Safer Molecular Manufacturing Through Nanoblocks

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Those responsible for the safety of a nation—leaders and military and police forces—might be hard pressed to deal with a world in which any weapon or dangerous device could be manufactured in large quantities at the press of a button, at the same time that economic and social norms are being overthrown by rapid change.

We can expect that—by default—authorities will want molecular manufacturing (MM) to be tightly restricted—kept out of private hands, and limited to the few nations that initially have it. That approach might provide some added security—or it might simply create such incredible pent-up demand that any barriers and restrictions are quickly overcome by black markets, intellectual property piracy, rogue-nation programs to duplicate MM, etc.

This essay attempts to chart a middle path for the early years of MM availability—one that allows most of the benefits of MM to be widely available to all individuals and nations, while maintaining some control over key elements. I will not go into who will hold that control, other than to suggest the obvious—that those nations that hold the reins of world power are likely to exercise it to retain power, by delegating it in a controlled fashion to cooperative nations and subordinate authorities.

It is not the objective of this essay to look at radical social changes that might arise due to molecular manufacturing, but rather to see how well MM can fit with existing forms.

DEFINITIONS

Atom Precise - each atom and bond between atoms in an object is as planned in a design. Also used to describe the process or capability of making atom precise objects.

Nanoblocks - atom precise constructs with size on the order of 100 nanometers that can be mechanically connected to form larger objects. Each nanoblock would have one or more functions—as simple as providing physical strength and support, or as complex as digital computation and communication.

Fabber - a device that automatically assembles individual products for human use. In the context of this essay, it will refer to a device that constructs products out of nanoblocks, specifically excluding atom precise nanofactories—those that build products directly atom-by-atom.

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TECHNICAL ADVANTAGES OF USING NANOBLOCKS

Nanoblock-based fabbers will have a number of technical advantages over direct atom precise molecular manufacturing. Even their disadvantages (less precision, lower strength in products) can be considered advantages for purposes of security.

Standardization of nanoblocks—their modes of interconnection and interaction, their functions, and so on—can greatly simplify the process of designing atom precise products. Use of nanoblocks raises the level of design above the point that requires deep understanding of nanoscale physics and chemistry, to the point where anyone could use automated software tools to design simple but useful products, and expert engineers could reasonably design extremely complex and capable products. For example, there would be no need to re-design a nanoscale computer out of individual atoms every time one wished to incorporate information processing into a product, or to re-invent means of digital communication throughout a product.

While the amount of energy expended to form a single atom-to-atom bond and the waste heat generated is tiny, the number of atoms and bonds in a typical finished product for human use is so large that energy and heat issues will be non-trivial when constructing human-scale products. The energy used and heat released to build things out of nanoblocks should be orders of magnitude smaller, as most of the energy is consumed and heat released in the process of making the nanoblocks. Energy supply and heat removal will be much easier for nanoblock fabbers, allowing them to be more compact and operate much faster—though, of course, they still will need a supply of "raw materials"—a store of nanoblocks rather than whatever atomic or molecular feedstock atom precise nanofactories may use.

The nanoblocks needed by a fabber could be made in advance. Energy consumption and heat dissipation would be spread over time, with nanoblocks being stored in the fabber for later quick construction of finished products. Alternatively, nanoblocks could be produced in bulk by centralized nanofactories near convenient energy supplies, to be distributed and sold to owners of fabbers. The energy required to ship a kilogram of nanoblocks, even halfway around the world, should be a fraction of the energy required to produce them.

It should be possible to design nanoblocks to allow controlled disassembly—i.e. recycling of products made out of reusable nanoblocks. Each nanoblock could have an ID embedded that specifies its type—reliably sorting nanoblocks would be far more efficient than sorting atoms. This would mean that the energy that goes into producing them would not be wasted when one no longer needs or wants the product they compose. Instead, the unwanted object could be taken apart, and the nanoblocks sorted for re-use in making new objects. This would save energy and avoid the massive production of junk that could result from large-scale use of inexpensive manufacturing.

A related concept—utility fog[1]—would be a programmable substance consisting of "foglets." Each foglet would be a tiny simple robot, able to interact with vast numbers of other foglets to form nearly any shape imaginable, including objects that are able to move and react to human beings. One might be able to re-create the Star Trek "holodeck" using foglets—an environment in which almost anything becomes possible. The flexibility that makes this idea

[1] J. Storrs Hall, "Utility Fog: The Stuff that Dreams are Made Of", http://discuss.foresight.org/%7Ejosh/Ufog.html.

attractive also creates the risk that the utility fog might be infected with an information virus designed to take it over for malicious purposes, harming or killing or simply trapping a human in the utility fog environment. The fixed-function approach of building things out of nanoblocks and recycling things when they are no longer needed seems safer, at least for the early days of molecular manufacturing.

FABBER SAFETY AND SECURITY ISSUES

The use of nanoblocks creates opportunities to make molecular manufacturing safer.

With a careful selection of the types of nanoblocks made available, a fabber should not be able to build an atom precise nanofactory out of nanoblocks, nor devices that will be a significant help in any attempt to "bootstrap" production of an atom precise nanofactory, reducing the risk of proliferation of atom precise MM to "rogue nations" or terrorists.

A nanoblock-only fabber (i.e. one which cannot produce its own nanoblocks, and so requires a supply of nanoblocks as input) could be distributed world-wide without releasing atom precise MM to everyone, avoiding any risk that anyone could start using it to produce massive quantities of dangerous products out of freely available atoms. Yet it would allow construction of almost as wide a range of products as an atom precise nanofactory, for not much more cost—reducing demand for atom precise MM.

There would be products that could not be made out of nanoblocks, of course—such as nanoblocks themselves. This fact could give official security forces with access to atom precise nanofactories an advantage, as weapons and systems made with atom precise nanofactories will be somewhat more capable than any created using nanoblock fabbers.

Products of commercial or security value that cannot be made out of nanoblocks and require atom precise assembly could be made in centralized plants where security measures could be taken. One simple security measure would be to have such products made by dedicated function nanofactories, with the design built in at the lowest level and unable to be altered without destroying the nanofactory. These dedicated function nanofactories would be produced using general-purpose programmable nanofactories in a few extremely high security plants.

THE RISK OF EXPONENTIAL SELF-REPLICATION

Anyone familiar with the "grey goo" exponential self-replication scenario might ask whether a device made of nanoblocks might disassemble objects made of recyclable nanoblocks and re-use those nanoblocks to produce copies of the device—a "lumpy goo" scenario.

To prevent this, one solution would be to design nanoblocks to require use of a key-like manipulator—too small to be made of or emulated by nanoblocks—to lock blocks together in order to fabricate objects. So long as the key-like manipulator is only built into fabbers, and never made part of or attached to a commonly available nanoblock, only fabbers will be able to build things from those nanoblocks—eliminating much of the potential to build a malicious self-replicator out of nanoblocks. The same key would be required to disassemble objects for recycling—preventing malicious disassembly of objects made of nanoblocks, outside of dedicated recycling devices.

One could object that preventing the fabber from making copies of itself would eliminate a potentially major advantage. A fabber that can make copies of itself could be distributed very rapidly, creating a huge market for nanoblocks and nanoblock-based designs in a very short period of time. That should be a significant advantage for a manufacturer willing to give up income from the fabber and focus on selling nanoblocks. So long as the nanoblocks were non-reusable, the risk of exponential self-replication would be minimized—and the manufacturer could expect their fabber to become a universal standard before competitors got to market, making their nanoblock business quite profitable.

However, other companies would very quickly begin producing reverse-engineered "clone" and improved nanoblocks, cutting into the original manufacturer's revenues. It would likely not be long before someone offered re-usable nanoblocks, opening the way to exponentially self-replicating systems.

Given the value of recyclable nanoblocks for energy and cost savings and convenient disposal, and the security risks of self-copying fabber components, it seems wisest to allow recyclable nanoblocks but prohibit fabbers that can self-copy. Very likely the cost of fabbers will fall rapidly in any case, since they would themselves be made with atom precise MM.

The above assumes a relatively free market in fabber and nanoblock designs. That may not be the case if the government is involved and sets a single standard that all manufacturers must follow. In that case, one might see a "utility" model, where nanoblock prices are controlled to allow manufacturers a "reasonable" profit. This scenario would be likely to slow innovation—but, of course, that might be exactly the effect desired by the government. Non-self-copying fabbers with recyclable nanoblocks seem the most likely choice in such a standard.

LIMITING OTHER POTENTIAL ABUSES

Fabbers will very likely be targeted with the equivalent of computer viruses—malware designs that will attempt to infect fabbers and transmit copies of themselves, and probably use the fabber to produce something annoying or dangerous. The greatest danger would be if fabbers were connected directly to the Internet, allowing very rapid spread of such a virus without human intervention.

One way to fight this would be to keep all fabbers "offline"—designed to only allow loading new designs by manually transferring a design on a physically separate storage medium. This should slow the spread of malware down to human speeds, allowing humans a chance to become aware of the problem and deal with it.

It may prove useful to establish a program that allows anyone with an interest in "clever fabber hacks" or atom precise molecular manufacturing to exercise their curiosity in a safe, controlled environment. This would help reduce the incidence of 'experiments' analogous to releasing computer viruses and worms into the wild, by giving hackers an alternative and encouraging environment. Their creative—or potentially destructive—ideas could benefit society or help plan defenses against potential dangers. It also provides an opportunity to catch the few who are going down the wrong path and turn them around - or at least keep know who they are if they seem inclined to persist in dangerous pursuits.

Malicious users could produce dangerous or otherwise undesirable nanoblock-based products. For example, a murderer might create a knife, kill someone, and disassemble the evidence. Or perhaps create a household robot - but program it to wreak havoc. Defenses against such abuses should be taken into consideration. There are several approaches that might be helpful.

Since recyclable nanoblocks would have a readable type-ID built in, it would be trivial to extend that to a unique ID, making it possible to backtrack the source of an otherwise anonymous malicious automated device, or obtain a clue from nanoblocks torn off a more mundane object such as a knife. With users knowing this, fewer will seriously contemplate engaging in malicious production.

LIFE WITH FABBERS

The use of nanoblock-limited fabbers (i.e. those that cannot make their own nanoblocks) has some likely implications for society. Certainly costs of many material goods should fall, raising the standard of living of many people around the world.

If instead, self-copying fabbers and non-recyclable nanoblocks are available, benefits for less developed nations may arrive a bit sooner, but the need to continually buy more nanoblocks will limit their long-term impact.

Some visions of life with atom precise MM have people going “off the grid”—quitting their jobs, setting up independent solar powered homesteads, and ending capitalism and perhaps economics as we know them. That scenario would be very unlikely with non-recyclable nanoblocks, and limited with recyclable nanoblocks, as people would still need to engage in productive economic activity in order to have money to buy replacement nanoblocks.

With most jobs in manufacturing and distribution eliminated, people would largely find jobs in the service sector. Service jobs will shift even more to specialization, due to increased competition. Developed nations have already gone far in this direction, and other nations will likely be forced to follow suit. This will be a difficult transition for nations that have only recently begun developing and have been heavily dependent upon manufacturing for export—services will be more difficult to export, and local consumers may not be as used to consuming services.

Another common vision of life after the arrival of atom precise MM has a tension between free “open source” designs and commercially available designs. The greater ease of designing with nanoblocks instead of atoms would likely give the open source approach extra impetus. Still, there will also be a fair number of things that people will not trust to be made from nanoblocks, and conventional commerce in those products will continue. Also, as always, there will be elements of style and usage that will cause people to pay for things even though free alternatives are available, just as people today will pay more for a real Rolex™ than a fake, or pay for a commonly used operating system even though free operating systems are available.

With so many choices, and so many people seeking employment in services, it seems likely that many stores will focus on personal service and product advice. Goods purchased in a shop will be priced based on a combination of service and the prestige of certain designers, with a very small component of the cost of the nanoblocks used in product construction. There still will be “big chain” stores with vast showrooms filled with goods, but even there, the key will be the service of providing one place to go see and compare a huge variety of goods. They may make some goods while you wait, others they’ll have available off the shelf, still others—

especially larger goods—they'll make and deliver to your home. Likely, there also will be a way to buy "limited uses" designs for home production.

CONCLUSIONS

Making nanoblock-limited fabbers available to everyone promises to provide most of the easily imaginable benefits of unrestricted atom precise MM, with significantly fewer risks. Fabbers can provide useful advantages of speed, efficiency, and safety. Certainly, they are not a cure-all, creating a perfect utopia—but the problems remaining may be humanly manageable.

Perhaps fabbers would only be a transition phase before a shift to a more liberal availability of atom precise MM, but given all the risks and uncertainties raised by molecular manufacturing, this more controlled introduction seems warranted. The most likely alternative is not free release of atom precise MM, but even tighter restrictions. Fabbers limited to constructing things out of nanoblocks seem like a reasonable compromise approach, and one that government authorities and others may consider acceptable.

About the author:

Tom Craver has been fascinated by the implications of molecular manufacturing for two decades. His writings have appeared mostly on the Internet and in NanoTechnology Magazine. As a senior software engineer at Intel Corporation, he analyzes and tunes the performance of video codec software for near-future microprocessors. Master of Science (Purdue University). Seven patents granted.