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"The Two Ages of Discovery, and the Reigns of Two Queens Called Elizabeth"

by Andrew H. Wilson

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#54/2020

TWO AGES OF DISCOVERY,

AND THE REIGNS OF TWO QUEENS CALLED ELIZABETH

by Andrew H. Wilson

March 2020

Abstract

This paper was originally intended as the basis for a talk by the author sometime during 2020, but plans for it changed.

Its main thrust is to compare two *Ages of Discovery* (the first one part of the Renaissance, and the second the years since the end of World War II) which were partly concurrent, as it happens, with the *Reigns* of England's two *Queen Elizabeths.* These Ages/Reigns brought significant world-changing circumstances and developments, based on the ability of humans to engineer and to apply new knowledge … but not always for constructive purposes!

The paper will also have some things to say about a possible future *Age of Discovery,* equidistant from the second one.

About the Series

Principally, the Cedargrove Series is intended to preserve some of the research, writings and oral presentations that the author has completed over the past half-century or so but has not yet published. It is therefore the modern-day variant of the privately published books and pamphlets written by his forebears, such as his paternal grandfather and grandmother, and his grandfather's brother John.

About the Author

He is a graduate in mechanical engineering and the liberal arts and has held technical, administrative, research and management positions in industry in the United Kingdom and the public service of Canada, from which he retired over 30 years ago.

He became actively interested in the history of engineering in 1975 on his appointment to chair the first history committee of the Canadian Society for Mechanical Engineering, and served both CSME and the Engineering Institute of Canada in this capacity for varying periods until 2003. He has since researched, written, edited and presented historical material for both organizations and for the Canadian Society of Senior Engineers. He is also a past president of CSME and EIC.

Preamble

This paper will discuss events during two historical periods in which geographical, scientific and other discoveries *and technical advances in engineering* appear to have been more influential than for other similar periods throughout recorded history.

The first Age of Discovery and the reign of England's first Queen Elizabeth run *concurrently*, from 1450 until 1603. The events during it were dominated by several countries in Europe, and include the discovery by Europeans of the Americas and other parts of the world, plus some of the European Renaissance. It was also an early attempt to globalize trade.

The second Age of Discovery stretches from the end of World War II in 1945 until 2020, and runs *concurrently* with the reign of England's second Queen Elizabeth. It has been dominated principally by the United States of America, but also at times by Russia, Japan and China. It includes the race into space and the explosion of communications. It also includes another attempt to globalize trade. Many readers of this paper will have lived through it. Charlie Chaplin would have called it 'modern times.'

How long was it between the first Age/Reign and the second? From 1603 to 1945 is 342 years. If we assume that an average human lifetime during this period could have been around 68 years, then five lives could have been lived *consecutively* during it.

But, first, let me set out a timeline for the development of our universe and for human beings. The Big Bang, when the universe as we now know it apparently began, happened an estimated 13.8 billion years ago. *Homo erectus* appeared almost 2 million years ago, *homo sapiens* around 200,000 years ago, and *modern man* dates from 50,000 years ago. The use of tools began around 300,000 years ago during the Stone Age, which was followed by further human, material and skill developments in the subsequent Bronze and Iron Ages that ended around 900 B.C. The last glacial period (or Ice Age), by the way, ended around 12,000 years ago.

So in terms of the passage of time, our two Ages are but twinklings of the eye when we compare them to, even, the time since the arrival of *homo erectus*, although there may have been time for a good blink between the Iron Age and ours. And from the 'passage of time' point of view, the engineered developments that have occurred during the second Age/Reign have been astounding.

For convenience, there are no illustrations in this paper. Readers can find those relevant to both Ages/Reigns on the Internet, and to the second one in the electronic and other devices they use every day.

The first Age/Reign…had begun by 1450, and it lasted for roughly two consecutive lifetimes, as suggested above. By 1450, the influence of several significant events in Europe had ended, or were in the process of ending. For example: in the later 1300s, as a result of the plague, or Black Death, millions had died and European population numbers had been halved; the 100 Years' War between England and France was ending, it being famous for the Battles of Agincourt, Crécy and Poitiers and for the achievements of the English bowmen, and for the French Joan of Arc. On the other hand, the skirmishes between the Scots and the English were not yet over, nor were various others between European countries. The English Wars of the Roses were just beginning, as was the rebuilding of the plague-decimated European populations.

In 1450, people stayed mostly at home. When they travelled, they did so at a slow pace. The sea was too dangerous. Some ships became lost, others were destroyed or sank, many never came back home. But travel across the world of land was not unknown, nor was commerce limited to local markets. For example, for hundreds of years merchandise had been transferred over the 8,000 kilometre-long 'Silk Road' from China to Europe, sometimes by way of India and Persia. There had also been maritime commercial traffic associated with the Road, along the coastlines of the Pacific and Indian Oceans and the Arabian and Red Seas. However, the Road pretty well shut down for good when Constantinople fell to the Ottoman Empire in 1453, although its maritime component had, before then, been enhanced by the re-engineering of the design and construction of newer and faster ships that could travel much longer daily distances than their landed competition.

But it was not until 1509 that the notorious Henry VIII ascended the English throne, and 1553 until his daughter Mary became Queen, to be succeeded in 1558 by the first Elizabeth, whose reign reached into 1603.

Essentially, what this first Age/Reign primarily did was to 're-engineer' and build ships that could explore, could sail longer distances, navigate better when at sea, and come safely back home - and know where they had been. This became a serious challenge when European kings, entrepreneurs, politicians and religious people became curious and began to look for shorter sea routes to sources, for example, of gold, spices, new colonies, and Christian converts that they knew, or thought they knew, existed in other parts of the world. At the same time, under mainly Italian influence, the curiosity of Renaissance people about science- and engineering-based phenomena was growing and stimulating thought and research.

But in the mid-15th century, Europeans - aware of the existence of the other side of the world and its potential riches - were unaware at first that China was so far away and that the Americas also stood in their way westwards. And even when they found out, they imagined it might be possible to sail around the new continent, through a Northwest Passage or round a southern cape, to reach their Asian destinations. So the prime technical advances for the longer voyages of the first Age/Reign were centred on ships and their design, although these might have been in use in *other* parts of the world for a long time, and on the instruments of navigation and the development of larger and more effective naval guns.

For example, the lateen, or triangular, sail had been developed much earlier in the Far East and Mediterranean to enable ships to sail more easily to windward and to supplement the existing square-rigged sails, which had less capacity for this. Sternpost rudders, which originated in the northern waters of Europe, replaced steering oars. And to the overlapping clinker construction of northern vessels was added the smooth-hulled Mediterranean, carvel construction that gave added speed, plus longer and broader hulls to vessels, although this edge-to-edge planking was leakier and required more maintenance.

Smaller, shallower-draft ships, called *caravels*, were developed for the easier exploration of unknown waters. Using lateen sails as well as square-rigged ones for manoeuvrability, they had sterncastles and smaller crews. Larger ships, called *carracks*, were also developed for commerce and war. They had high platforms fore and aft, were armed with cannon, and could carry large payloads. There were also some re-designed *galleons,* particularly while Elizabeth reigned. They were three-masted, longer, lower and narrower, with a smaller forecastle and were faster than their predecessors. Galleons were usually smaller than carracks.

By the first Age/Reign, naval artillery had been developed from land warfare guns during the 100 Years' War. Long before then, war ships had thrown stones and flaming pots of oil at one another and, later, militant vessels were tied together to allow the fighting men in one to attack their enemies in the other. By 1500, however, several types of new naval weapons had appeared. One was a light, iron, breech-loading gun on a movable carriage. Another was the much heavier bronze muzzle-loader with restrained firing movement. To accommodate the new artillery batteries, the decks of warships were reinforced. Gunports were also installed at lower levels in warships that allowed the heavy artillery to be fired without destabilizing the ships, and the tactic of broadsiding was born.

Another reason for the non-return of ships from their ocean voyages before the first Age of Discovery and in its early years was a lack of accurate navigation instruments. But as the explorers ventured farther into the unknown, the incentive to develop better instruments increased, not only to get home, but to establish the locations of the new places they had discovered. For this, the assistance of heavenly bodies was essential. But while the development of sextants and similar instruments to take advantage of these to measure latitude (north-south) reasonably accurately was relatively simple, the measurement of time required for longitude estimates (east-west) was a much bigger problem since the clocks of the day were inadequate for the job. (This had to await the development of Harrison's chronometer in the mid-1700s.) Meanwhile, techniques for 'dead reckoning' were developed, aided by the application of magnetic compasses that had been developed much earlier in China. These were suspended with their cards in binnacles, supplemented by hourglasses to measure lapsed time, and by knotted lines trawled in the sea to establish vessels' speeds. Some very experienced sailors, such as Columbus, also learned to navigate using their knowledge of the prevailing winds and tides. The accuracy of marine charts also advanced during this first Age/Reign, and especially after 1569 when Gerhard Mercator published his cylindrical map projection.

The first Age/Reign was dominated by events that opened up West Africa, the Pacific and the New World of the Americas to European adventurers, explorers, sailors, and not a few rogues.

The first European nation to pursue discovery on a world scale was Portugal and, in particular, under the leadership and influence of Prince Henry the Navigator, from his base at Sagrès. Although the Prince never went to sea himself, nor did he build ships, he despatched others to do the discovering, particularly into the southern waters and islands off the Atlantic coast of Africa. By the time of Henry's death in 1460, Portuguese ships had reached Sierra Leone and their captains had returned with gold and slaves, although Henry latterly forbade slave-trading. As his title suggests, he may also be remembered for contributions to the design of the c*aravel* and for dissemination of the art and techniques of navigation.

By 1470, the Portuguese had reached the Equator and, by 1488, Bartholomew Diaz had rounded the Cape of Good Hope and entered the Indian Ocean. A decade later, Vasco da Gama became the first European to reach India by sea, round Africa, on a trip that took two years. By 1510, the Portuguese had captured Goa. Six years later, their ships reached Canton, and 40 years later they established a permanent base at Macau. They were the first Europeans to visit Japan. During the 16th century, Portugal's wealth depended on the trade in slaves from West Africa and in spices from the Far East. They also traded for cotton and spices in India. But the Portuguese in Asia became overextended and lost their advantage to the Dutch, English and French.

The Portuguese went east, the Spaniards went west. In 1492, with Spanish sponsors, Italian Christopher Columbus reached what are now Caribbean islands, believing he was well on his way to China - his presumptive destination. He, apparently, believed that China was only about 2,500 miles from the western edge of Europe, when the actual distance is 8,000. Nor did he realize that the American continents stood in his way. His three-ship fleet consisted of two caravels - the *Nina* and the *Pinta* - and his flagship, a carrack, the *Santa Maria.* He reached, first, the Bahamas, followed by Cuba and Haiti. His second voyage, a year and more later, explored more islands of the (West) Indies. On his third voyage in 1498, Columbus discovered Trinidad and the coast of what is now Venezuela, and annexed it for Spain. On his fourth and last voyage, 1502-1504, he explored the eastern coast of Central America, presumably looking for a navigable passage to the west, and Asia.

While Columbus was discovering the Caribbean islands and Central America, others were discovering Newfoundland and Canada. History suggests to us that Ericson's Norsemen were the first Europeans to live on the island, around 1000 AD. A half-millennium later, in 1497, John Cabot landed briefly from the *Matthew* while on a journey in the service of England's King Henry VII. He didn't stay, but found the waters around the south shore of Newfoundland to be teeming with fish, which he reported on his return to Europe. This led to annual expeditions by the English, Portuguese, Spaniards, and French fishermen to what became Newfoundland's Grand Banks. But it was not until 1583 that Sir Humphrey Gilbert took possession of the island in the name of Queen Elizabeth, and Newfoundland became England's first overseas possession. Formal colonization began some years later.

Meanwhile, in 1497, Cabot proceeded farther west and made landfall on what is now Cape Breton Island, which he claimed for the King, but no settlement took place. Jumping now to 1534, Jacques Cartier's first mission (to find a Northwest Passage) led to his discovery of the St. Lawrence River and the

Gaspé Peninsula, which he claimed for France. In 1535, he returned to map the river and spent the winter on the island that became Montréal, barely surviving it. The French colonization of Canada began with Champlain in the years just after the end of the first Age/Reign.

The first quarter of the 16th century brought many expeditions to what is now the coastline of Eastern North America and the Caribbean, led by experienced sailors from Europe, such as Sebastian Cabot, son of John, Giovanni da Verrazano, an Italian in the service of the King of France, Amerigo Vespucci, who gave his name to the new continent, and Cabral who discovered Brazil in 1500. In 1513, Vasco Nunez de Balboa was the first European to cross the Isthmus of Panama and see the Pacific Ocean. In 1519, the Spaniard, Cortes, sailed to Central America, conquered the Aztecs, and discovered gold, silver and other treasures, some of which would later make their way to Spain, or into the hands of the buccaneers.

Also in 1519, Spain sent a five-ship expedition under Magellan to find a route round the southern tip of the Americas. He found Cape Horn, found a way round it, and sailed west to the Philippines, where he was killed. But a surviving ship from his expedition made its way back to Spain, the other four having been lost during the three-year circumnavigation of the world. By 1565, Spain had colonized the Philippines.

By the 1550s, expeditions by European explorers were taking place in the interior of what is now the United States.

By 1580, Portugal had fallen under the influence of Spain and its contributions to world exploration declined. And while a route round South America had been found by Magellan, a successful search for a Northwest Passage, especially by the English and the Dutch, would take a great deal longer. Names such as Frobisher, Davis and Barents were associated with it.

Beginning around the time of Columbus (and continuing for two centuries), Spain supported an empire that included pieces of North, Central and South America. Francisco Pizzaro, for example, fought and defeated the Inca in Peru - but never, apparently, found the mountain city of Machu Pichu. From this empire, among other things, they extracted gold and other precious materials which, during the first Age/Reign, were pirated by the English (led by Drake and Hawkins, for example) while being shipped to Spain. The slave trade between West Africa and the Caribbean also flourished.

Two English seamen, Drake and Cavendish, circumnavigated the world from west to east in the late 1500s. Drake's three-year voyage also took him up the west coast of the Americas where he plundered Spanish ships carrying gold, silver and other precious materials. Meanwhile, domestic wars were not unknown within Europe during the first Age/Reign. Holland and Spain and Portugal and Spain fought, as did Scotland and England. England and Spain fought intermittently from 1585 until 1606, on land and at sea. The most famous episode of this War was the defeat of the Spanish Armada in 1588.

Just before the end of the first Age/Reign, the English set up their privately-financed East India Company in 1600, and the Dutch one was established in 1602. After 1595, the Dutch, who were also establishing their independence from Spain, had first tried unsuccessfully to find a way to Asia round Europe's north. So they followed the Portuguese round the Cape of Good Hope, and later took over some of their Asian possessions. They concentrated on the spice trade and established a base of operations on the island of Java. The Dutch were also active in America, where they introduced the drinking of tea a half-century before it became popular in England.

When the Spanish first arrived in America, they found there were no horses, and promptly began to supply them … and to use them to terrify the indigenous people. Other animals, crops and foodstuffs were exchanged. Turkeys, for example, went from Mexico to Europe, but it was more than a hundred years before they began to appear there on Christmas dinner tables. Tobacco plants, from the Americas, were first cultivated in Spain in 1550. Diseases also migrated. Smallpox, diphtheria, flu and measles went westwards, but the east or west origin of syphilis was apparently in doubt.

While the European/Italian Renaissance 'officially' began in the 14th century, there were a number of significant scientific discoveries and engineering contributions made during the years of the first Age/Reign. Around 1450, Johannes Gutenberg developed the first movable type printing system, using a screw press. It helped to encourage the spread the new scientific and technical information that was being discovered and the spread of religious information generally, including the Luther-led protestant Reformation in Europe in the 16th century. But initially there was a problem: not everyone could read. Other contributions dealt with the earth's place in the heavens in relation to other bodies seen to be there, and were made by Copernicus, Kepler and Brahe. Some were concerned with very large buildings and with fortifications and more deadly weaponry. George Bauer produced his book on metallurgy. Machiavelli published *The Art of War.* The polymath Galileo spent half his life during this Age/Reign. But perhaps the most noted luminary was Leonardo da Vinci, born in 1452 in Italy and died in France in 1519. He worked mainly in Florence and Milan. His main credits are for painting, sculpture and drawing, but he also contributed to engineering and science, leaving behind notebooks, manuscripts, models and sketches that show the enormous range of his intellect and his ability to imagine new engineered devices. Examples of these include a workable parachute, a flying machine, a clock with a pendulum, a wheel-lock musket, a roller bearing and a rolling mill. There were others, perhaps less talented and well-known, such as Brunelleschi, who designed and built the cupola for the cathedral church of Santa Maria del Fiore in Florence, and Ramelli, who published a book with drawings of 'various engineering machines' in 1588, among which was one that could qualify as the 16th century equivalent of the iPad.

Some other engineering innovations of the first Age/Reign are worth mentioning. The first peppermill was working in England in 1494. The first pocket watch appeared in 1502. By 1530, spinning wheels were in use in Europe. The lead pencil was invented in England in 1564. The musket was in use by 1565. The *camera obscura* dates from 1570, in Italy. The knitting machine was invented in England in 1589. And believe it or not, the flush toilet was invented during this first Age/Reign, in 1597, as was toilet paper. But it took three more centuries before they were in common use. So while land-based engineered innovations also saw the light of day, the key ones influenced the design and construction of ships and set the stage for exploration.

The main lesson of the first Age/Reign is that it began the opening up of the global world as we now know it, and speeded up trade and commerce. And America was discovered. Not everyone behaved well, and there were wars, skirmishes, acts of piracy, and the Spanish Inquisition began in 1478.

And as Boorstin wrote in *The Discoverers*:

> Never before had the arena of human experience been so suddenly or so drastically revised. And the earth became more than ever explorable.

The second Age/Reign… In terms of the passage of time I used earlier in this paper, this second one - *if it were to end today* - will have been just a little bit longer than a single 'consecutive' lifetime. Many of the readers of this paper will have lived through most, or all, of it.

The major events preceding the second Age/Reign were the Great Depression, the aggressions of Germany, Italy and Japan, the isolation of the United States, and World War II. Also, the strength of the postwar American research/engineering/production dominance that has been evident during this second Age/Reign was established during the very technical War, although some contributions to it, from Britain and Germany in particular, in the electronic and aeronautics fields, were also significant.

This American strength was also foreshadowed and strongly influenced by the July 1945 report, to the U.S. president on a program for postwar scientific research, written by Vannevar Bush, then director of the U.S. Office of Scientific Research and Development, after much consultation with colleagues. It was called *Science: the endless frontier.* It promoted basic research as the key to future economic prosperity, and 'endless' as no end to it was then in sight. But while this report 'showed the way,' it failed to emphasise sufficiently the *engineering* steps that would be needed for the translation of new research into new products … and Bush, himself, was an engineer! Interestingly, the activity called 'innovation,' heard daily nowadays, was not discussed in the report. Bush was, in essence, the Prince Henry of the second Age/Reign.

Advances in three areas of 're-engineering' appear to have led the way since 1946.

The first was nuclear power, applied principally to the production of electricity and the prime movers of ships, replacing some steam and diesel engines. As science, it was descended from the physics done in England by Rutherford, Thomson, Chadwick and others, and by Fermi, Oppenheimer, Teller and others in the United States. It was also descended directly from World War II's *Manhattan* 'Bomb' *Project,* and exploited peaceful uses for 'atomic' energy, which was the Canadian nuclear mantra from the beginning, led by the National Research Council of Canada and Atomic Energy of Canada Ltd., at Chalk River.

The United States, Great Britain, Russia, Canada and France were the leaders in the commercial exploitation of nuclear power, which began seriously in 1957, when a U.S. nuclear power reactor went critical at Shippingport, Pennsylvania. It thrived until the accidents at Three Mile Island in the U.S. in

1979 and Chernobyl in the Ukraine in 1986, when new power reactor construction virtually ceased for many years. But its revival was interrupted by the combined earthquake/tsunami and nuclear incidents at Fukushima, Japan, in 2011, which encouraged some ‘nuclear’ countries to phase out their nuclear energy programs. Even so, by 2018, nuclear energy was estimated to be supplying 10% of the world’s electricity through over 400 power reactors in 30 countries, and some new reactors were under construction. There were also several hundred research reactors operating worldwide.

The United States, through Admiral Rickover and his nuclear submarines and the cargo ship USS *Savannah,* led the way with marine applications, followed by the Soviet Union, with its submarines and icebreakers.

The second area of ‘re-engineering’ during the second Age/Reign was the development of vehicles for the human, physical and scientific explorations of the earth’s atmosphere and of outer space, far beyond the earth-bound aviation/aeronautics world that had begun at Kittyhawk, North Carolina, in 1903 and had been a decisive factor in bomb delivery in World War II, along with German rocket engineering, which the Americans acquired postwar and used in their space program.

This program also began seriously in the fall of 1957 when Russia (not the United States) sent the first unmanned earth satellite - *Sputnik I* - into orbit. The Americans, however, were quick to respond and in 1958 launched the earth satellite, *Explorer I.* From then on, and for many years, the space program took a large slice of the U.S. national budget. In 1959, the Russian spacecraft, *Luna* 3, reached the moon and sent pictures of it back to earth. The following year, Russian Yuri Gargarin became the first human to fly in space, and later that year Alan Shepherd became the first American. In 1962, Canada joined the U.S. and Russia in space when the *Alouette I* topside sounder research satellite was launched. In 1966, the U.S. spacecraft *Surveyor I* touched down on the moon. America and Russia raced one another to land on the moon, and America won. In July 1969, its astronauts landed, from Apollo 11 … and, like Gargarin, Shepherd and others, returned home safely, much as da Gama, Columbus, Cabot and others did from their sea voyages during the first Age/Reign.

There have been no moon landings since those of Apollo 17 in 1972. Preparations for the next distant ‘human’ target, Mars, have been slow and expensive. Many unmanned spacecraft have, however, been sent on exploratory missions well beyond the earth’s atmosphere, to Mars, Venus, Jupiter, Saturn, Uranus, Neptune and Pluto, as well as the examination of comets and asteroids. Human flights in space have been limited to low earth trajectories based on space stations, such as the Russian *Salyut I* in 1971 and the U.S. *Skylab* in 1973.

The first weather-monitoring U.S. satellites went up in 1960, and since 1969 other stationary or earth orbiting spacecraft have been functioning as communications, survey and weather satellites.

While the principal ‘space-racers’ since then have been the U.S. and Soviet and non-Soviet Russia, other countries have been participating. Canada, for example, in 1962, launched the *Alouette I* - a topside-sounding satellite - on a multiyear study of the upper atmosphere, and has followed it with other research, weather and communications satellites. China, India and Japan have joined in the exploration of space and, like Canada since 1989, now have agencies responsible for their programs. There have also been regional agencies in Europe, beginning in 1962, and now merged into the European Space Agency.

The construction of an International Space Station (ISS) began in 2000, and it has been in use constantly, hosting astronauts from various countries, including Canada. Space shuttles have been used by the United States for a variety of purposes, beginning in 1981 and ending in 2011. For example, U.S. shuttles docked with the Russian *Mir* station in 1995 and later with the ISS. Canadian astronauts have participated in the U.S. Shuttle and the ISS programs and Canadian industry has provided robotic arms (the *Canadarms* and the *Dextre* enhanced vision manipulator) for the shuttles and the ISS.

But there have been two unfortunate shuttle accidents. In 1986, the *Challenger* was destroyed on lift-off and, in 2003, the *Columbia* was destroyed on re-entry. Both accidents delayed the progress of the U.S. space efforts by years. With no U.S. shuttles still in operation, the servicing of the ISS is currently dependent on Russian cooperation. Meanwhile, commercial interests are developing space vehicles and services, including tourism.

The third 're-engineering' area of the second Age/Reign has been electronics … in the widest sense, including its application to computers, the Internet, GPS systems, space satellites and services, and a variety of small devices that use the electronic components that get smaller with time. In the world of engineering, generations of electronic calculating machines have made what was once the engineer's main and very visible tool, the slide rule, obsolete.

Electronics got its start with the development of radio in the early 20th century, with pioneers such as Marconi, Hertz, Ambrose Fleming, and De Forest, and in the 1920s, with J.L. Baird and Philo Farnsworth when it was television's turn. Radar and Robert Watson-Watt shot to prominence during World War II, as did the huge early calculator/computers used by Alan Turing, John von Newman and others to analyse information relating to the War, at places like Bletchley in England. Postwar, and into the second Age/Reign the computer work begun by Turing and Newman continued, much of it in the United States at, for example, Princeton and other Universities and at Bell Labs. The early programmable computers like ENIAC were, relatively speaking, huge, generated a lot of heat, and required multitudes of diodes, triodes and technical support people to function.

The first notable change – in keeping with the Renaissance aspect of the earlier Age/Reign, and linked to the worlds of science and engineering – was the development of the first transistors, beginning in 1947 with the work of Shockley, Bardeen and Brittain. This was advanced farther by Noyce and Kilby in 1959 when they separately developed the integrated circuit, and further still in 1971 when the Intel Company introduced the 'computer on a chip,' leading the development of the microminiaturization that we know today.

The rate of change in the number of components that could be accommodated on individual chips became known as Moore's Law. It said, at first, that the doubling time would be one year, but was later changed to 2 years. A second linked law, the 7/10 Cost Law, said that the price of similar chips would be reduced by 30% each year. These laws ‘ran out of steam’ a few years ago.

Electronics became divisible into hardware and software. In addition to Bell and Intel, hardware companies that have contributed have included IBM, Apple and Cray. Their faster and faster desktop, laptop and supercomputers have been developed and designed for sale in larger and larger markets. Microsoft has prospered in the software field and FORTRAN, COBOL, PASCAL and JAVA, for example, have become well-known software languages. And theoretical and experimental solid state physics have evolved within the world of science. At least one Nobel Prize, to Canadian B.N. Brockhouse, was awarded for research using a specially designed triple-axis spectrometer for experimental solid state work at Chalk River.

Stepping back for a moment, one of the U.S. Government’s reactions to the launching of Russia’s *Sputnik* satellites was to establish an Advanced Research Projects Agency (ARPA) in 1958 to serve the Department of Defence. Over the years, this administrative Agency (which was renamed D(efence)ARPA in 1972) has been tasked with supporting R&D contractors - as many as 250 at a time - that are associated with new and significant technologies. In practice, DARPA’s support has been given to a wide clientele, both government and private. Among the prominent projects that it has supported are stealth aircraft, nuclear and other weapons, robots and drones, the ARPANET (or prototype for the Internet), computers, the miniaturization of GPS systems, automated voice and translation systems, chemical weapons, neuroscience systems and brain injuries, among others. In other words, DARPA has been heavily into electronics.

On a world-wide scale, the transistor and its successors changed just about everything. Distances became less important in communications. In addition to the United States, countries such as South Korea, Japan, and China have been making electronic devices for the world’s markets. Cordless phones date from the mid-1970s. By 1980 the Sony *Walkman* recording device had arrived. Letters began to be replaced by e-mails. Printing went electronic. By 1990, the World-Wide Web had been invented. The IT industry and the Internet arrived, as did the Internet of Things. Cameras went digital. Text messaging began to be widely used. Landline telephones gave way to smart phones that could also take pictures and store information. By 2000, GPS systems were in use. The *iPhone,* which can do a number of things, has been ubiquitous since 2007, and the *iPad* arrived three years later. Apple’s watch appeared in 2014. A whole new social medium evolved. Nowadays, on an average Saturday, on their TV’s or other playing devices, Canadians can watch football being played in Australia in the morning, followed by soccer from Europe in the afternoon, and by baseball from somewhere in North America in the evening. The signals involved come via satellites in space.

Among the other ‘re-engineering’ developments that have had considerable influence on the world during the second Age/Reign include these:

… the development of the jet-powered commercial aircraft, beginning with Britain’s *Comet* in 1949 (and the ill-fated *Jetliner* in Canada), which led to the Boeing 707 and the Douglas DC-8 that revolutionized world air travel, to the Boeing 747 *Jumbo Jet,* and to the supersonic French-British *Concorde*; but, in 2020, while jet travel dominates, commercial supersonic travel has been withdrawn from service; meanwhile, military aircraft still go supersonic, but are being replaced by drones and rockets, both of which (as noted above) can be controlled remotely;

… the development of a number of medical-related innovations, including: the oral contraceptive pill, which has significantly influenced human behaviour, population growth and family sizes, and was first approved for use in the United States in 1960; personal identification through DNA; the successful surgical transplantation of human organs, which began in the 1950s and 1960s in a number of countries, the most notable, perhaps, being the heart transplant performed by Dr Barnard in South Africa in 1967;

… the increasing use of robots and artificial intelligence, especially in industry, which has had some effect on industrial employment but, so far, not as much as was anticipated;

… the exploration for, and the recovery of, oil and gas from beneath the seabed and the development of oil rigs to do this work;

… the construction of some very tall buildings and very long bridges and the development and adaptation of new metallic and non-metallic materials, some of which are superconductors of electricity, light and heat;

… the conception, development and design of machines such as the Large Hadron Collider to be used in the pursuit of the physics of both matter and anti-matter, machines for the pursuit of diagnostic medicine, devices for using smaller and smaller particles, and techniques for describing and changing the human condition.

But all of this (and more) 're-engineering' during the second Age/Reign has not always been equal to human expectations, or to its distance from the first Age/Reign. For example, wars did not end with World War II, nor have terrorism and revolution disappeared as threats. Many still go to bed hungry. Disastrous fires, floods and storms continue to disrupt people, life and living. Criminal activity has become more sophisticated and more pervasive. Currently, we are living in a period of concern about the rate and nature and rate of the changing climate, about the adverse effects of the 'electronic' social media, about the theft of the identities of individuals … and, most recently, about the effects and after-effects of a medical pandemic.

Few would disagree with the thesis that the second Age/Reign 're-engineerings' owes much to basic science. But when the chips were down, so to speak, in the years that have followed 1945, the American companies and people doing the applied research and the development and the design and engineering of products and processes were better able to spot and exploit the most promising basic results … and to make and sell them. On the other hand, apart from China since Deng Xiaoping took power and until quite recently, the top ranks of national governments throughout the world have benefitted from the political and economic expertise of their members but have been seriously lacking in the engineering expertise needed to guide contemporary decisions. On the other hand, not even Leonardo da Vinci could have imagined the world of the second Age/Reign.

The Boorstin quote is still relevant, but with the word ‘world’ substituted for ‘earth.’

The reader will realize that the writing of this paper was begun prior to the arrival of the COVID-19 pandemic in the early months of 2020 and ended after most of the world had been ‘locked down’ for several weeks. However, no attempt has been made in it to draw inferences or lessons for the post-pandemic period. But in the future, the engineering experience gained during the second Age/Reign will undoubtedly influence the modification to economies, political imperatives and lifestyles that may arise.

What, then, about the future ... assuming we will have stopped the second Age/Reign in 2020 and are imagining that there will be a third Age/Reign beginning around the year 2360 of the Christian Era?

Aspects of this proposition that we think we can see right now include, more usefully, what personal, national and international climate changes will be in place by then? Will they have slowed, stabilized or stopped? Less usefully, we may worry about how much smaller useful nuclear particles might go? Will some dominating entity have gathered up all the generated information about everybody and used it to its advantage and the disadvantage of society as a whole? What will we eat and wear, and how will we get around? Will some of us be living on Mars by then?

Da Vinci would have had absolutely no ideas, imaginative or not.

We have to remember that *prediction* brings with it varying degrees of certainty, even for relatively short periods of time. All you have to do is look at predictions that were made around 1975 for the year 2000. Or consider tomorrow’s weather forecast. In this dangerous environment, let me make two brief comments … but no prediction for any time in the future, and especially not for a third Age/Reign.

One: Some years ago, I wrote a piece for the Canadian Association for the Club of Rome called *It is the business of the future to be dangerous.* The thesis was not original; it was borrowed. The connection was based on the thought that the element of danger in the future can never be fully eliminated, in spite of our best intentions to do so.

Two: The first modern institution to warn that things are not well with the world was the Club of Rome, in the report to it called *Limits to Growth.* It was published in 1972, became known as the Meadows Report, and the Club itself became known as the ‘Doomsday Club.’ It drew the world’s attention to what it called the *World Problematique*, which had five elements: population; economic growth; energy use; non-renewable resource exploitation; and environmental pollution. The Club insisted that all five elements should be treated holistically, and not singly. Its overall objective was to develop a global, sustainable world model for the future. By identifying ‘environmental pollution,’ it was signalling what we now call climate change. This report quickly attracted critics, notable among then economists and believers in the ability of 'technology' to solve all the world's problems.

In 2020, the Club of Rome still exists and has over 20 national associations worldwide. It has continued and expanded its studies into the *Problematique* using new techniques, statistics, experience and projections. It has also had competition from other 'Doomsday Clubs.' But its message is the same, only 'doomsday' may be a whole lot nearer since growth is still the primary economic target of countries worldwide for the simple reason that it is seen by economists as the only way things will get better.

To sum up: In spite of some downsides, it could just be that we, who are here today, and our contemporaries, have lived during the best 'discovery age' in human history. But who is to say that history could, or could not, repeat itself 350 years from now?

Thank you for your kind attention.

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