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## **Challenge for society of scale and speed of technological change**

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Let us imagine that it is 1895. Telegraphy and telephony are well established. Common forms of transportation include ships, canals, railroads, horses and horse drawn carts. Automobiles are still a rarity but mass production lies about a decade ahead. A year ago, Guglielmo Marconi demonstrated short range radio transmission and this year has just shown that it works at ranges over two miles. Six years from now, he will demonstrate trans-Atlantic transmission and in 1912, the sinking of the Titanic will underscore the enormous importance of wireless telegraphy. Henri Becquerel is about to discover radioactivity. Einstein's four miraculous papers<sup>1</sup> will appear in just ten years. The Wright Brothers heavier-than-air Kittyhawk flight is only 8 years away. Charles Lindbergh will make his famous trans-Atlantic flight in 1927. John Logie Baird will demonstrate television ("Televisor") in early 1926.

While we may think of today's technology as speeding faster than we can keep up, it's fair to say that over 100 years ago, people's heads were spinning with new technologies also arriving with unexpected speed and effect. People, practices, laws and norms adapted to these new technologies and the products and services they enabled. Nor should we be surprised. Thinking of fire, the wheel, roads and aqueducts, water wheels, windmills and electric power, reaching back thousands of years in some cases, humanity has managed to accommodate and adapt to a wide range of inventions. It may be hubris to believe that today's technologies are somehow more profound and have had greater impact on society than today's latest developments.

When you are living in the maelstrom, however, it is not hard to feel as if change is overwhelming. This is especially true of inventions that serve as the basis for a cornucopia of consequential inventions. Digital technology, first with mechanical calculators, vacuum tubes but more recently with semiconductors since the 1947 invention of the transistor, has created an unprecedented opportunity for the creation of new products and services. The animating force behind these products is software. Programmable devices appear to have infinite malleability - limited only by what

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<sup>1</sup> Brownian motion, photo-electric effect, special relativity and mass-energy equivalence.

human intellect can program. Some forms of AI may even take over some of that task in the future!

Mainframe computers running in “batch” mode gave way to timesharing in the 1960s. By the early 1970s, packet-switched networks of computers emerged in the form of the ARPANET<sup>2</sup> which became the progenitor of the Internet<sup>3</sup> which was formally launched into operation in January 1983 after a ten year development cycle. Commercial operation of Internet service began in the United States in 1989 with three networks (UUNET<sup>4</sup>, PSINET<sup>5</sup>, CERFNET<sup>6</sup>). In 1991, the World Wide Web was launched at CERN<sup>7</sup>. The MOSAIC<sup>8</sup> browser, with its graphical user interface, arrived from the National Center for Supercomputer Applications (NCSA)<sup>9</sup> in 1993. That, in turn, morphed into the Netscape Navigator<sup>10</sup> made popular by the Netscape Communications Corporation.

At this point in 1995, 100 years after our starting point in this essay, Internet-related companies, applications and technologies were rapidly proliferating. The so-called “dot-boom” was on with billions of dollars being thrown at startups that appeared to have some, often tenuous, relationship to the Internet. This came to an abrupt halt in April 2000 when most of these companies ran out of capital and had no revenue. But the Internet continued to grow. Companies like Google<sup>11</sup>, Yahoo!<sup>12</sup>, MySpace<sup>13</sup> among many others continued to grow as did countless Internet Service Providers, and, often, cable television or telephone companies that had gotten into the Internet service business.

Going back into history, Martin Cooper, then at Motorola, demonstrated a handheld mobile phone in April 1973<sup>14</sup>. Of course, mobile telephony had a long history by that time, but this was the first handheld unit, thanks to miniaturization of components. About that time, Robert Metcalfe and David Boggs were inventing Ethernet<sup>15</sup> at Xerox PARC and Robert Kahn and I were meeting at Stanford to discuss the design of the

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<sup>2</sup> <https://en.wikipedia.org/wiki/ARPANET> [retrieved 8/27/2020]

<sup>3</sup> <https://en.wikipedia.org/wiki/Internet> [retrieved 8/27/2020]

<sup>4</sup> <https://en.wikipedia.org/wiki/UUNET> [retrieved 8/27/2020]

<sup>5</sup> <https://en.wikipedia.org/wiki/PSINet> [retrieved 8/27/2020]

<sup>6</sup> <https://en.wikipedia.org/wiki/PSINet> [retrieved 8/27/2020]

<sup>7</sup> <https://home.cern/> [retrieved 8/27/2020]

<sup>8</sup> [https://en.wikipedia.org/wiki/Mosaic\\_\(web\\_browser\)](https://en.wikipedia.org/wiki/Mosaic_(web_browser)) [retrieved 8/27/2020]

<sup>9</sup> <http://www.ncsa.illinois.edu/> [retrieved 8/27/2020]

<sup>10</sup> <https://en.wikipedia.org/wiki/Netscape> [retrieved 8/27/2020]

<sup>11</sup> <https://en.wikipedia.org/wiki/Google> [retrieved 8/27/2020]

<sup>12</sup> <https://en.wikipedia.org/wiki/Yahoo!> [retrieved 8/27/2020]

<sup>13</sup> <https://en.wikipedia.org/wiki/Myspace> [retrieved 8/27/2020]

<sup>14</sup> [https://en.wikipedia.org/wiki/History\\_of\\_mobile\\_phones](https://en.wikipedia.org/wiki/History_of_mobile_phones) [retrieved 8/27/2020]

<sup>15</sup> <https://en.wikipedia.org/wiki/Ethernet> [retrieved 8/27/2020]

Internet<sup>16</sup>. There must have been something in the air in 1973! Computer networking and mobile telephone evolved on independent paths for several decades until in 2007, Steve Jobs at Apple announced the iPhone<sup>17</sup>: a handheld smartphone that could interact with servers on the Internet by way of applications (“apps”) running in the smartphone. These two technologies, Internet and the smartphone, were hypergolic. The smartphone made the Internet readily accessible from wherever you could get a mobile signal and the Internet made the smartphone more useful by supplying it with access to the world’s knowledge, online.

In the thirteen years since the arrival of Apple’s iPhone, many competing products have arrived and all of them have been increasing their processing and memory capacity, communication speeds and improving their accessories, notably cameras and motion sensors. They carry multiple radios to include 3G, 4G and 5G mobile telephone capability, Bluetooth, NFC<sup>18</sup> and Wi-Fi. But the most notable expansion has been the library of applications available for downloading. There are millions of applications. A recent statistic says there are 2.2 million apps for the iPhone and 2.8 million apps in the Google Playstore.<sup>19</sup>

This brings us to the key question: is innovation coming at us more rapidly than ever before? It is surely tempting to say so, but perhaps it just feels that way. The ease with which apps are built for smartphones, pages created for the World Wide Web, software is produced for Internet-enabled devices (Internet of Things<sup>20</sup>) all contribute to the feeling that we are rushing into a future in which we are being overwhelmed with change. There is some truth to this. In a “consumer economy” getting the next and newest thing is in some ways the reason the economy is sustainable or growing. New features can be added to software without necessarily changing hardware and that adds to the feeling and reality of rapid change. There is something Einsteinianly relative about this feeling. If software were delivered in the air from a fan, we could be standing still and the fan increasing in its speed making us feel like we are moving faster and faster when, in fact, we are standing still but the world is rushing past.

There are many reactions to this phenomenon. Some pine for the “good old days” when things did not seem to change so quickly. But see the opening paragraphs of this essay! Some people see this as a challenge to learn more and more quickly. Just-in-time learning is a skill and we can see interesting evidence of this phenomenon. A Google search quickly answers “how do I X?” for some value of X. I learned recently that “young folks” [that’s everyone younger than I am which is almost everyone in the world now!] often turn to YouTube for advice. I tried this out recently when my wife and I

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<sup>16</sup> <https://www.internetsociety.org/internet/history-internet/brief-history-internet/> [retrieved 8/27/2020]

<sup>17</sup> <https://en.wikipedia.org/wiki/IPhone> [retrieved 8/27/2020]

<sup>18</sup> [https://en.wikipedia.org/wiki/Near-field\\_communication](https://en.wikipedia.org/wiki/Near-field_communication) [Retrieved 8/27/2020]

<sup>19</sup> <https://buildfire.com/app-statistics/> [retrieved 8/27/2020]

<sup>20</sup> [https://en.wikipedia.org/wiki/Internet\\_of\\_things](https://en.wikipedia.org/wiki/Internet_of_things) [retrieved 8/27/2020]

decided we wanted to make Chinese eggplant; a spicy and delicious dish. We turned to YouTube: “How do you make spicy Chinese eggplant?”, we asked. Instantly we found a 12 minute video<sup>21</sup> showing us exactly how to do it. We followed directions. It was delicious!

This notion of just-in-time learning has implications that are relevant for our future. If our life spans are increasing, this implies that our work lives may extend for sixty or seventy years. We are not likely to learn enough in the first couple of decades of our lives to sustain our productivity and relevance for such a long period. We will have to learn new things if only to adapt to the new technologies that arise at a steady if not increasing pace. Learning online as needed has the advantage of immediate utility and relevance. This is not to say that a more organized form of learning is irrelevant. Rather, it suggests that online learning may be increasingly relevant. In mid-life it may not be feasible to drop everything and go back to school full time. Short courses and certificate training are useful alternatives. Self-guided and paced learning is increasingly feasible and available.

The 2020 COVID-19 pandemic has underscored the value and importance of online learning. At a time when “social distancing” is necessitated for health reasons, learning online has become a necessity. Universities are adapting to this, such as Georgia Institute of Technology’s online masters program in applied systems engineering<sup>22</sup> is a good example. It is the same program as is taught in residential settings but costs much less per student because class sizes can be much larger. New universities have been created for online, large scale learning such as Udacity<sup>23</sup> and Coursera<sup>24</sup>. A quick search of the WWW for online degrees produces a plethora of responses. Universities are adapting rapidly to these new formats. With high probability, these systems will evolve to be increasingly student-centric with self-pacing and adaptive remediation becoming the norm.

So, where does that leave us in this debate over the pace of change? I think digital technology has enabled more rapid discovery and development in virtually all disciplines. We hear the term “computational-X” for many values of X: astronomy, biology, chemistry, linguistics, to name a few. The consequence is that we really are experiencing more rapid evolution of knowledge, tools, techniques, products and services. This need not lead to despair! This same technology is also helping us cope with the need for adaptation and learning. We will become all the more productive in consequence.

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<sup>21</sup> [https://www.youtube.com/watch?v=q3V\\_ibwxBXg](https://www.youtube.com/watch?v=q3V_ibwxBXg) [retrieved 8/27/2020]

<sup>22</sup> <https://info.pe.gatech.edu/pmase/> [retrieved 8/27/2020]

<sup>23</sup> <https://www.udacity.com/> [retrieved 8/27/2020]

<sup>24</sup> <https://www.coursera.org/> [retrieved 8/27/2020]