The Fourth Industrial Revolution — End of the Beginning or Beginning of the End?

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It sounds like hype, a publicist's dream of a phrase to describe the current moment as the beginning of a Fourth Industrial Revolution. A look back at the first three, how they came about, will help to see why the description is indicative.

The First Industrial Revolution

If there is one thing that defines the First Industrial Revolution it is steam. The idea of capturing the heat and energy in steam had been around for millennia. But to capture steam as an energy source requires many things. First, on a very simple level, there has to be an incentive. In this case Britain, with its system of patents, proved to be the ideal. Britain had other things as well: large deposits of coal and iron, demand from nascent industrial sectors (mainly textiles, though that would change), and an understanding of metallurgy. Even with all those, the first steam engines for transportation on railways and ships were not very impressive and required frequent refueling. Yet steam did change a still pastoral society into William Blake's poetic "dark Satanic mills". And while fast clipper ships would hold speed records until later in the 19th century, steam ships were crossing the Atlantic regularly and as demonstrated in the Battle of Hampton Roads during the US Civil War, the clash between the *Monitor* and the *Merrimack* showed that the future belonged to steam powered ironclads (the era of the true battleship was still half a century off).

The Second Industrial Revolution

As steam defined the First, even while it was still ongoing, the Second would be defined by electricity and light, and inseparable from Thomas Edison and the team he assembled at Menlo Park, New Jersey. Edison was present at a strange juncture when steam-powered trains crossed the North American continent, side by side with telegraph poles which carried messages via electricity.

It was clear that electricity could do far more, and that to maximize the utility of large steam-powered industrial devices there had to be some way to light a factory, or an office or a home, after sunset. Edison solved that problem with his invention of the incandescent light bulb. But while a single bulb in a lab was a marvel, the infrastructure to actually make it work beyond that did not exist. So Edison designed and created that as well, lighting the area that would now be around Wall Street from a power plant constructed nearby.

Edison was both an inveterate tinkerer and a rapacious monopolist. He invented the first movie cameras, but when people wished to make movies without paying the royalties demanded by Edison they ran off to a place that would come to be known as Hollywood. It is an inconvenient fact that the entertainment industry prefers not to remember that it was essentially started by people who today would be called pirates.

The Third Industrial Revolution

It is important to note here that there were decades of overlap between the First and Second Industrial Revolutions and that electricity did not then, or even now, replace steam entirely (most nuclear reactors work by heating water into steam to drive turbines to create electricity). The Third Industrial Revolution is one that does not break along easy lines. On the science it would certainly be the discovery and development of nuclear power.

Without questioning the science, or the genius of the men involved in the early development for all the tens of thousands of nuclear warheads ever built, only two were ever used in war, and no hydrogen bomb has ever been used in a war. There have been many tests over the years, most recently in North Korea, but even as a power source nuclear power was a fraction of the total even before the meltdowns at Fukushima. Without nuclear power there might have been a greater build-up of greenhouse gases and increased global warming, or conversely the push for greater efficiencies from sustainable and renewable sources might have begun and kicked in far earlier.

Both are counterfactuals that serve to illumine something else. Something that in good ways and bad dramatically changed the lives of people across the world: the development of the automobile (and trucks). Both the diesel and internal combustion engines have been around for over a century, but it was not until they were put to use in mass production (itself made possible by the electrification of

factories) that they were affordable and began to be used in ordinary life.

It would be hard, perhaps impossible, to find an ordinary person who has not driven or ridden in a car or a bus or a truck. And it would be hard (not impossible but not easy) to find someone at random who has been near a nuclear weapon or a nuclear reactor (I can write that with some personal knowledge of both: as a child I was shown the reactor room of the civilian nuclear ship *USS Savannah*, and can still remember the Cherenkov glow, and as an adult I have been to a NATO site where nuclear-tipped cruise missiles were stationed as part of a counter to the Soviet deployment of SS-20s).

Which should win for the Third Industrial Revolution depends on one's perspective and will certainly be a subject of contention for many decades to come.

The Fourth Industrial Revolution

It is an arbitrary starting point but arguably the Fourth Industrial Revolution started in a place whose purpose was one of the deepest secrets of the war, and where huge electro-mechanical proto-computers labored at decoding the millions of possible permutations of messages sent on the German Enigma encoding machines. The next jump was the invention of the transistor. Even if most people at the time associated the word with the small radios that were just beginning to appear, the transistor was the linchpin that moved computing from electro-mechanical to electronic.

For most of the next decades progress was slow, and the machines that most people could see were near room sized and required punched cards to operate. The more advanced ones were in labs or very secure military facilities. That changed in the mid-1970s, the unlikely demand driver being the large and growing law firms which had real-time pressures to get huge documents written and submitted to court and to opposing counsel — briefs that were often started by associates and edited by partners (with additional citations and corrections) and all input on what were called Vydecs, which looked something like the computers on the original *Star Trek* TV show and were so sensitive that the room they were in had to be swept for static electricity every few weeks (it built up on the carpeted floors and was enough to throw the machines off).

The Vydec might have been closer to what was at Bletchley Park — Britain's secret wartime code-breaking center — three decades earlier, but things fast forwarded after it. Within 12 years after the Vydec was in wide use, special effects crews in Hollywood were using run time animations to see the best placement for cameras and models on a *Star Trek* movie. Four years after that in *Terminator 2*, the liquid metal T-1000 (which never really lived outside the computer and was inserted into scenes — in its raw form, the actor who played it, Robert Patrick, of course does) appeared to audiences, and before the century ended the first of the *Matrix* films (with the sub-theme that the existing world as we think we know it is a computer-generated fantasy which we must wake up from) had a very computer graphically assisted Keanu Reeves doing the tango around bullets flying at him.

Put in different terms, that is a dedicated document correction machine to the creation of a believable and startling world, within its own terms, where human stunts are not parlor tricks or acrobatics but actually instruction sets programmed into a computer and rendered onscreen (a company that pioneered some of the techniques was Pixar, which is now one of the standard setters for movies that are entirely computer-driven animation).

Those few illustrations which most people recognize were followed by the same types of leap in every single field. Better and faster chips made for better and faster programs, whether word processing, spreadsheets, simulations, games, game consoles and more.

Frankenstein Unchained

It might be possible to talk about all of the developments on desktops and laptops as a logical continuation, an evolution, perhaps portending a paradigm shift, but not as an industrial revolution since it took the computer industry a long time to get into the mainstream. It is a counterfactual to do so however, because it leaves out the other development: mobile phones.

My first mobile phone was a Nokia. It was quite thick and would have doubled nicely as a blackjack had I need to use it that way. I got it in 1998 — it was simple, it made calls, I could send texts. The one given to me in China some years later, still a Nokia, was about a quarter of the width and half the height, but it too made calls and

could send and receive texts.

The idea that before another generation had passed there would be smartphones with greater memory capacity than the laptop I had then, which would take pictures, play music and movies and that there would be thousands of programs for them, even if I could not see the sense of many of them, would have seemed to me as unlikely as it did when I called back to the US from Tiananmen Square. But not only would they exist, they would come to be themselves key drivers in the economy.

Adjusting these to the Fourth Industrial Revolution we take the patents and the legal schemata for granted, though aspects are contestable. Resources and raw materials should be examined more closely, as should infrastructure and demand for products by technology.

Indispensable Resource & Materials

Without power, specifically electricity, everything goes away and the revolution, to paraphrase a song, is not televised (or we might say streamed live). Remember that more and more of these devices are wireless, untied to any fixed electrical source. Their power, as much modern power in everything from smartphones to electric cars, comes from lithium ion batteries.

Why lithium? Because these batteries can be charged to higher densities of power and can power their respective devices longer. And they come in sizes from the buttons you want to keep from small children and animals to those huge packs you are sitting on in a Tesla. (It is those huge packs that have recently been banned from being shipped on passenger planes and the recommendation is that even on cargo planes they be charged to only 30% of capacity, while even passengers are being discouraged from carrying packs of spares.)

The reason is simple: a runaway reaction in a large stack of lithium cells can cause a fire that burns dangerously near the melting point of aluminum, enough to compromise an airframe and bring a plane down. There is substantial evidence that this has already happened.

Dr. Hans Meyer, the CEO of Tecop International, a company involved with aircraft security and other specialized equipment, cautioned: “We have to remember that this, despite what seems like a long time line, is actually a young technology and nowhere near fully mature. I have read papers where the efficiencies in some lab research going on now exceed what is currently being used by a factor of three to four. If that proves to be so outside the lab in mass production, it would make electric cars far more feasible and affordable. ”

Dr. Meyer added, “With lithium we do not have the same issues as surfaced with China and rare earths. The element itself is common, though the purest form is found in the desert in Bolivia. We have to look at the ways the constituents are reprocessed or disposed of.”

That kind of leap in lithium ion capability would make electric cars more feasible and cost effective, and much more besides cars. These new batteries, though, could not be three to four times as volatile; that would pose an unacceptable risk, so the double problem is to get more power while lowering the volatility.

Fortunately it may work; lithium mixed with other electrolytes may prove to be both faster and less volatile. There is also the certainty that chips, in the near term, will improve, and some of that improvement in performance may translate into greater power efficiencies (up till now most such improvements have been used for putting as many devices and apps inside a smartphone or pad or

Sidebar 1

A battery, any battery, has a lot in common with a stick of dynamite. They are both forms of stored energy based on chemical reactions. Dynamite releases all its energy at once: that is its purpose (and why it was such an advance on black powder blasting which had been previously used). A battery gives up its energy in a much slower and sustained reaction between its constituents. With lithium ion batteries, because they are primarily using lithium salts, they must be folded in certain ways for optimum energy release. That is why the shapes vary so widely from the coin size used in watches, to the small, keep away from pets and small children, to those in laptop or tablet computers, right up to the huge stacks needed for electric cars. Some are round, but not cylindrical as the classic C, A, AA and AAA batteries are. Also, it should be noted that although most battery companies do refine their products or find better shells and cathode and anode materials, the lithium ion battery, because of the large differences in size and function, has gone through iterations that are still ongoing (the last major one was 2013).

other mobile device as possible).

Your Way or the Highway

There was a tagline to an old commercial that went "All we ask is that you let us serve us your way." That is about to become reality in more ways than we can imagine now, due primarily to 3D printing, which has advanced far more rapidly than was initially foreseen.

The smartphone market seems almost to be a natural first stop along the way. Want your smartphone to look like a bowtie? Apple or Samsung software can sell you the plans which you can have printed out to see if you like them, and if you do, the item may be able to be made in the same store (using alloys requires a different kind of 3D printer than that used for plastic mock ups, but they, too, are coming down in price). There may be a few different configurations, depending on what you want on the smartphone. The one constraint right now seems to be the glass for the screen but that is not an insurmountable obstacle.

Shoes are another area where customization, previously something only affordable by very well-to-do customers, will come down to the mass level because your foot can easily be scanned and modeled, and some kinds of shoes may be able to be made in house; others may require sending out and waiting a week. When they arrive, though, they will fit. They will be your shoes in every sense of the word. Some of the very famous custom shoemakers may find there is more money to be made in licensing their designs to this new market than in serving a sliver of the 1%.

The same may go for wristwatches and most accessories, and clothing. It will be a time shift back to an era before mass marketing when everything was custom and artisanal, and artisans knew all their customers and kept a limited amount of inventory on hand (the infrastructure to support mass marketing was not even in place until later in the 19th century, and even in the early 20th it was still very top down, as epitomized by Henry Ford's famous quote that customers could have their Model T Fords in any color — so long as it was black).

Inevitably this will change supply chain relationships and it may be one of the things that drives a lot of low-wage job centers out of that way of climbing the value chain, because the value chain itself will undergo a complete change.

Sidebar 2

Cybersecurity — The Worm in the Apple

The issues raised by the need for cybersecurity in a world where even more sensitive data must flow are complex and will be dealt with at length in a forthcoming article. For now, suffice to say that for any of these to work, end users and companies alike will have to be satisfied that what they send is secure — something that today is still not within immediate or foreseeable reach.

Robotics & Attendant Dangers

Robotics is the field where half the future is already here. Japanese car manufacturers pioneered the assembly line robots that are now standard, and Cyberdyne, a Japanese company, has received a permit for a robotic exosuit for mobility-impaired patients. The skies over conflict zones are patrolled by drone aircraft, most armed with missiles. The United States has begun testing a submarine drone that could last months at sea — this will take some years in the proving, but it could make the ballistic missile submarine, the battleship of our age, obsolete because boomers, as they are called, are noisy, and gathering sound signatures is something that has been done routinely since the 1960s. A drone can hang motionless on any transit or entrance or exit route undersea, and if given the order, fire at a target before the target is even aware it is there.

It is not only happening at sea, but in the air — the next Top Gun may not smile like Tom Cruise but it will not miss many shots — and on the ground, where the US Army is experimenting with drone tanks. With no humans in them, they are smaller and can stay out longer.

The debates have already begun on what powers can or should be delegated to autonomous weapons systems when the actions they may take will involve killing humans. They are deeply troubling debates, more so given that we are on the cusp of where these things can not only be envisioned but where they can be built. They are not the only set of troubling questions raised by the Fourth Industrial Revolution.

This part of the revolution is closer than many people realize.

Already, as you read this, Aegis destroyers are at sea. When a missile is launched in an area they are focused on (for example North Korea) their X-Band Radars go on to give a 3D cross section of the launch vehicle. Its vulnerable moment, if it is an ICBM or IRBM, is at its apogee as it turns to make its descent. The captain of the ship has a margin of 120-180 seconds, approximately, to make the decision to fire or not. For a human, faced with a rather consequential decision, that is not a lot of time.

Taking humans out of the loop may make the process seamless and faster, but we are still at the stage where what seems like Artificial Intelligence is really only brute force computing done at speed. When Big Blue (IBM's supercomputer) beat a chess master people were already talking about AI having arrived. What Big Blue did was not think, but mathematically crunch every possible move and the benefits and deficits of that move. The difference is subtle but very real. A drone, whether seaborne or airborne, given a fire order has no capacity to weigh the moral implications of its action. It is in the truest sense only following orders, or if it is sufficiently autonomous to have been programmed with a parameter set, following its program.

The missile submarine it fires at will not be unmanned: there will be a crew of 100-120 sailors on board, just as a vehicle on land will not be self-driving (yet) and there will be a driver and passengers. We almost surely will get to a rudimentary form of AI before we can program moral considerations into a machine. (Science fiction readers will be familiar with Issac Asimov's 10 laws of robotics which anticipated this dilemma.)

Where to Next?

Matthew Bugler, a strategic analyst, has been looking at the issues. "I don't doubt that we are right at the start of the Fourth Industrial Revolution," he says. "And there are many ways to look at it; for example, in Japan they have been dealing with robotics for years and were pioneers in using robots in industry. In the US we were pioneers in using information, in the form of software and hardware. But putting them together is an entirely different matter.

"What I am concerned about is whether governments and corporations are thinking about how many jobs will be eliminated or completely changed when we get 3D printing just a little bit further on and entire parts of the supply and logistics chains that we use today become redundant."

Bugler points to a lot of recent trends, such as the rise of disruptive services and technologies like Uber. "We are seeing that the younger group that has entered the workforce in the last five or so years, and probably the cohorts that will come behind them, are less tied to the idea of owning things, whether it be a house or a car, than they are interested in having the convenience of them when they want them. That changes, for instance, the tax basis for most cities and towns which is, to an extent, based on home ownership. What will replace that and how will it be made available so that governments can deliver the services that citizens expect?"

His point stands in direct contrast to that often-abused term "creative destruction" which, taken out of context and used to describe what has happened to cities like Detroit and Flint, and to towns and villages across Japan, sounds like a macabre joke. Pittsburgh and Seattle could easily have been on that list, but both were fortunate enough to reinvent themselves and become bigger (some might argue about better) than they were. But they are the exception that proves the rule Bugler is reaching for.

It is the nature of these kinds of large paradigm shifts to drive change: change in law, change in economic arrangements, change in social arrangements (sociology got its start as a science when those "dark Satanic mills" in England filled with people who had formerly lived in the countryside and were now jammed into cities without planning for water, sewerage or transportation).

The cities of the First, Second and Third Industrial Revolutions were mostly unplanned and many of the infrastructure problems facing large cities around the world bear this out (clean water and sewerage treatment are still a problem almost a century and a half after the benefits of both began to be implemented). It may turn out that the ideal city of the Fourth Industrial Revolution will be a kind of "super city" or "super region" which allows for the fluid movement of people and goods, is integrated with agriculture by hydroponically grown crops and could supplant the nation state as we know it today. The notion may seem fanciful, but many of the factors that could be key drivers would have seemed fanciful not long ago. JS

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