten to withhold from the other). An autarkic world will be a world without dependency. The reason "rogue states" such as Iraq and Libya can cause so much commotion in the world is that they are relatively unrestrained, due to their lack of integration into the larger, international system. For a more globally integrated state to pursue a reckless course of action is quite rare today; major states generally seek the consent of (or at least inform) other major players before making any important moves that would impact the world system (5). A world of autarkic states will also mean that dangerous behavior will become a more viable option for states (though not necessarily a more desirable one), and this will contribute to instability.

But even if interdependence should be pursued as a global policy by states that are seeking to preserve some vestige of the old order (perhaps for the sake of continuity or stability), the dependence that states may artificially foster will still not be a source of soft power. The reason for this is that there are two kinds of costs that can be imposed on a dependent state, and both must be real costs if soft power is to be effective, and MNT will render one of those costs negligible.

There is a short-term cost that a state will pay when it finds itself at the receiving end of an exercise of soft power. This short-term cost is the suffering experienced when a needed thing is withheld by another state. An example of this short-term cost would be the difficulty encountered by a state that is

dependent on another nation for imports of a popular luxury vehicle when the producing nation stops exporting. This might appear to be the only cost of dependency, but there is another cost: the long-term cost. The long-term cost of dependency is the cost of changing either the domestic system or the international system in order to end the suffering. In the case of our luxury car importing nation, the long-term costs of ending its suffering might be the costs associated with forcing the producing nation to restart its exporting of cars, or of finding another source of cars, or (crucially) of building up a domestic luxury car industry. This last option is crucial because with an advanced molecular manufacturing base, building up domestic industries to replace whatever good one is dependent on is a low-cost option. Dependency thus loses its real bite; any suffering that may be imposed through the use of soft power is at worst a temporary one, and therefore soft power is a chimera. And if soft power is less useful, then hard power, that is, the use of military force, will become relatively more useful. This only adds to the trend of an increasingly violent world that was examined earlier.

But a world of autarkic states may also mean a more peaceful world, if the true advantage of autarky is taken into account and acted upon; that advantage is the possibility of official isolationism, a state policy of avoiding entanglements (6) with other states and limiting contact as much as possible. In the same way that surfaces that have no contact will produce no friction, so may conflict between states be limited by limiting the contact between them.

Notes

(1) Autarky has another, often-overlooked, benefit; it is sometimes a way to deny access to a certain good to another state, when the autarkic state is the only source of that product. Thus, a technologically advanced state could practice autarky as a way of maintaining its technological lead. This is especially true of weapons technology. However, when the desire for lower domestic costs of products overrides this concern and drives a state to allow exporting, "the consequence has sometimes been to place technology and weaponry in the hands of potential enemies." (Defense & Dependence in a Global Economy, Vernon, Raymond and Kapstein, Ethan B., eds., Congressional Quarterly, Inc., 1992, p. 39) Witness the arming of Iraq prior to the Gulf War as evidence of this.

(2) There is one way to influence a nation as independent as North Korea without resorting to military means, and that is the "carrot" (i.e., offering something in return for a desired behavior, as opposed to withholding something already granted). One carrot might be financial aid, another might be access to an important technology. However, as we shall see later, with molecular nanotechnology, this carrot will cease to be as effective as it might be today.

(3) "The division of labour, ...so far as it can be introduced, occasions, in every art, a proportional increase of the productive powers of labour. The separation of different trades and employments from one another, seems to have taken place, in consequence of this advantage." (An Inquiry into the Nature and Causes of the Wealth of Nations, Smith, Adam, University of Chicago Press, 1976, p. 9).

(4) In this way, it may defeat the "autarky-efficiency dilemma," a situation in which greater autonomy can only be bought at the price of reduced efficiency in production. See Vernon and Kapstein, p. 23.

(5) And consider what happens when other states strongly oppose a particular action. When military force is not an attractive or appropriate course, trade sanctions are very common. In recent years the international community has punished South Africa for its policy of racial segregation. More recently,

protest over French plans to test nuclear weapons in the South Pacific in 1995 came in the form of anti-French boycotts down to the private citizen level. Longshoremen in Denmark, for instance, refused to unload French goods in Danish harbors.

(6) Or "entangling alliances," as the first American President, George Washington, expressed it to his countrymen in his farewell speech.

Good Fences...

Isolationism may sound a bit out of place in today's world, a throwback to an age when travel between distant lands was slow and prohibitively expensive, and communication was limited and unreliable. But in fact, the roots of isolationism are strong even now, and bare themselves not only at the state level, but in individual regions of states as well.

Isolationism, and its cousins irredentism (1) and separatism, are quite common, even in the industrialized world. In the advanced nations, isolationist sentiments usually take the forms of protectionism (the desire to keep foreigners out of the domestic market) and economic nationalism. While a strong and popular force, the position of protectionism is a generally discredited one. The experience of the industrialized world after the last major incidence of protectionism (which was triggered by the outrageous Hawley-Smoot Tariff Act of 1930, by which the U.S. imposed the highest tariffs on imported goods in its history) is still a bitterly remembered one; most economists agree that it was this extreme protectionism, and the trade wars that followed, that brought on the Great Depression. But irredentism and separatism, in contrast, have an irresistible quality to them, an association with some of the finest impulses in mankind, such as the desire to be independent and to resist oppression.

Irredentism and separatism are found in many industrialized states, such as Canada (the province of Quebec), Spain (the Basque region) and Great Britain (Northern Ireland), and in many other parts of the world (such as Sri Lanka). They are fueled by a variety of causes, such as linguistic differences (as in the case of the French-speaking Quebecois and English-speaking Canada), religious differences, ethnic differences, historical and political differences. The desire of many groups to be separate from others is an old one, and the modern system of large states with strong central governments is a relatively recent innovation. Given these impulses, there is reason to believe that the large state may not survive the advent of molecular nanotechnology, which is sometimes characterized as a state-killing technology. MNT seems likely, however, to prove to be the opposite kind of technology, one that will kill large states but also help give birth to many small states; in this way it will be a state-creating technology.

Consider the cost that would be associated with a small group's choosing to isolate itself from the rest of society. Were the members of this hypothetical group part of an advanced economy, then daily life would immediately become a matter of hardship, relative to the life they were giving up. This would be due to the fact that by separating, they would be losing the benefits of participating in a large economy; i.e., they would lose the benefits of the division of labor. This cost makes the prospect of small group independence either a pipe-dream or too harsh for most to contemplate (2). But if MNT makes it possible for people to create all they need to survive, and even prosper, in extremely small groups, then to some it may become an attractive alternative to a continued existence in a larger, possibly hostile society.

The discomforts and even dangers of being a minority are well understood by European Jews, millions of whom died in the Holocaust. At the end of the war, Jews established their own state in the Middle East, Israel. This was a rare occurrence, but that should not lead us to believe that the desire for such an occurrence is equally rare. As was pointed out above, irredentism and separatism are strong, and the separatist impulse may be even more common than separatist movements, considering the high costs associated not only with being an independent small group, but also with the process of establishing a separate state, which is often long and bloody.

MNT may take the bite out of independence by removing the need to capture economies of scale in order to prosper. By making the cost of capital (in the forms of factories and production equipment) negligible, "one-offs" and limited production runs of goods may have the almost the same cost as their mass-produced counterparts. This would eliminate the need for participation in a larger market in order to capture the benefits of economies of scale; thus, trade, and with it the interdependence that accompanies trade, would shrink by an enormous degree. This opens up the possibility of small, autarkic states, ones that can form on a basis other than economic need, so that religious, ethnic, linguistic and any number of other reasons for association can take precedence. What may result is the formation of small, independent, autarkic communities for specific groups of people; these designer communities may be the state of tomorrow.

Atoms as Bits

The concept of designer communities should not be as surprising as it might sound at first; after all, there is ample precedence for it, found in the on-line world of bulletin boards, chat rooms and MUDs. For anyone unfamiliar with these terms, a brief, yet comprehensive, way of explaining them is hard to produce; they are best experienced first-hand. Nonetheless, the core concepts of the communities formed via the Internet and other electronic means of communication and their relevance for designer communities can be captured in this phrase: they are virtually costless communities. In this key respect, they resemble the state of tomorrow.

Economic demands often force individuals to make unpleasant decisions. One of those is engaging in work they do not enjoy. Another is working somewhere they would rather not be. It is not uncommon in many countries, particularly mobile ones such as the U.S., for workers to move far away from their hometowns in pursuit of work, and it is also not uncommon for them to move quite frequently. In Japan, workers are often separated from their immediate families; many men are forced to leave their wives and children behind for years at a time due to being assigned to a distant post. These high costs are tolerated because they are (presumably) outweighed by the benefits. There is no doubt that many or most of these workers would like to live differently, but there is an economic imperative that drives them to make sacrifices. Changing their lives to more closely suit their desires would entail high opportunity costs, which are the costs associated with choosing one option over others. (For example, choosing to eat a pasta salad precludes eating whatever else is available; the opportunity cost is what is not chosen.) The opportunity cost of working near one's family may be not getting a better paying job, or even not finding work in one's chosen field. Not accepting a transfer overseas may entail not being promoted at a later date.

Similarly, many potential communities that "exist" across the world may become reality due to the way an advanced molecular manufacturing capability could lower the costs of building them. Consider the products of such a technology; they would be cheap, they could be as advanced as any available design on the planet, and they could be made in small, easily affordable "factories," if the technology lives up to today's engineering estimates (3). If so, there should be fewer incentives to make large sacrifices such as those illustrated above. The economic imperatives for such sacrifices (such as greater wealth somewhere else) will become weaker as equivalent alternatives (such as greater wealth at home) become available, and thus the opportunity costs of living in the community one wants, as opposed to the community where one can make a living, become smaller. A preview of this situation is therefore

afforded by the virtual communities we find sprouting on computer screens across the globe, as these communities have very low opportunity costs (which consist primarily of lost time).

The future these virtual communities point to is one of very narrowly defined communities. When one thinks of a traditional community, what may come to mind is an image of a small town, one where everyone knows each other, but not everyone gets along. Those that do not "fit in" or who do not belong are tolerated because there is often no other choice; moving is sometimes prohibitively expensive, either in direct costs or in opportunity costs. Likewise, individuals may choose to stay in communities they are not comfortable with, simply because that is where the jobs are. That certainly seems to be part of the reason for the rapid urbanization taking place in the developing world, where cities are popular destinations, despite being dangerous, overcrowded and disease-ridden. But in virtual communities, new homes, new friends and sometimes new cultures are often just a mouse-click away. These communities are virtually costless in the sense that the costs involved with choosing one over the others are extremely low, and the result of their having this characteristic is that communities tend to be custom tailored to specific groups, tailored in a way that would be impossible in the physical world. It is possible to associate only with fans of certain authors, or with stamp collectors, certain ethnic and linguistic groups, or people with particular philosophical or political beliefs. The options are almost endless, and so they may be when the material world becomes as easily and cheaply manipulated as the bits in a computer. When we can treat atoms as bits, our material world may come to resemble the virtual one in some crucial ways, including this one.

Even without the incentive of custom-built societies tailored to the needs of certain groups, there is ample reason to believe that at least some of our present societies will experience a natural disintegration into smaller units. Consider that one of the advantages of being a citizen of a large state today is that they are relatively safe, in the sense that they are harder to destroy than small states. If MNT makes all states equally deadly to attack, then this advantage evaporates. So will others, such as the advantage enjoyed by manufacturers in having a large domestic market in which to do business, since economies of scale become achievable in small-scale and even "one-off" production. The disadvantages of large states will become more obvious in contrast to the diminished advantages.

Large democracies are quite difficult to manage. They are inefficient in the conduct of their internal state business, and are inefficient in their conduct of external affairs. The decision-making process can be painfully slow, and will possibly be dangerously slow in a future of widespread MNT. All else being equal, it is reasonable to assume that small democracies will perform relatively better in the process of converting potential power to realized power, since they generally have fewer layers of bureaucracy involved in decision-making and in the implementation of decisions. (This is true only relative to large democracies; autocracies, regardless of their size, can have very few layers of government involved in decision-making and implementation.)

The above implies that large democracies may become an endangered species. There certainly seems to be little cause to expect them to retain much popularity in the face of disappearing advantages. Whether they will dissolve or instead pass through some intermediate stages on the way to decentralization and dispersal of state power remains to be seen, but it is unlikely that they will survive in their present form. The fate of autocracies, however, is less clear. If a given autocracy should adopt MNT early on, there is a possibility that it may employ the technology to achieve a level of control over its internal society that will prevent the use of the technology for anything other than government

purposes. On the other hand, any delay may give access to the technology to small groups that may then use it to challenge government oppression, and unlike many past challenges (such as the Chinese student democracy movement in 1989), these movements may be on more even footing with government forces, thanks to their possession of nanotechnological tools.

Note that as mentioned earlier, it may be the case that these designer communities, many of which will be based on narrow interests, may make nationalism an even stronger force than it already is. Compared to the nationalism of today, the nationalism of tomorrow may be much more fervent, since it can be more difficult to have strong feelings for a large state. When state populations number in the thousands or even hundreds, extreme devotion should be much more common, for the same reasons that most people feel more devotion to their families than to larger groups. This new, more intense form of nationalism may only make the prospect of a world state even more remote than it already is, by making a world community harder to forge.

This would be in keeping with the trend of modern nationalism, which is one of declining influence on the side of supranational forces (such as religions and the like) and increasing influence on the side of nationalism. Designer communities, built expressly to meet the needs of their citizens, will be more deserving of their loyalty than are traditional states, and therefore will likely contribute to the continuing rise of nationalism at the expense of more universal forces. (4)

The potential of molecular manufacturing technology to free states from economic interdependence is a crucial element in the possibility of perpetual peace among them. But while the independence of states is a necessary condition for peace, it is not a sufficient one. Due to geographic reasons, states will still be forced into contact. The earth is a globe, and there is a limit to how far apart states can be from each other; the farthest two terrestrial points can be is only 12,756 kilometers. If states remain earth-bound, they will continue to have a necessary relationship with each other, one based on proximity. Presently, geographic isolation is not an option, but in the same way that MNT may make the economic isolation of states possible, so may it may geographic isolation possible.

From One, Many

As addressed in more detail by other authors, molecular nanotechnology is likely to open up the frontier of space settlement by making it far cheaper and more practical than it is today. The settlement of space will be attractive for many reasons, to be sure, such as the thrill of pioneering, the pressures of population growth, and the lure of unexploited resources in the asteroid belt and on other planets. Based on the intolerable situation states will find themselves in due to the development of MNT (that is, being brought closer to the state of nature without the option of forming a world state), there will be an added incentive to settle space: the need of states to get away from one another.

It may not be intuitive to think of simple proximity as a cause of conflict, but in the state of nature, anyone who is not part of one's state is a threat by virtue of his proximity alone. The philosopher Immanuel Kant has this to say on the subject, which may serve to clarify:

"It is often assumed that one is not permitted to proceed with hostility against anyone unless he has already hurt him, and this is indeed very true if both live in a civic state under law, for by entering into this state one man proffers the necessary security to another through the superior authority which has power over both. But man (or the nation) in a mere state of nature deprives me of this security and

hurts me by this very state, simply by being near me, even though not actively (facto). He hurts me by the lawlessness of his state (statu iniusto) by which I am constantly threatened..." (5).

Kant is saying that the very fact of being close together is destabilizing if individuals or nations are in a state of nature, as there is no guarantee that one will not attempt to hurt the others. There are, Kant goes on to say, only two paths to peace in the face of a proximate, independent state: "...I can compel him either to enter into a communal state under law with me or to leave my vicinity." But as we saw above, a world state (a "communal state under law") is not yet an option. The only other choice, then, is to separate from each other, not just economically and politically, but also spatially. Kant gives us the postulate "(A)ll men who can mutually affect each other should belong under a joint civic constitution," and as states cannot join under a constitution in the short-term, they must make themselves unable to affect each other (or at least do what they can to approximate such a situation), as that is the only other path to peace. It is in their interest to spread out and have as little state-level contact as possible.

The settlement of space will allow states to do just that. Other planets and their moons will present the same problem that the earth does (i.e., being a globe, the earth forces a constant proximity of each state to the others), but planetary surfaces are not the only options for off-world settlements. Another option is the creation of settlements that are self-contained worlds, existing independently of a planetary surface. These settlements have been explored in other works in greater detail than can be devoted to them here, but given the potential power of molecular manufacturing, it is safe to assume that if it lives up to its advance billing, it will make such settlements a real and affordable possibility.

Settlements that do not depend on a planetary surface, but rather may be located in almost any position around the sun, will make space settlement a solution to the problem of geographic proximity by removing the constraints of global geometry. On a globe, any move away from one point moves one closer to that point in the opposite direction; spreading out in space, on the other hand, will mean separation in an absolute sense, rather than only relative to one direction. Man will be able to expand like points on the surface of an expanding balloon, and thus can "leave [each other's] vicinity," as Kant advised.

Notes

(1) "Irredentism is a movement by members of an ethnic group in one state to retrieve ethnically kindred people and their territory across borders." (Irredentism and International Politics, Chazan, Naomi, ed., Lynne Reinner Publishers, Inc., 1991, p.10) The word comes from the Italian term Italia irredenta (unredeemed Italy), which refers to Italian areas of Austria which Italy sought to reclaim during the First World War.

(2) There are, of course, some groups for whom the difficulty involve in isolation from the society around them is viewed as an acceptable, or even desirable, price to pay; the Amish (a religious sect in the Northeast of the U.S.) serve as an example of this phenomenon.

(3) Nanosystems, p. 421-434.

(4) "The supranational forces, such as universal religions, humanitarianism, cosmopolitanism, and all the other personal ties, institutions, and organizations that bind individuals together across national boundaries, are infinitely weaker today than the forces that unite people within a particular national

boundary and separate them from the rest of humanity. This weakening of supranational forces is but the negative by-product of ... nationalism." Morgenthau, p. 350.

(5) Eternal Peace, Kant, Immanuel, The Philosophy of Kant, Friedrich, Carl J., ed., Random House, 1949, p. 436.