Designing a Nano-Safe Future

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Nanotechnologies are fast becoming one of the most ubiquitous of the emerging technologies to have a commercial and economic impact. Along with artificial intelligence systems and biotechnologies, nanotechnology is a billion-dollar global industry that has massive product implications.

Made famous by K. Eric Drexler, Molecular Manufacturing (also known as atomically precise manufacturing, molecular engineering or productive molecular nanosystems) is an emerging manufacturing technology that has the potential to shift current economic, societal and cultural norms radically. As the name implies, molecular manufacturing is the name given to a manufacturing technology that is capable of constructing objects from the molecule up. This atomic level of control will allow for an unprecedented scale of accuracy and tolerance in products manufactured

Molecular manufacturing promises to usher in an era of radical abundance in which products such as medicines and foods can be manufactured in large quantities, using input materials of our choice, with little-to-no harmful by-products and at little cost. Although this technology does not yet exist; once created, we should possess an efficient and cost-effective system for controlling matter. These breathtaking advances in medicine, food supply and general material wealth will substantially change the very conceptions of contemporary economics, but also improved the quality of life for billions of people around the globe. Those ends, however, with promises of great material wealth and abundance, also come with the potential for existential risks. The most significant risks come not even from nanotechnology itself but from its convergence characteristic. What does that mean exactly? It means that nanotechnology, biotechnology, and artificial intelligence have many overlapping qualities that make them symbiotic with one another. Nanorobots require artificial intelligence systems to build specific infrastructures. Some may require the capacity to be programmed so that they can discriminate between specific types of cells to terminate and which to leave unharmed.

This convergence characteristic blurs many of the lines of liability. More importantly, it makes the application of existent governance systems hard to apply. What may apply to one domain may not apply to another. However, what happens when a particular technology

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simultaneously exists in two or more domains at one time? The differentiates brings to bear emerging ethical and social issues.

One of the primary concerns, however, is ensuring that effective governance is undertaken proactively to ensure recursive improvement over time and avoiding ex-post facto, reactive governance measures that may ultimately prove to be ineffective. The difficulty in accomplishing this, however, is that many of the technologies, particularly artificial intelligence, are making developmental leaps on a continual basis, with almost no governance measures put in place to curtail any adverse outcomes that may potentially emerge. This failure of implementing early stage regulatory controls is a recipe for disasters as the issues that may emerge from a hard takeoff of AI, and the unrestricted use of nanotechnologies and biotechnologies can prove to be catastrophic.

Major stakeholders and policymakers must ensure that the current developmental trends are directed in such a way that best ensures the beneficial development of molecular manufacturing systems. Doing this requires not only regulatory measures at an international level to be implemented but also an incorporation of values at the early design phases of these technologies to ensure a safe developmental trajectory. This two-pronged measure is the best feasible way to guide technologies development on a desirable pathway.

- Value Sensitive Design (VSD): Taking into account the scope of the impacts of APM, technology is not value neutral. A design approach such as Value Sensitive Design must be employed to account for the broad range of stakeholder values during early design phases. Ensuring that the values held by both direct stakeholders (e.g., users) and indirect stakeholders (e.g., developers). This instrument provides a systematic means to identify stakeholders, value implications, and effects of a proposed design early in the design process. By adopting a VSD approach to the design of molecular manufacturing the values held by stakeholders at all socio-economic statuses can be accounted for and incorporated into the design of the technology to ensure the highest likelihood of producing a beneficial product.

- International Regulation: The design of technologies such as APM, with their far-ranging impacts, requires the design and implementation of international regulatory frameworks that are capable of efficient surveillance of developmental groups (governmental, private, or rogue) as well enforcement and intervention. This will require the unilateral cooperation between nation states in drafting de novo legislation that is both potent, yet not burdensome to innovation. Additionally, international regulations must be delicately balanced according to existing regulations governing nanomaterials and products at the state level to ensure better harmonization and reduce any regulatory overlap. Soft-law strategies pose as the best option for exploratory and speculative technologies that are built upon existing technologies (i.e., nanotechnologies). This form of anticipatory soft-governance permits the adoption of new changes into a regulatory framework that can keep pace with the continually advancing technologies it aims to govern.

One of the difficulties in determining what exactly should be done now with technology is the fact that the technology that is in question does not yet exist. However, the risks associated with its ubiquitous enrollment make questions about its design and governance essential questions to ask *before* it becomes a societal issue. The risks associated with the releases of nanotechnology, AI, and biotechnology are existential with global catastrophic impacts should something go awry. This means that we have to seriously account for the fact that there is a cost for not adopting a design philosophy that accounts for real human values during design. Ignoring the design of technologies, particularly ones that have these types of risks associated with them, may prove devastating in the long run as latent issues emerge over time. The moral of the story then is that we should have already acted in this way, yesterday would have been better today, but today is still available for action. A design-for-values approach like VSD provides the best means of designing nanotechnology with values. Although something may come along later that make VSD obsolete, debating which is better may ultimately prove all design philosophies useless, especially if the technology in question is developed before anything is implemented.

Nanotechnology and other converging technologies can without a doubt potentially provide us a future of peace, security, and material abundance. However, just as quickly they can cause harm of devastating proportions. Reducing those risks, in light of the continuing research and development of these technologies is paramount. We must take the steps necessary to ensure that not only the use of the technology is regulated once it is developed, but the course of its development is regulated now before we are faced with issues too big to deal with.

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