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# How did the General Purpose Technology Electricity contribute to the Second Industrial Revolution (II): The Communication Engines

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## Abstract

The concept of the General Purpose Technology (GPT) of the late 1990s is a culmination of many evolutionary views in innovation-thinking. By definition the GPT considers the technical, social, and economic effects of meta-technologies like steam-technology and electric technology. This paper uses Schumpeter's concept of 'cluster on innovations' to create insight in the nature of the GPT- Electricity. Complementing the earlier presented invention of the Steam Engine, Electromotive Engine and Electric Light (Kooij, 2015a), three additional case studies are presented about the Content of the invention of the Communication Engines Telegraph, Telephone and Wireless. In addition, the Context for these inventions is presented. We found that these inventions— better 'clusters of innovations'— were the core elements in the technical contributions to the Second Industrial Revolution. These General Purpose Engines (GPE) that used electricity as carrier of information in stead of power, fuelled the Communication Revolution and made 'electricity' contribute so considerably to the Second Industrial Revolution.

## Keywords

General Purpose Technology, Industrial Revolution, technological innovation, cluster of innovation, innovation, history of technology.

JEL: N7, O31, O33, O40,

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## 1. Introduction

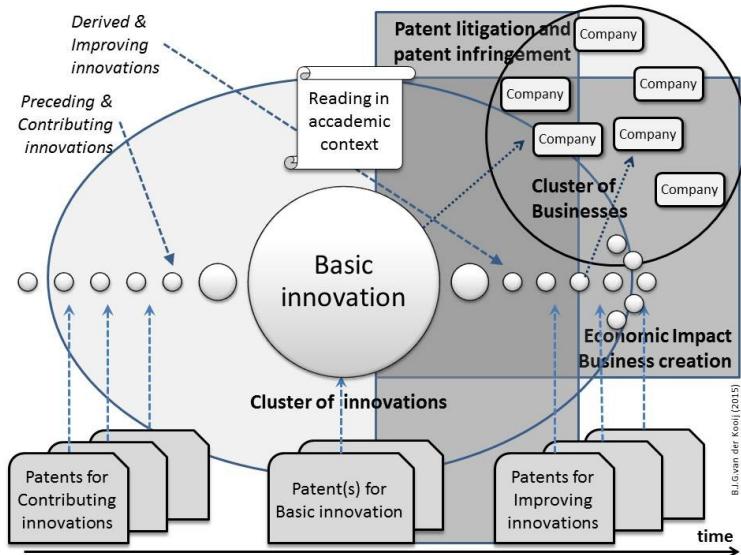
This is a story about change and novelty. So, let us start to consider some classic scholarly contributions on the themes of invention and innovation. Firstly, invention/innovation can be seen as the result of bringing *Science* (the carrier of knowledge), and *Engineering* (the carrier of know-how) together in a *cumulative synthesis*. This theory – based on empirical evidence from his analysis of the ‘History of Mechanical Inventions’ (Usher, 2013) — was developed by Abbott Usher in the 1930s. For him the ‘Act of Insight’ and the ‘Act of Skill’ create novelty labeled as invention; an idea, a theory, a model of a (natural) phenomenon. Secondly, to become practical that novelty has to be nurtured, developed, matured into a workable artefact; the innovation itself. The result of this process of innovation —the *New Combination*— is then transferred by the creative entrepreneur to the market. This was the concept developed by Alois Schumpeter (Schumpeter & Fels, 1939) in which he observed the swarms off innovations that disrupted the equilibrium of economy with its ‘creative destruction’. Thirdly, apparently all innovations are important, but some are more important than others: the disruptive *basic innovations* that fuel economic cycles. This was the subject of a view created by Gerhard Mensch (Mensch, 1979).

These three themes describe in short the views on ‘change and novelty’ of some eminent economists. Views that over time were complemented by a myriad of other views, theories, models and definitions of innovation. Views that became accepted, creating followers in an economic School of Thought: eg the Schumpeterians. But the economist where not the only scientists interested in the phenomenon of ‘change and novelty’. Also, sociologists, anthropologists, psychologists warmed to the innovation-concept. After WW-II followed by those scholars interested in the ‘management of innovation’. From the perspective of Technical Change resulting in technological innovation, their perspective broadened into Social Change and Economic Change. New ‘Schools of Thought on Innovation’ emerged, each with their own collective views, theories and models.

A collective view of more recent origin is the paradigm of the *General Purpose Technology* (GPT), combining technical change with social change and economic change (Bresnahan & Trajtenberg, 1995; David & Wright, 1999; Helpman, 1998; Jovanovic & Rousseau, 2005; Lipsey, Carlaw, & Bekar, 2005). The GPT-concept, as a meta-technology, tries to explain the major changes that took place in societies and economies where a dominant technology results in creating considerable novelty and is having a major impact on society and economy. This theory is the focus of this article. Again, we observed in detail the same phenomena as those earlier scholars. But now we investigated another domain of the GPT of Electricity: the domain of tele-communication (Kooij, 2015b; B.J.G. van der Kooij, 2016; Kooij, 2017b).

## 2. Extended Methodology

As we already explained extensively the theoretical framework and our methodology in the first article, that part is omitted here. Just to summarize, our unit of analysis for an invention is the ‘Cluster of Innovations’; a swarm of related contribution innovations, the basic innovation itself and the improvement innovations. To identify these elements of our unit of analysis, we identified them by their patents. To identify the basis innovation we looked at the subsequent patent litigation and economic impact. Among which the business creation resulting in ‘clusters of business’ (Figure 1). This created the Content of our analysis.



**Figure 1: The Content of the Cluster of Innovations.**

Concerning the semantic aspects of the words ‘invention’ and ‘innovation’, we will follow the choice made by the authors we investigated. They can be quite different, shifting over time. For example, Usher’s definition of invention: “*Invention finds its distinctive feature in the constructive assimilation of preexisting elements into new syntheses, new patterns, or new configurations of behavior.*” (Usher, 1929, p. 11). The new combination was the result of the ‘act of skill’ and the ‘act of insight’: “*Practically, we characterize as an invention only some concept or device that represents a substantial synthesis of old knowledge with new acts of insight.*” (Usher, 1955, p. 530). He described the ‘inventions’ of the atmospheric machine that became the steam engine (*ibidem* p.308). Surprisingly, that same steam engine could also be defined as being an ‘innovation’. For Schumpeter Innovation was the result of ‘New Combinations’ realized by the entrepreneur (Schumpeter Mark-I); “[...] *innovation combines factors in a new way, or that it consists in carrying out New Combinations, [...]*” (Schumpeter, 1939, p. 84). Again, the element of combination is used. Both Usher’s and Schumpeter’s definition reflects the combination-approach in novelty-thinking at the beginning of the twentieth century up to the 1950s. It was not the only definition of innovation —as we have explored in its heterogeneity elsewhere (Kooij, 1988, 2013)— but we would like to suffice with defining innovation for the moment in the spirit of Schumpeter:

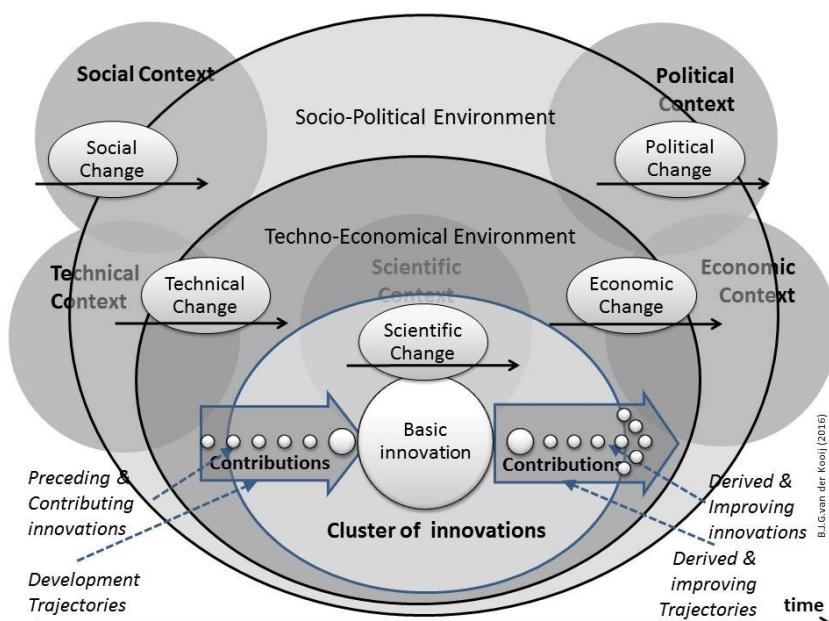
*Innovation is the new combination that creates new products, markets, organizations and production methods.*

A short word about our extended methodology. As cases studies are about Content & Context (Yin, 2014, pp. 16-17), we described in the earlier cases the personal situation of the relevant people: their upbringing and family, and educational background. Now we enhanced our analysis with the analysis of the broader context in which those clusters took place: the geographical context and the societal context. As a consequence, in the present case studies, next to the *Content* of the clusters of innovations, we add the analysis of the *Context* on a higher level of aggregation (Figure 2).

**The Change-element:** We use the concepts of Social Change, Political Change, Scientific Change, Technical Change and Economic Change that characterize the dimensions of these Contexts. They create the environment for the clusters of innovations. For example: Scientific Change was the mechanism of the Scientific Revolution, Social Change the mechanism of the Enlightenment, Economic Change combined with Technical Change was the mechanism of the Industrial Revolution. We analyzed the latter in depth for one specific geographic and societal situation: the British Industrial Revolutions (B.J.G. van der Kooij, 2016).

**The Environments:** We combine those Change-elements in the ‘Techno-Economic environment’ and the ‘Socio-Political environment’ of those days. The Techno-Economic environment is illustrated by our (partial) analysis of the Scientific Revolution and of the Enlightenment ultimo resulting in the Industrial Revolution. The Socio-Political environment is illustrated in the case studies by an analysis of the American Revolution, the French Revolution and Italian Revolution. Space does not permit us to include them in this paper.

Enough about our method, it is time to look at the results of our case studies.



**Figure 2: The Context of Innovation in which the Cluster of Innovation occurs.**

### 3. The Age of Revolution

As described by Eric Hobsbawm, the late eighteenth/first half of the nineteenth century can be characterized as the Age of Revolution (Hobsbawm, 2010b). It was the time of social-political revolutions: the American Revolution (1765-1783), the French Revolution (1789-1799), and the European Revolutions (1848). In addition, it was also the time of the First Industrial Revolution (1760-1840). Revolutions that were preceded by two major other developments: the Scientific Revolution and the Enlightenment-movement.

The *Scientific Revolution* saw the emergence of modern science. The study of the ‘Nature of Matter’ and its specific fields —such as the ‘Nature of Motion’ up to the ‘Nature of Chemical Mechanics’ (Figure 3)— by so many natural philosophers, changed the way we look at our natural world. From the classical (Greek) worldview, dominating human thought for millennia, now the scientific method (as developed by Descartes, Newton) created insight never realized before. Insights in both the macro-cosmos of the Universe (facilitated by the new instrument of the telescope), as well as in the micro-cosmos (facilitated by the invention of the microscope). Not too surprisingly, their views conflicted with the establishment

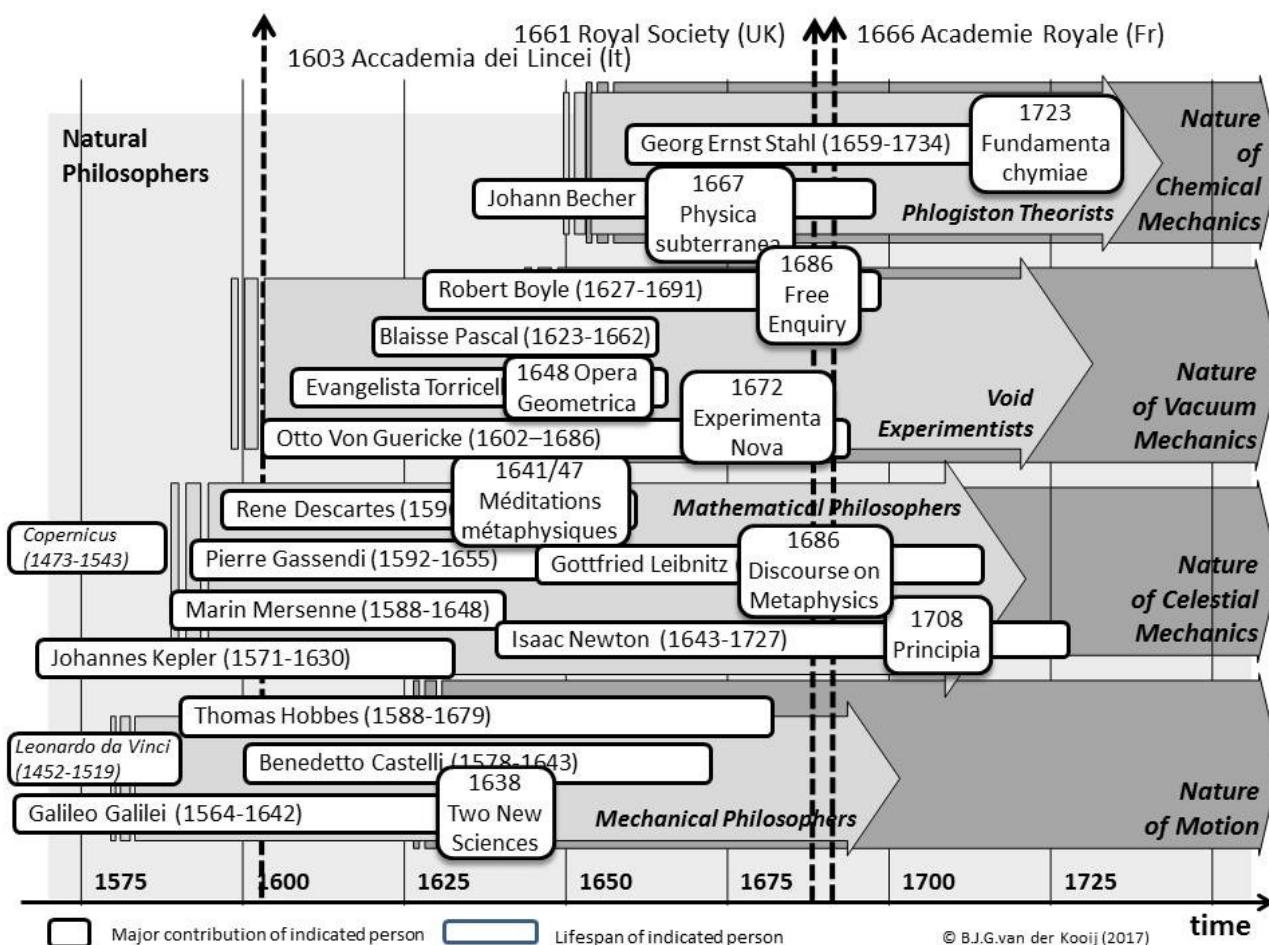


Figure 3: The Scientific Revolution as result of the work of the Natural Philosophers.

of those times. For example with the doctrines of the Roman Catholic Church when they proposed the heliocentric universe (eg the sun as the center of our Universe).

The *Enlightenment* was a movement that evolved from the work of the natural philosophers (eg Descartes) who extended their inquiries outside the realm of nature into the realm of society. They became the Enlightenment philosophers who studied the ‘Nature of Society’ (Figure 4). Some —living in the times of absolute monarchies and dominance of aristocracy—studying the ‘Nature of Government’, looked at how society was governed. Others, observing the dominance of religion and the Roman Catholic Church over society, studied the ‘Nature of Being’. For some that included questioning religious dogma’s (eg Spinoza) and the existence of a supreme power. Their views also challenged the classic doctrines and dogmas. Such as the justification of absolute monarchies (who ruled by their Divine Rights), and the dominance of the Roman Catholic Church. They proclaimed a new ‘liberal’ order based on natural law where people had natural rights: such as the freedom of movement, thought and speech. Some proposed the separation of power (eg Montesquieu), others proposed the social contract between rulers and rules (eg Locke).

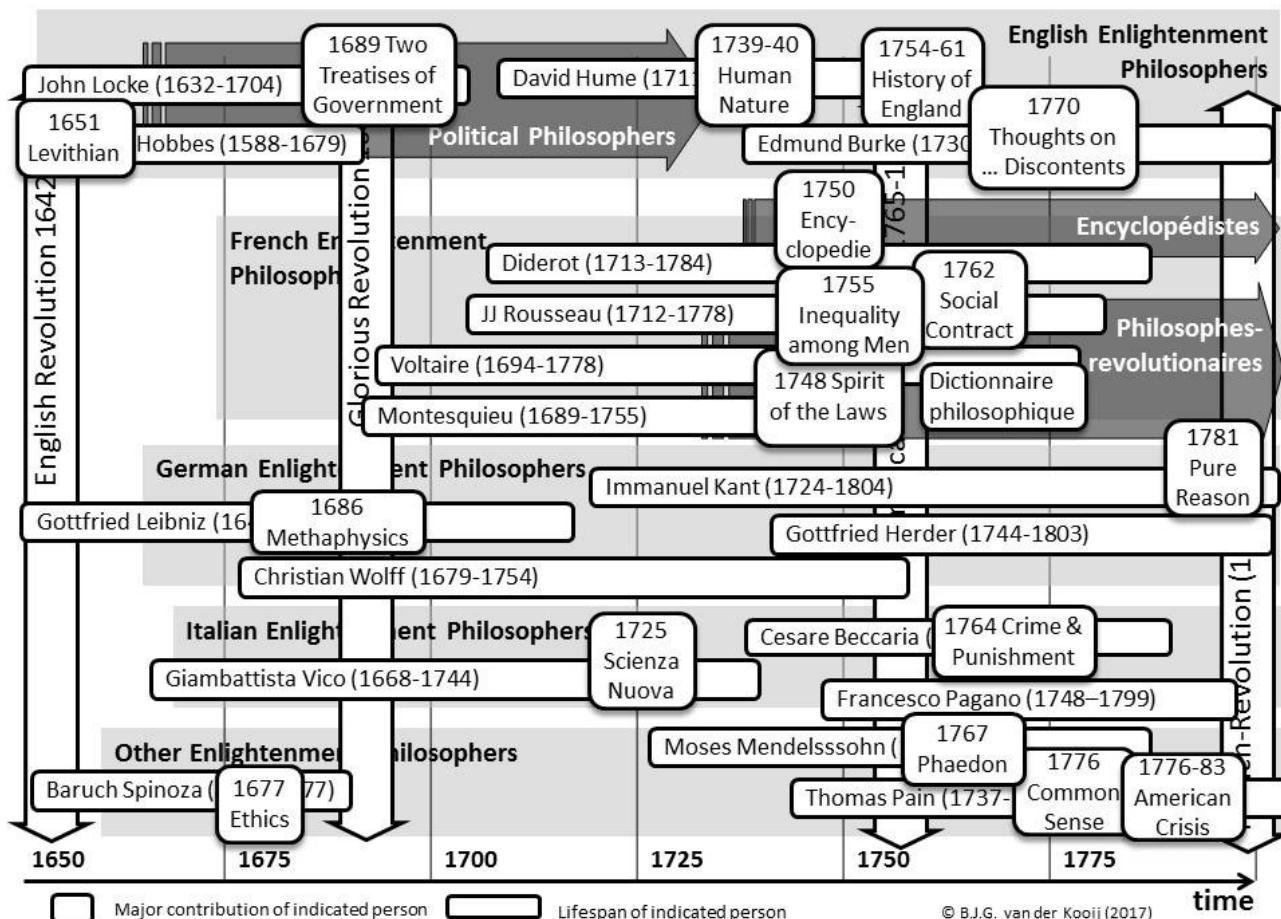


Figure 4: The Enlightenment movement as result of the work of the Enlightenment Philosophers.

Together, the Scientific Revolution and the Enlightenment created the Age of Reason; the historical period when philosophy, scientific thought and social thought were associated with the principles of rationalism. They changed the world and created the context for the emerging Communication Revolution.

## 4. Case studies

In our first contribution (Kooij, 2015a) we presented the result of three GPT-case studies: the Invention of the Steam Engine, the Invention of the Electromotive Engine, and the Invention of Electric Light. The ‘electric’ case studies focused on electricity as carrier of power. In this article, we focus on electricity as the carrier of information. We present the result of three GPT-case studies: the *Invention of the Communication Engine ‘Telegraph’*, the *Invention of the Communication Engine ‘Telephone’*, and the *Invention of the Wireless Communication Engine*. Together they cover the dawn of the Communication Revolution.

### 4.1 The Communication Revolution

Electricity was a dormant technology in the late eighteenth century, with different ‘electrophysicists’ contributing to its slow development. However, that changed around 1800 (Figure 5). Originating from Alessandro Volta’s invention of the electro-chemical battery and clouded by the Galvani-Volta controversy, ‘electricity’ had baffled the scientific community initiating the ‘Battery Mania’. Scientist all over Europe started experimenting with the new phenomenon, in the process discovering its properties: electromagnetism (Oersted), electromagnetic induction (Faraday), electro-magnetic radiation (Herz). Mathematicians (Ampere, Arago, and later Maxwell and Herz) created further understanding. The totality of their work would result in a technical revolution where electricity was used as carrier of energy to create *linear movement* (i.e. the electromagnet) and *rotative movement* (i.e. the electromotive motor).

Just as the First Industrial Revolution — that saw the use of mechanical power (aka steam power) complementing the natural power sources of wind, water, animals and humans, and had freed human society from the limitations of natural power — the Second Industrial Revolution saw the rise of electro-motive power and its applications such as the electric light. It freed human society even more, such as from the limitations of daylight. Those Industrial Revolutions were the result of Technical Change creating new technologies, such as the *General Purpose Technology (GPT) of Electricity*. One of the early application areas swarming around the discovery of electricity was ‘communication over distance’ where electricity was used as carrier of information. Preceded by its mechanical equivalent —the Chappe

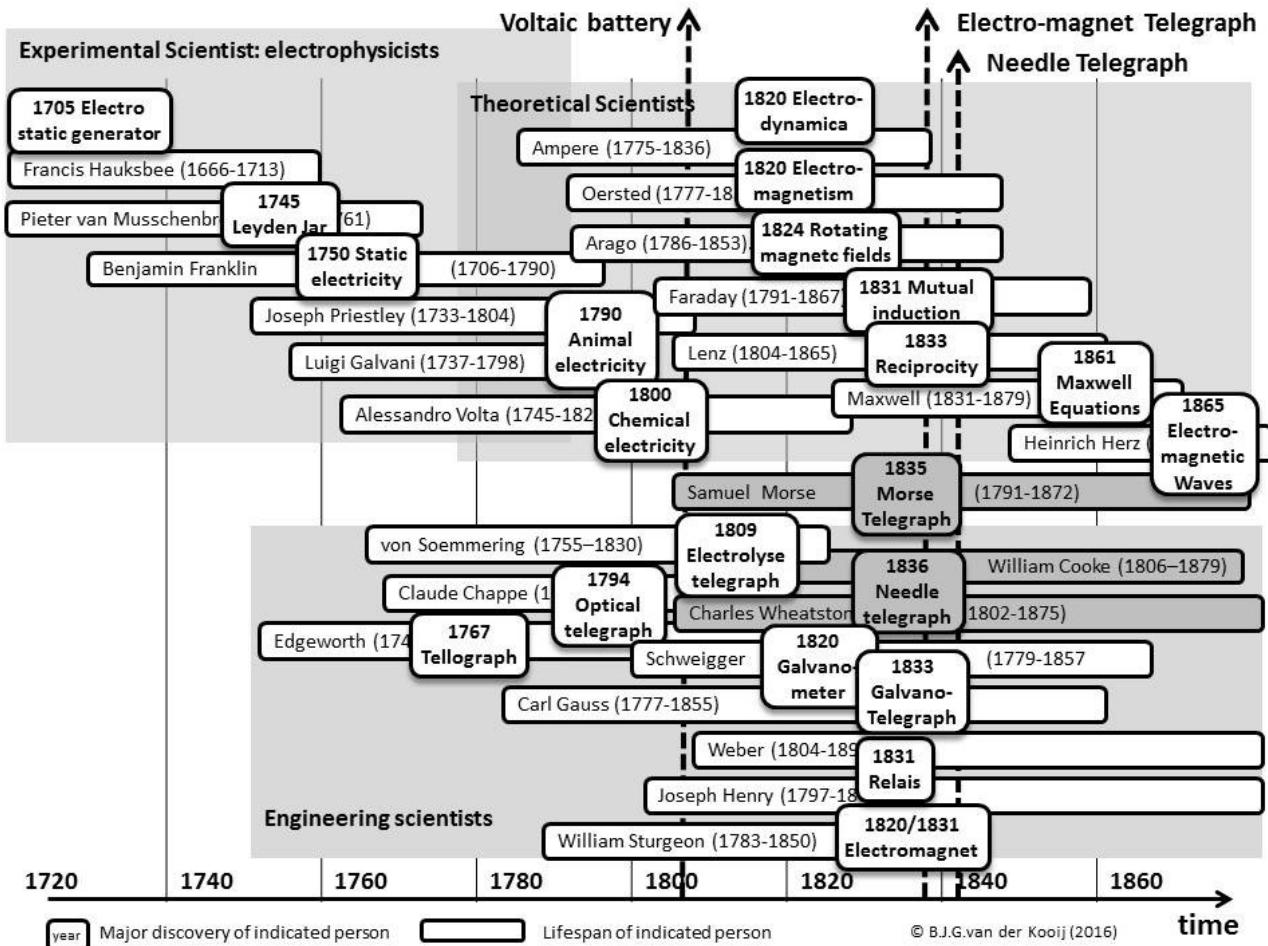


Figure 5: Experimental, engineering and theoretical scientists discover telegraphy.

Semaphore that served Napoleon's armies so well—the new phenomenon of electricity was applied to invent the telegraphic engines fulfilling the basic human need of communication over distance.

## 4.2 The invention of the Telegraph

True, the discovery of electro-chemical electricity by Volta, was not the beginning of telecommunication. Before that, other systems had enabled communication at a distance (eg the post carried by the Royal Mail). Apart from the old 'smoke message system' (SMS) applied by Indians in America, an optical semaphore system had been developed in France by Claude Chappe (1763-1805). After showing its usefulness during the French Revolution, the system was used on a large scale all over Europe up to the Crimean War (1853-1856). Telegraphy obviously was military affair.

By then electric experimenting was in full swing. However, early experimenting with its static and chemical properties had not resulted in successful communication systems. First, some important components had to be developed: in casu the electromechanical relay and the galvanometer, both creating movement as the result of an electric current and a magnetic field. The electro-mechanical relay

emerged from experiments with electromagnets (Henry, Sturgeon). Such as the ‘bel-experiment’ where an electro-magnet made a bell ring at a distance: ‘distant sound’ was born. The galvanometer developed from electro-motive experiments; electricity made a coil rotate within the field of a magnet: ‘distant rotation’ was born. One could say this was the development of electric ‘technology’ by trial and error. As a result it saw the Galvanometer Technology and Electro-magnet Technology creating components. The same goes for the early systems based on a specific property: such as the electro-chemical and electro-static reaction used in the systems as a whole. They proved to be dead-end technologies for communication. This was the Dawn of Electric Telegraphy in the 1830s that would occur in two parallel events (Figure 6).

In England, it was Thomas Cooke who, after having seen demonstrations of early Galvano-meter based telegraphs made by the Germans Schilling and Gauss, conceptualized a communication system using the galvanometer. Together with the ‘electricien’ Charles Wheatstone, he created the Needle Telegraphs for which they were granted GB-Patent № 7,390 in 1837. The first application of needle telegraphy was by railroad companies that needed better signaling. Further application showed that telegraphy was to become a governmental affair.

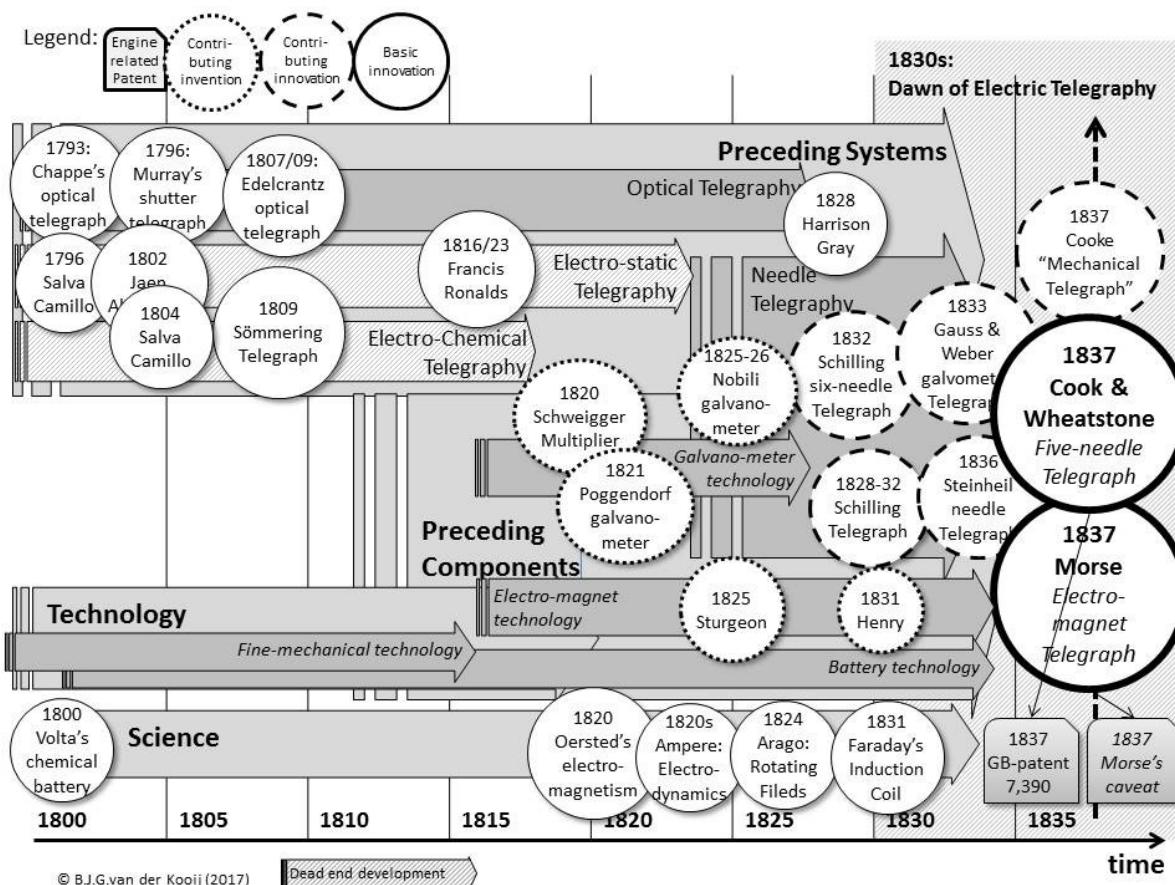


Figure 6: Overview of the Contributing Innovations that created the Telegraph.

In America, Samuel Morse developed telegraphy based on the electromechanical relay. After a stay in France and Italy, the quite successful painter returned home from Paris to New York on the steamer 'Sully'. There he conceptualized, after dinner table discussions with his fellow travelers during the six-week voyage, a system for communication with 'lightning speed' (ie electricity based). As he also developed the corresponding code of 'dots and dashes' —aka the Morse-code—, it would become known as the Morse System. In 1837 he got a patent caveat —ie provisional protection— and in 1840 he was granted US Patent № 1,647. His early application, next from public demonstrations, was for the transmission of public messages. After the slow start of his pioneering enterprise, the Magnetic Telegraph Company (est. 1845), his invention would result in a worldwide telegraph system crossing oceans and spanning the globe. Now telegraphy had become a societal affair.

As it became clear how important telegraphy was for government, business, and private parties, the market for telegraphic services exploded creating an industrial bonanza of telegraph manufacturers and service providers. Soon technical developments followed different trajectories; from the Printing Telegraph and Recording Telegraph comparable to Morse's concept, to the Needle and Dial/Pointer Telegraphs based on Cooke & Wheatstone's concept. Many inventor-entrepreneurs brought their own

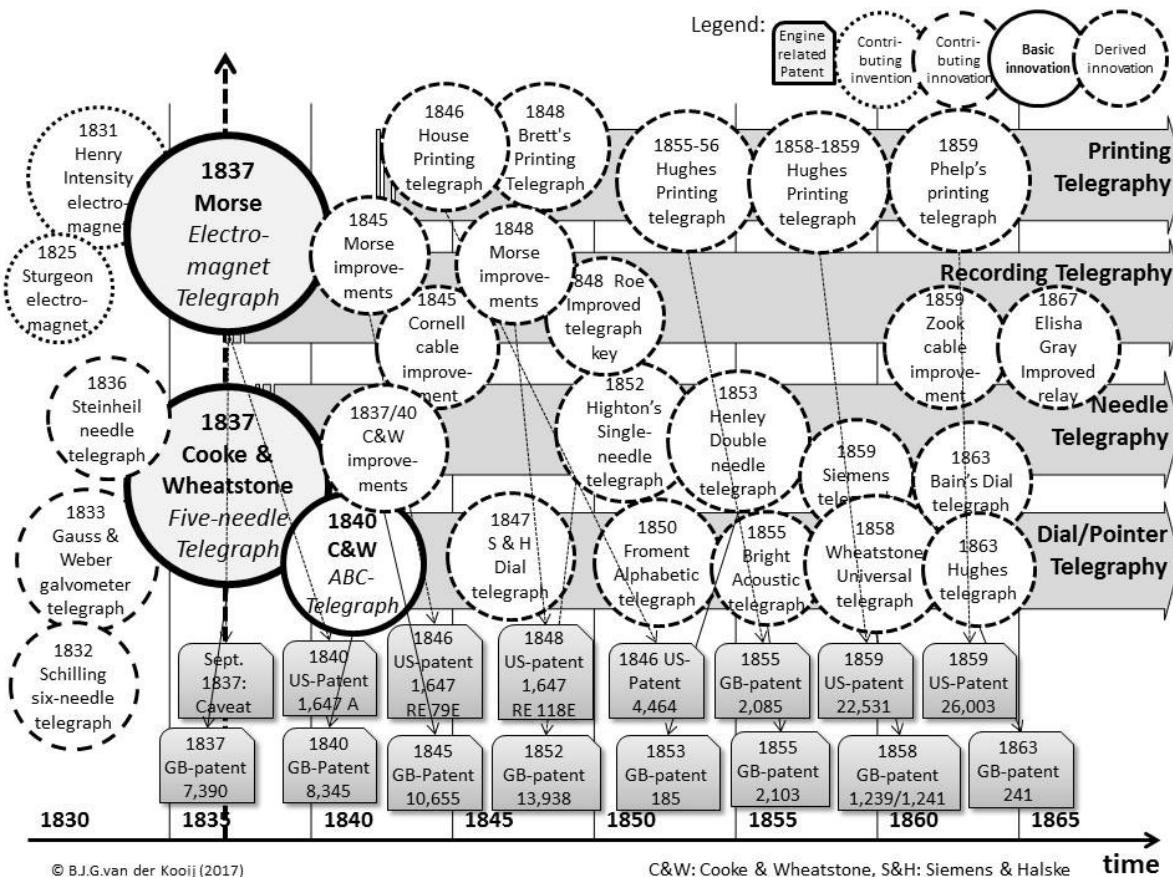


Figure 7: Overview of the improving Innovations that followed the invention of the Telegraph.

improved telegraph machines —some infringing on, and others designed to circumvent, Morse's patents— on the market for a range of service providers (Figure 7).

Remarkably, business-wise, the Telegraph Boom saw different developments take place on both sides of the Atlantic Ocean. In America, after the initial pioneering companies grew and matured, a range of mergers and acquisitions created 'corporate monopolies' of Telegraph Tycoons and their empires. The American Telegraph Acts of 1866 regulated —after much political wheeling and dealing— the industry, but did not prevent the rise of the monopolist Western Union Telegraph Co in the capitalist society. One of its adversaries was the lawyer Gardinard G.Hubbard, the father-in-law of the teacher of his deaf daughter called Alexander Graham Bell. In England, where a telegraphic message was considered to be similar to a written message for which transportation the British Postal Office had the monopoly —a feudal heritage from the seventeenth century— telegraphic service became part of a state monopoly. Formalized by the nationalization policy established by the British Telegraph Acts of 1868-1869, the British Postal Office acquired the then existing service providers. Only the manufacturing of equipment was left to private enterprise. Nevertheless, telegraphy conquered the world in some decades and by 1870, even the Atlantic Ocean was successfully crossed.

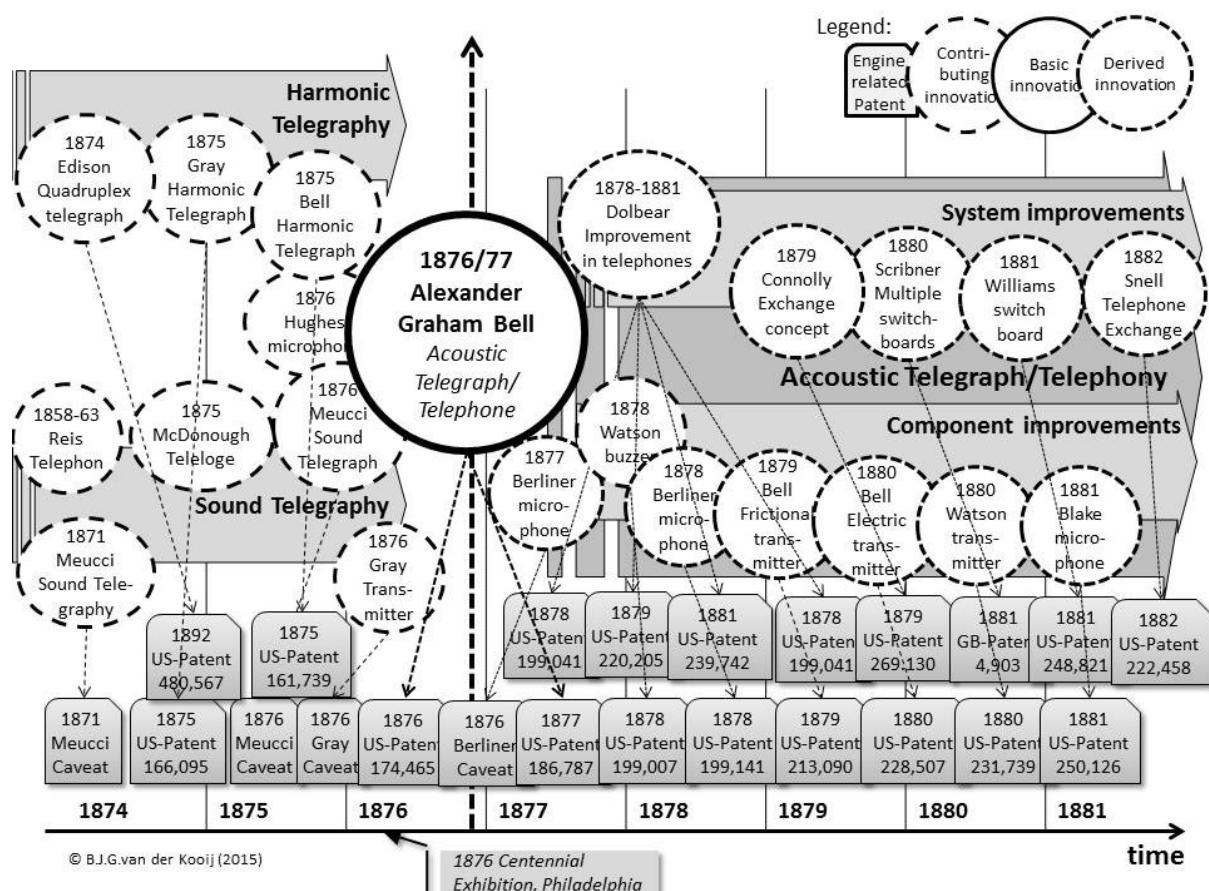


Figure 8: Overview of the Cluster of Innovations that created the Telephone.

### 4.3 The invention of the Telephone

Originally telegraphy was powered by batteries, but with the invention of the electric dynamo, electricity came available in abundance and enhanced the Telegraph Boom of the 1860s (Figure 5). It was one of the many developments that resulted from those creative efforts in the middle of the nineteenth century. Some tinkerers were experimenting with the creation of sound electrically, others were developing recording systems, and components as the microphone were developed. A development that created many acoustic technologies (such as recording music with microphones). It all contributed to the trajectory of Sound Telegraphy; the transmission of electric tones over the telegraphic wires (Figure 8).

By the 1870s also many efforts were undertaken to improve upon the telegraph system itself; multiplexing (transmitting more signals simultaneously over one line) being one of them. It was then that in America, a young teacher of deaf called Alexander Graham Bell, became involved in the development of Harmonic Telegraphy. It was the time that many thinkers and tinkerers tried to increase the capacity of the telegraphic cabled infrastructure. Among them the young Bell who —stimulated by the earlier mentioned lawyer Hubbard trying to crush the monopolistic situation— was looking at other ways to send multiple messages over the same cable. Using separate frequencies of AC-currents, after much

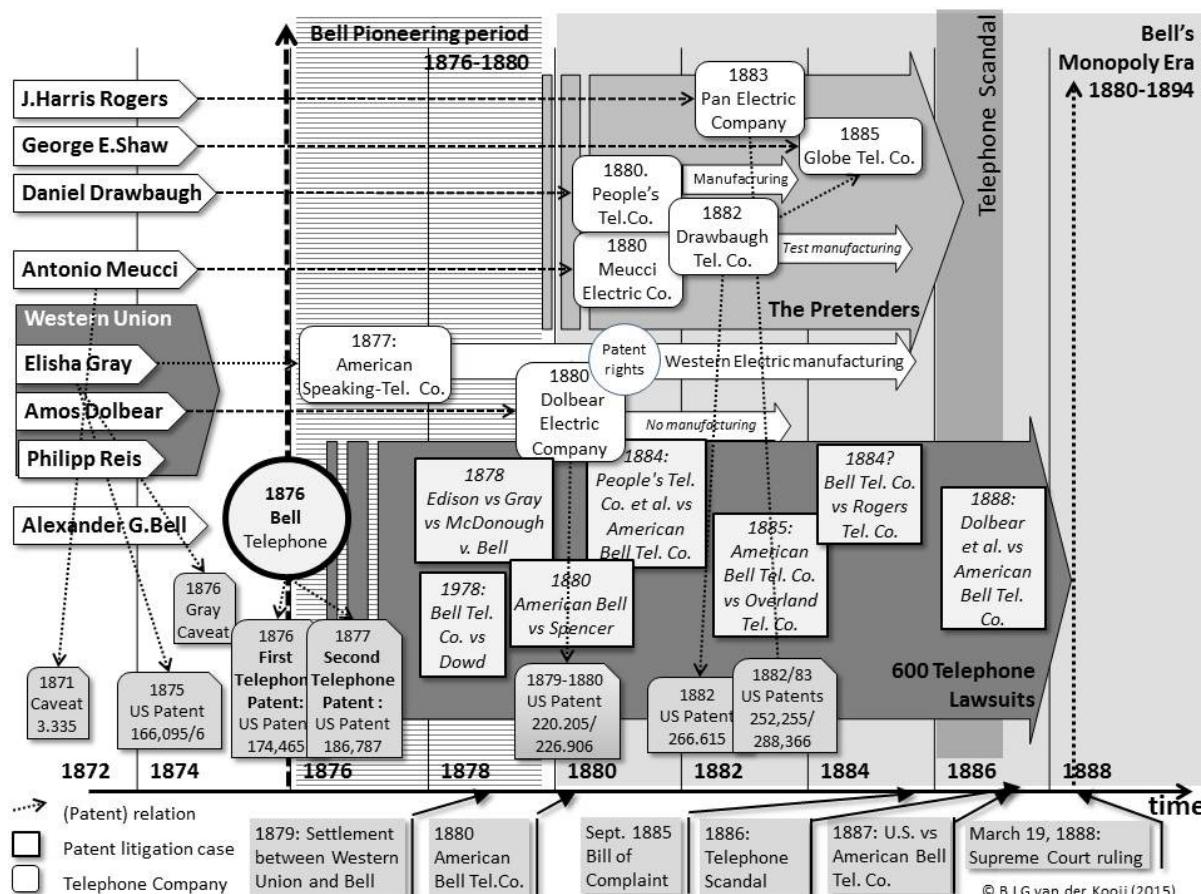


Figure 9: Overview of the Patent Wars for Bell.

experimenting, he managed the transmission of 'electric speech'. For his invention he was, after a race to the Patent Office beating Elisha Grey's caveat application, granted US patent № 174,465 in 1876 and US patent № 186,787 in 1877. These patents would create the Bell Monopoly Era (1880-1894) that dominated the early days of telephony. An era that was marked by patent wars in which Bell had to fight some 600 court cases on litigation (Figure 9).

The newly formed Bell Telephone Company, created from the Bell Patent Association in 1877 to exploit the patents, licensed the rights to telephonic service providers using the Bell System (and buying Bell equipment). The result was the emergence of a cluster of Bell-businesses all over America. The small Bell company was challenging the large and monopolistic telegraph service providers: a David against Goliath battle. Surprisingly, the Bell-company managed to enter into a settlement in 1879 with the mighty Western Union Telegraph Co. Bell got the telephony-business, and Western Union kept the telegraphy business (Figure 9).

At the same time, the development trajectory of telephony saw a range of improvements: both components (eg the microphone) as well as systems (eg the telephone exchange). Telephony changed from an ugly quacking duck into a mighty swan.

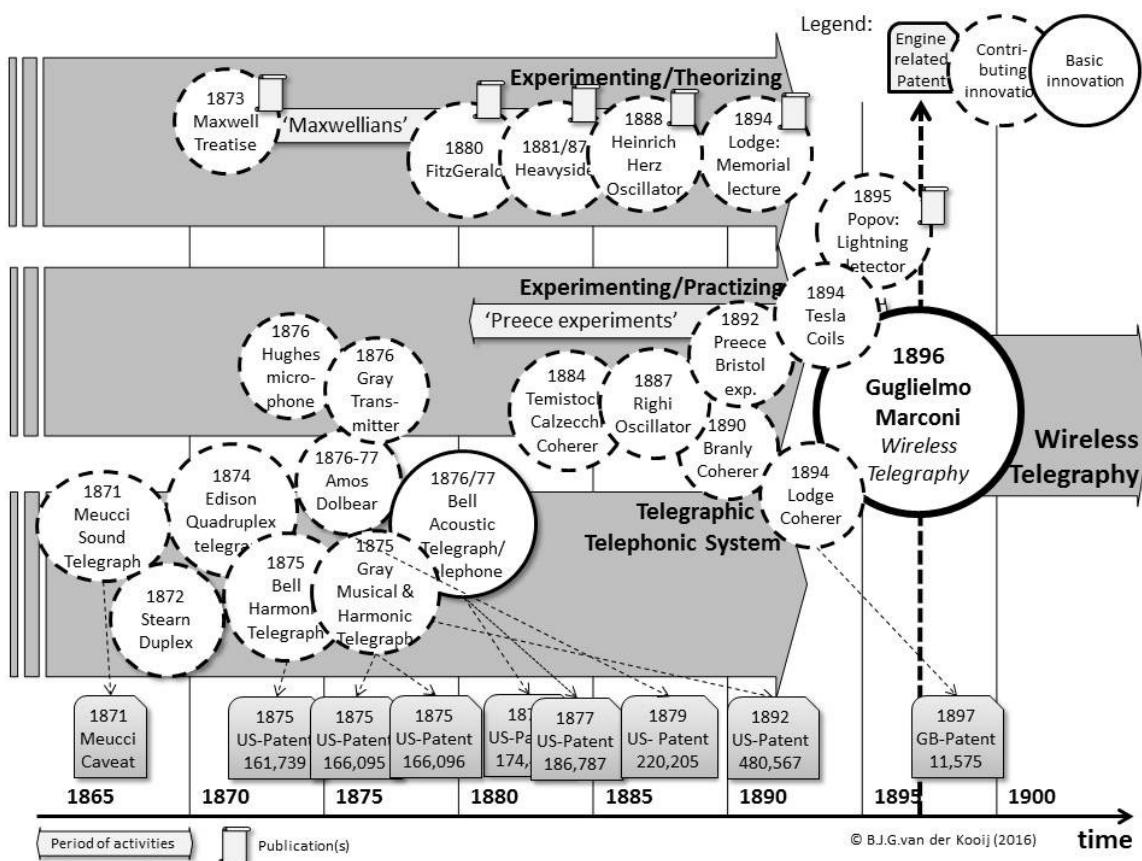


Figure 10: Overview of the Contributing Innovations that created Wireless Telegraphy.

## 4.4 The invention of Wireless Communication

Over time telegraphy expanded, hundreds of miles of copper cables created a mighty telegraph infrastructure spanning the globe by the end of the nineteenth century. However, cables also limited its application: they were vulnerable to vandalism, could not be used in mobile/marine situations. By then scientist had discovered a new property of electricity: the electromagnetic waves. The German Heinrich Hertz caused uproar in the scientific community when he discovered that electric waves could be used for communication over distance. Soon, the thinkers and tinkerers were experimenting with 'Herzian waves'. In Britain, it lead to a controversy between the practitioners of the Post Office, and the Maxwellian scholars exploring the same phenomenon (Figure 10). Then, in the midst of that debate, a young Italian stepped from the boat carrying his 'black boxes' that would turn the tables.

In Italy, Guglielmo Marconi, the child of an Anglo-Italian couple, had grown up after the Unification of Italy. In the wake of the industrial revolution, also the era of electricity had reached the Italian Peninsula. Thinkers started paying attention to electricity, tinkerers developed industrial activities; such as Alessandro Cruto developing his incandescent lamp in 1880, just after Edison had patented his design. Also fascinated by the Herzian waves, scholars developed their own components. Like Augusto Righi

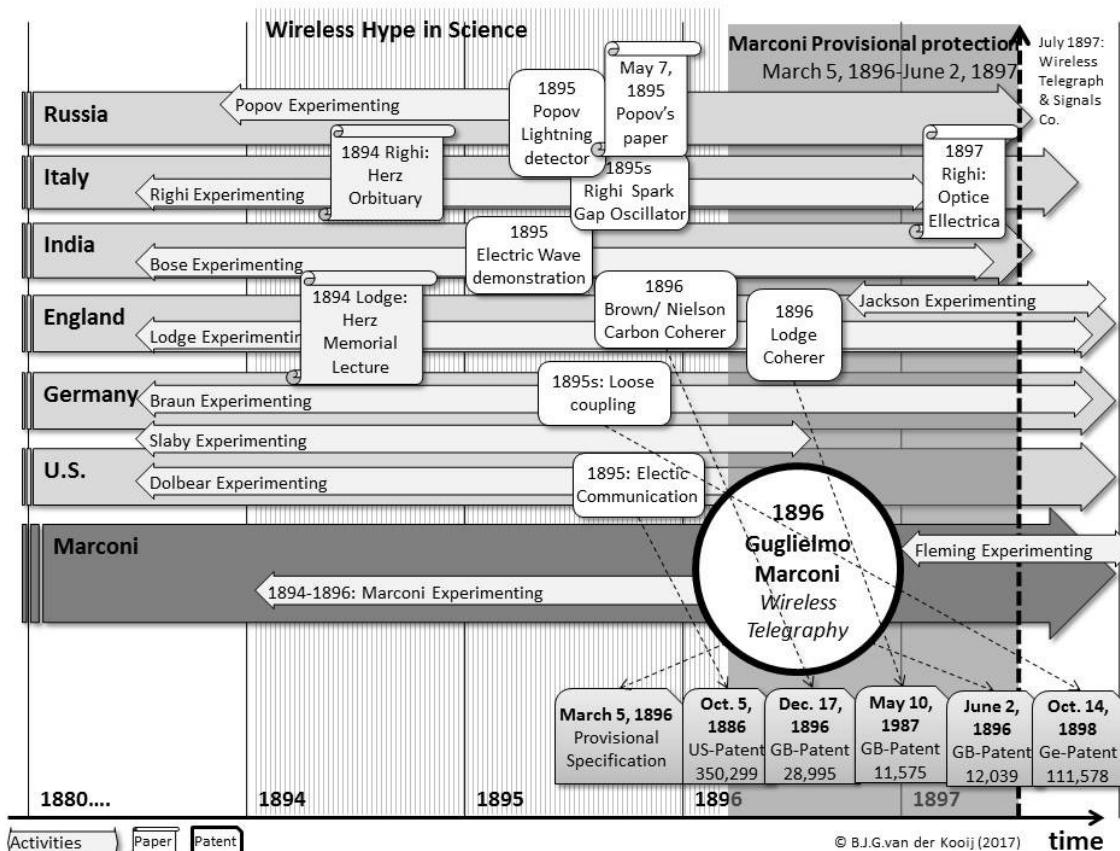


Figure 11: The Wireless Hype of Science.

improving on the oscillator producing the Herzian waves. It started the wireless hype in science in the western world (Figure 11).

Fascinated by electricity, the privately educated young Marconi started experimenting on his own in the attic of his parental home. Soon he was able to create a circuit for ringing a bell without a connecting cable: his wireless system was conceived. It took some further experimenting in the garden, every time increasing the distances bridged without a wire. By 1896 he had a working artefact. As Britain by that time was at its zenith, both as a seafaring nation (Britain ‘Ruling the Waves’) and as an industrial nation (Britain as ‘Workshop of the World’), it was decided that the best environment for further developing his invention was to be found in Britain.

There Marconi soon discovered that he had entered a hornet nest of conflicting interests that emerged from the Wireless Hype in the scientific community. Scientists from different countries disputed his work, claiming priority over the work of a young tinkerer (Figure 11). The more after he was granted GB-Patent 12,039 on June 2, 1897, and started the *Wireless Telegraph and Signal Co. Ltd* in 1897. The Post Office was initially quite content with his invention, and gave support for further experimenting as their own experiments had failed. However, that changed when commercialization

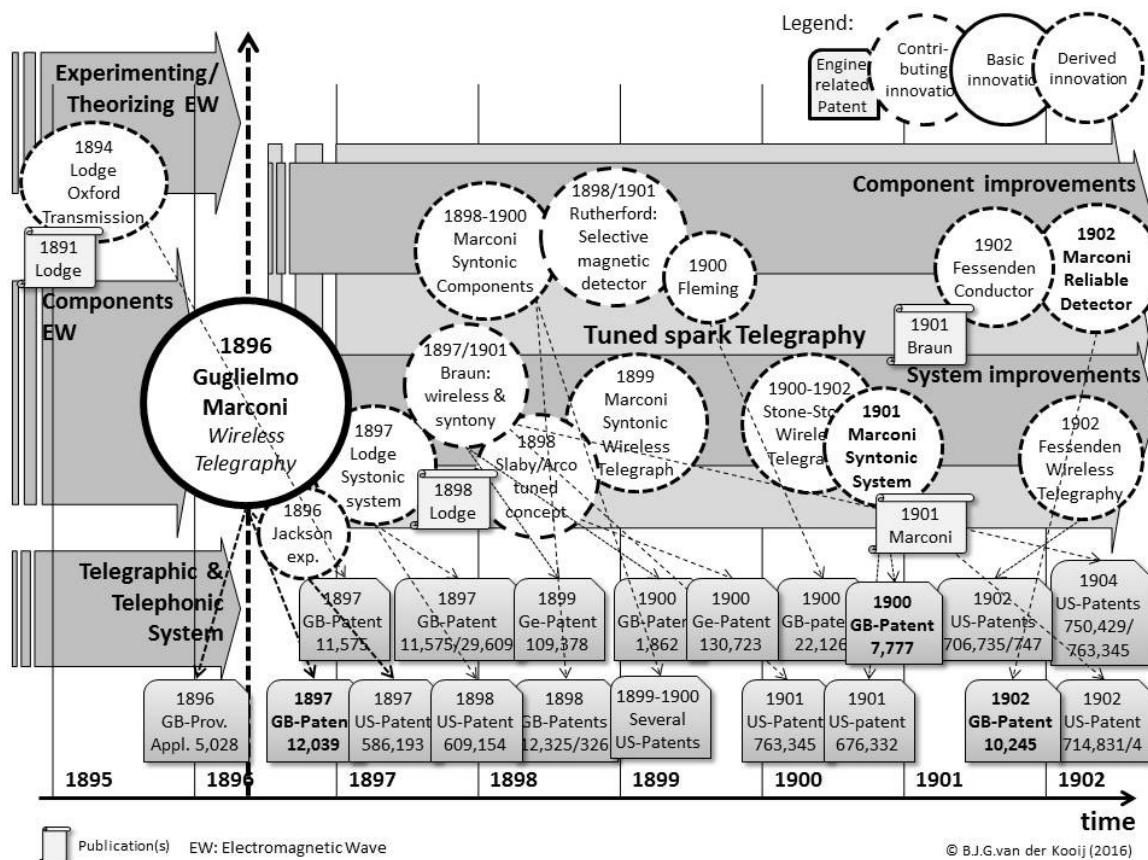
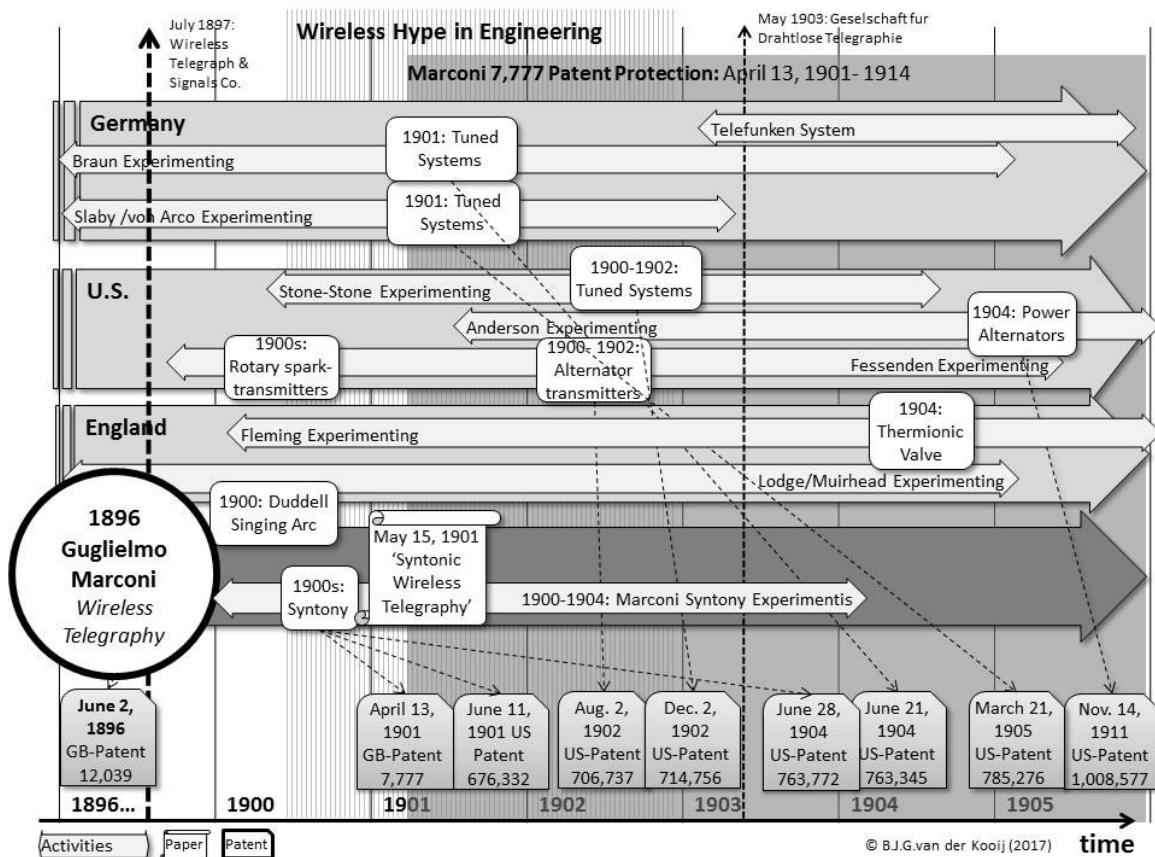


Figure 12: Overview of the Improvement Innovations that created Wireless Telegraphy.

came into play. The War Office, Royal Navy and Army, also claiming priority, were similarly curious and soon copied his design. Germany, developing imperialistic aspirations, had their own scientists working on wireless communication. All in all, wireless was too important to leave to the whims of a foreigner.

But that foreigner continued his experimenting, showing quite some aptitude for publicity. He managed to demonstrate his system to British, Italian and Russian royalty, on sailing Regatta's in England and America, crossed the Atlantic with messages between boats and his wireless stations. This all heralded by the press worldwide, and fiercely opposed by the telegraph companies. Extending his patent-protection in other countries, he started the Marconi Monopoly creating companies like the *Marconi Wireless Telegraph Company of America* (1899), the *Marconi International Marine Communication Company* (1900) and *Marconi's Wireless Telegraph Company of Canada* (1903), each serving specific markets. In the meantime, improving the components and the total system (Figure 12), wrinkling out the youth problems of his spark-generated transmitter and his receiver in the early 1900s, he started selling wireless systems to companies in Britain (eg 'Lloyds of London'), and the Admiralty's of Italy, Japan, and America. Circumventing the Post Office monopoly, soon he dominated the international long-distance ship-to-ship and ship-to-shore market.



**Figure 13: The Wireless Hype of Engineering.**

By that time, the Wireless Hype had reached the engineering community. In America, as well in Germany the development of wireless systems progressed (Figure 13). The German-made Telefunken System became Marconi's dominant competitor. Wireless Telegraphy matured, but still was obstructed by its basic technology of the spark-generated electric waves. It would need other technologies to pass that barrier: such as the invention of the vacuum-tube diode (Fleming) and triode (Lee deForest). Marconi's patent protection just ended by the World War I.

## 4.5 Overview: GPT Electricity and the Second Industrial Revolution

In three phases 'communication at a distance' matured during the Communication Revolution. Starting in the 1840s with cabled telegraphy, followed by telephony in the late 1800s, by the start of the twentieth century it had conquered the world with its wireless equivalent. It was a response to a diversity of needs in society as it solved the time-problem of earlier forms of communication (postal mail), the incommunicado-problem of shipping, the regional time-problem of society. It added to the transparency of the stock market and national trading, it facilitated business activities and government. The spin-off that resulted from these three inventions was enormous, and could not have been foreseen by its innovators when curiosity sparked their creativity and entrepreneurship. It certainly flabbergasted the people who flocked the Exhibitions of those times: from the Great Exhibition in London (1851) to the Exhibitions Universelle in Paris (1855, 1867, 1878, 1889), the Centennial Exhibition in Philadelphia (1876), and the Columbian Exposition in Chicago (1893).

It were these Communication Engines that, next to the electro-motive engines of the electric dynamo and the electric motor, created with their societal impact a stimulus for the developments we label as the Second Industrial Revolution (1850-1920). Next to the infrastructures of the First Industrial Revolution (the roads, canal and railways) now the communication infrastructures were added (the electricity distribution-, telegraph-, telephone- and wireless networks). Next to the massive industries of the First Industrial Revolution (building steam locomotives and steamboats), now the electric industry, the communication industry (both service providers and equipment manufacturers) and a range of others supporting industries (eg cable manufacturers) developed. It was the overture to the Age of Empire (1875-1914): the British Empire, the German Empire, the Russian Empire and the Italian Empire that collided in the First World War (Hobsbawm, 2010a).

## 5 Conclusions

Our earlier analysis shows the different *clusters of innovations* that constitute their own General Purpose Technologies: The GPT-Steam and the GPT-Electricity. Our further research into the GPT-E identified an additional three clusters of innovations related to ‘electricity’: the cluster of the telegraph, the telephone and the wireless (Figure 14). The basic trajectory of the GPT-E was spawning into the unrelated application area of distant communication, having a dramatic economic and social effect in new trajectories. The relatively slow start with telegraphy accelerated when the electric dynamo started supplying electric energy in abundance. Then, together with the development of the electric light, the communication engines created with the help of electricity, penetrated society in a rapid pace.

Based on our observations we are inclined to conclude the following:

Firstly, our inventors had something in common, apart from not being an expert in their chosen field.

Normally one expects technical expertise (eg knowledge of electricity, knowhow of mechanics) to be the source of the technical inventive act. However, Morse was a painter, Cooke a medical student, Bell a teacher of deaf, and Marconi —in today’s— jargon something like a dedicated nerd. So, although highly interested in the phenomena of electricity, they were not burdened with too much knowledge of electricity. Obviously they must have been capable of abstract thinking as they were able to conceptualize at a functional level. Morse saw communication at a distance with ‘lightning speed’, Cooke made (business) plans for ‘rapid telegraphic communication for political, commercial and private purposes’, Bell saw the ‘musical telegraph’ transmitting sound and had the vision of ‘electric speech’, Marconi envisioned ‘signalling into Space’. In addition, they were able to convert that vision into a working artefact.

Secondly, being no expert themselves, at a moment in time they were converting their concept into prototypes, they looked for complementary knowhow. Morse created a partnership with the mechanically skilled Alfred Vail, Cooke worked first with the clockmakers Kerby and Moore, later became partner with the electrician Charles Wheatstone. Bell hired the instrument maker Thomas Watson working in the mechanical workshop of Charles Williams Jr., Marconi had the help of George Kemp, originally employed by the Post Office.

Thirdly, our inventors of the Commercial Revolution were the children of their time: a time that created the context for their endeavours. Their work was not only enabled by developments in their technical environment (eg Boston for Bell, London for Cooke & Wheatstone, Bologna/Milan for Marconi), it was strongly influenced by the *spirit of times* and the *madness of times*. The end of the nineteenth century, for example saw the Gilded Age in America (1870-1900), and La Belle Époque (1871-1914) in

France. Times of optimism and progress. It was the time of the World Fairs, that started with the Great Exhibition in London (1851), where people marvelled at all those inventions. But there were also the times of pessimism and despair. America had the Civil Wars (1861-1865), Italy their Wars of Independence (1848, 1859, 1866). France was defeated in the Franco-Prussian War (1870-1871), and faced the French Civil War (1871). England, splendidly isolated, fought in Africa the First Boer War (1880-1881).

Fourthly, the development of the communication engines was confronting the political climate. In England it had resulted in the communication monopoly of the British Post Office, historically a state affaire. In America, the Telegraph Boom, the Telephone Boom and the Wireless Boom were the result of the capitalist politics of free enterprise. From the different development of the telegraph business in America and Great Britain, one can conclude that the environmental business-condition dictate the development of the business clusters. In America the capitalistic 'laissez faire' policies and the entrepreneurial-industrial mentality created an Industrial Bonanza. In England the government reserved for itself the monopoly on telegraphic services, and the British Post Office dominated business development for decades to come.

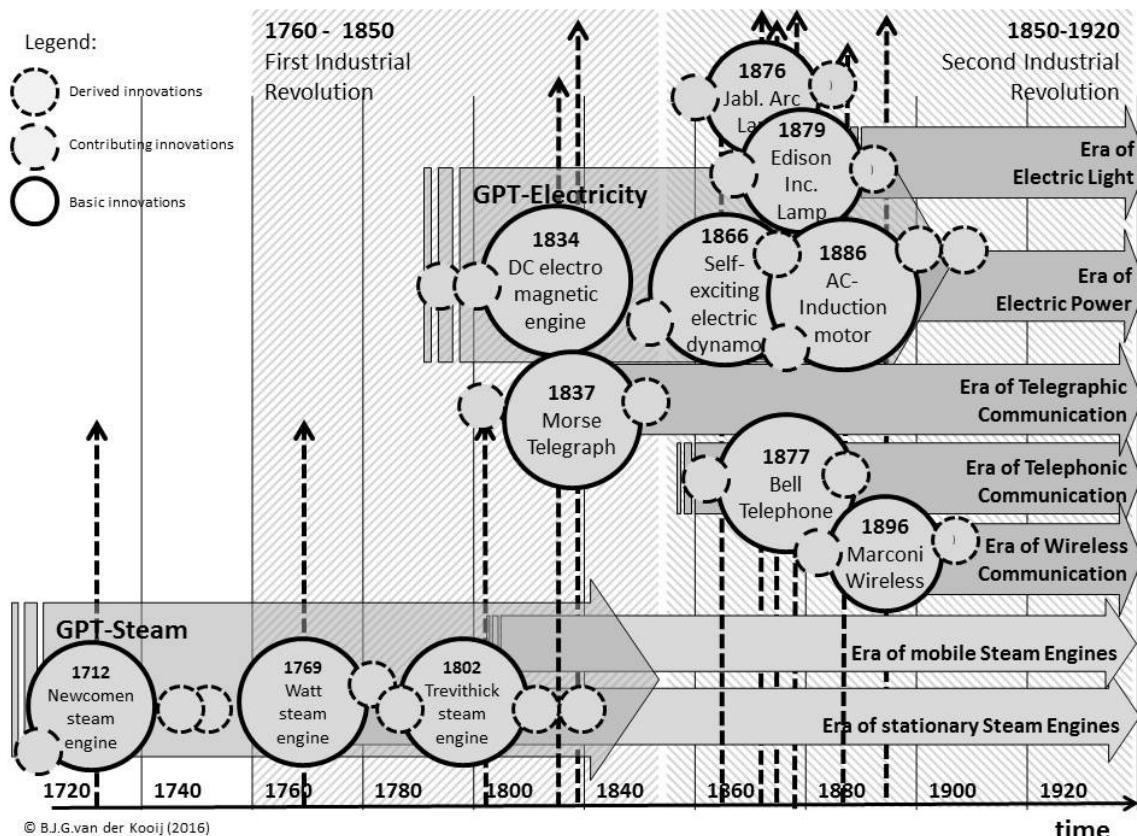


Figure 14: Overview of the General Purpose Technologies of Steam and Electricity.

This range of successive clusters of innovations that created the Era of Communication, is part of the way the GPT-Electricity — with its information processing capabilities — contributed with the General Purpose Engines to the Second Industrial Revolution. It would create the foundations of the Information Revolution to come. But that is another story... (Kooij, 2017a)

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