The Fourth Revolution: Additive Manufacturing and Society

When looking at the history of humanity, Toby Ord highlights three defining shifts that "accelerated our accumulation of power and shaped everything that would follow" (Ord, 2020). These revolutions– agricultural, scientific, and industrial– each fundamentally shaped how humans interacted the world. Additive manufacturing, or 3D printing (3DP), promises to be the next great shift. As a technology with the potential to decentralize the manufacturing process and cut out the middlemen between producer and consumer, it is rapidly becoming a technology affecting how we all live our lives. There are, however, two temporary limitations preventing its transition into becoming a truly transformative technology.

The first is that the most commonly printed material, manufactured plastic, is degradable, structurally unsound, and can be near impossible to source for many across the world (Marinescu, 2018). The second is that of scale, with only the most fortunate having access to industrial-quality 3DP capabilities, able to create massive constructs and delicate circuitry alike (Brans, 2013). Additive manufacturing must improve in order to truly impact humanity. When this happens, and towns from Austria to Zimbabwe hold printers capable of refining concrete into commodities, society will encounter a transformative technology with stakes just as high as the threats analyzed in *The Precipice*. The immediate parallel to compare this to would be that of AI, with technologies, if implemented to their fullest potential, making te a massive portion of the modern economy obsolete, while also posing tangible threats to the security and well-being of people across the world.

Speaking idealistically, this development could be the most significant one humanity will ever undergo– an elevation into a post-scarcity society. *The Precipice* defines human potential as "the set of all possible futures… including everything that humanity could eventually achieve" (Ord, 2020). By unshackling each individual from the demands of basic survival, 3DP not only promises to dramatically increase the standard of living for all, but also expand the capacity for humanity to spend time innovating and creating. In the short-term, though, additive manufacturing threatens to undermine society by concentrating wealth and destabilizing the economy. Additive manufacturing done in a local context "can fully displace a series of employments in the manufacturing sectors" with ripple effects extending far beyond the manufacturing sector itself (Pierrakakis, 2014). The retail industry is expected to grow to about 31.7 trillion U.S. dollars in 2025, and 3DP threatens it in its entirety as the 3DP industry grows into its maturity (Sabanoglu, 2022).

For ways to mitigate these challenges, we can look to the past. Both the trends of industrialization and digitization share commonalities with additive manufacturing, characterized by a displacement of labor, destabilization of society, and eventual economic equilibrium. The Industrial Revolution saw the Luddite movement in response to a loss of employment due to machinery (O'Rourke, 2013). Automation, as an ongoing process, is similarly marked by layoffs, friction, and retraining initiatives (Illanes, 2018). In this iteration of economic metamorphosis, governments and corporations alike can take coordinated action by incentivizing a movement away from traditional retail and promoting new economic sectors. In more specific terms, developing nations "need to capitalize on 3DP to 'leapfrog' development stages and to create local enterprises to manufacture goods," while countries with strong

industrial bases must enact economic strategies to disincentivize traditional manufacturing and introduce additive manufacturing (Garrett, 2014). Similarly, companies must begin to move their own techniques and workers away from methods outclassed by 3DP, both in order to maintain a competitive edge and to help their employees adapt to a new economy. With these initiatives, society can withstand the transition to 3DP so long as we stand together.

However, there are dangers to the proliferation of additive manufacturing beyond economic shocks. 3DP puts advanced manufacturing capabilities into the hands of any organization with access to the Internet. This is an incredibly powerful and dangerous tool made freely available to the public, which poses serious risks and multiplies the ability of fanatical groups to destroy humanity's potential. Additive manufacturing closes the gap between established authorities and radical forces, allowing the latter to reach industrial parity with the former. In practical terms, this means state-of-the-art, mass produced weapons in the hands of any group with 3DP capability, a phenomenon already occurring with the spread of digital blueprint for printed guns across the internet (Cronin, 2019). This capability propagates a mindset and capacity for widespread violence, not only harming humanity's potential but also potentially destroying the lives of millions across the world.

Taking this one step further, 3DP will expand the capabilities of smaller groups to create more than just conventional weapons. Additive manufacturing would allow radical organizations to create WMD components such as "delivery vehicles/components (e.g., missiles and engine components), some payloads (i.e., chemical and limited biological), and supporting infrastructure" (Nichols, 2018). Additive manufacturing is also currently used to print advanced laboratory equipment, which holds the risk to facilitate more nefarious aims– for instance, allowing the creation of biological or environmental weapons that could threaten humanity as a whole (Capel, 2018). The general effect of maliciously used additive manufacturing would be to increase the likelihoods of existential threats.

However, authorities can take advantage of a fundamental limitation on the additive manufacturing: scarcity of specialized resources. The printing of components such as heavy elements (such as Uranium, Plutonium, or Beryllium) or biological agents out of reach for the foreseeable future (Nichols, 2018). 3PD can only facilitate the production of WMDs, which reinforces Mr. Ord's proposals for strengthened international regulation of high-risk materials (Ord, 2020). There must be preemptive action from all parties with a responsibility to protect the world, from corporations to nations to regulatory bodies. Those with the technical information to create WMD components– governments and corporations– need to increase the security, both digital and physical, surrounding these components. Similarly, regulatory bodies must collaborate with countries to monitor exports from radioactive materials to biohazards, as that protection may become the last barrier against a malicious organization creating a WMD. Finally, we must contend with the fact that minimizing the possibility of misuse means restricting research and growth. Experts in the 3PD and security fields alike must remain vigilant, even at the cost of slowing down the development of further 3DP capabilities, for careful consideration of the effects of further research could prevent threats before they even arise. Ultimately, with a coordinated effort to ensure the wrong materials and expertise never fall into the wrong hands, we can protect humanity's future.

3DP will change the world, and it is the decisions of our time that will determine how that change is felt. By anticipating 3DP's problems in implementation and maximizing the benefits it can bring, humanity can take its greatest step towards the future. In a world not held

in check by scarcity, by the daily labor of surviving, there's no telling what wonders we could create. If we use this technology against one another, transforming additive manufacturing into yet another tool of destruction, we would stifle both the possibilities of 3DP and the potential for humanity to escape the tyranny of scarcity. A combination of vigilant regulation and applied empathy with our fellow humans is what makes the brightest future possible, built on a 3D-printed foundation.

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