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Acts of Invention and Acts of Business in the GPT-Electricity: What did Morse, Bell and Marconi have in common?

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Abstract

The General Purpose Technology of Electricity (GPT-E) as a meta-technology has been a driving force of economic growth in the Second Industrial Revolution. Fuelled by inventions (eg the electric motor/dynamo, electric light, telegraph, and telephone), its micro-foundations were the General Purpose Engines (GPE). The GPEs were the basic innovations surrounded by their of Clusters of Innovations. These basic innovations, characterized by their social and economic impact, were the result of the work of single individuals. It was their respective Acts of Invention that created the artefacts that played such an essential role in the spawning of the GPT-E; and it were their Acts of Business that created their patent-based commercial monopolies. Based on extensive case studies, we investigated the individual contributions of Samuel Morse (telegraph), Alexander Bell (telephone) and Guglielmo Marconi (wireless), to find that they had much in common. Their Acts of Invention—the process from idea to prototype and product—and their Acts of Business—the process from prototype to commercial product—are presented and show remarkable similarities.

Keywords

General purpose technology, technological innovation, cluster of innovations, act of invention, history of technology.

JEL: N7, O31, O33, O40,

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1. Introduction

Economists discovered, in the 1920s-1930s, the ’new combination’ creating innovation as an important contributor to business cycles (Gilfillan, 1935; Schumpeter, 1935, 1939; Usher, 1929); in the 1950s included ’technology’ in their production function (Solow, 1957); and found in the 1970s ’basic innovations’ to be fundamental to economic cycles (Mensch, 1979). In the 1990s the concept of the *General Purpose Technology* (GPT) was developed (Bresnahan & Trajtenberg, 1995; David & Wright, 1999; Helpman, 1998; Jovanovic & Rousseau, 2005; Lipsey, Carlaw, & Bekar, 2005). The GPT-concept tries to explain the major changes that took place in societies and economies, where a dominant technology results in creating considerable novelty and has a major impact on society and its economy. It resulted in a range of macro-economic views, on a high level of aggregation, describing their characteristics.

It was Lipsey et al., describing (radical) innovations, who stated that describing the characteristics of a phenomenon does not explain the phenomenon itself: “*[...] If the concept of GPT is to be useful, then GPT’s must be identifiable. [...] However, if we want to develop theories [...], we cannot define them* [the GPT’s] *by their effects.”’* (Lipsey, Bekar, & Carlaw, 1998, pp. 21, 32). So, the comprehension of the basic elements of the GPT-concept was limited: *“This leaves a gap in our understanding of the micro-foundations of GPTs.”* (Moser & Nicholas, 2004, p. 388), or as Richard Lipsey formulated it: *“What is needed to identify a technology as a GPT is to locate a technology identifiable as a single generic product, process or organizational form over its whole evolution, such as the computer or steam engine, and then collect evidence that it fulfills the condition that we have identified in our definition.”* (Lipsey et al., 2005, pp. 109-110)

We studied the inventions in the GPT-Electricity extensively[1], both their contents and contexts, and introduced the concept of the *General Purpose Engine*. We concluded that these General Purpose Engines are found as the basic innovation, in a clusters of innovations, that create their own technical trajectories, which then spawn into unrelated, new technological trajectories, each with their own specific clusters of innovations. Therefore the ‘general purpose <u>engine</u>’ seems to be the core of these GPT’s, representing the micro-foundations that Richard Lipsey was looking for. We subsequently redefined the GPT: “*A General Purpose Technology is a collection of ‘general purpose engines’ fulfilling a basic societal need: the result of a range of related clusters of innovations, each with its own basic*

[1] In a range of seven case studies, published as The Invention Series, we analyzed the Cluster of Innovations that created the inventions like the steam engine, electric motor/dynamo, electric light, telegraph, telephone, wireless, and the resulting Industrial Revolutions. They are available on https: //www.amazon.co.uk/B.-J.G.-van-der-Kooij/e/B00SUS2RZA.

innovation. It is a meta-technology that creates a discontinuity disrupting the economic equilibrium and social order, pervasively creating technical artifacts as the result of its spawning and improvement potency." (Kooij, 2015c). In addition we explored in a case study the context for innovation, that resulted in the industrial revolutions, and analyzed how the GPT-Electricity contributed to the Second Industrial Revolution (Kooij, 2015a, 2016a, 2017a). We concluded that the Invisible Hand of Innovation was the driving factor (Kooij, 2017a).

Now we look at how those GPEs were created. What was the process behind its emergence? Based on the case studies into the communication engines (Kooij, 2015b, 2016b, 2017b) we will analyse in detail how the inventor-entrepreneurs Samuel Morse, Alexander Graham Bell and Guiglielmo Marconi 'invented' and commercialized their GPEs.

2. Conceptual framework

Innovation-scholars, the off-spring of philosophers interested in change and novelty, began investigating the Nature of Change and Novelty in the nineteenth century. Among them the French sociologist Jaen Gabriel Tarde (1843-1904), observing the evolution of art, law, institutions, and social change, formulating his 'Laws of Imitation' (Tarde, 1890). For Tarde, as with social sciences and the natural sciences, his universal law of imitation was applicable both to change and novelty. He saw 'individual renovative initiatives' (IRI's)— which could be described as inventions, discoveries or innovations—spread by imitation. These acts of imitation diffuse the novelty, in the process improving by combining them with other IRI's. "Invention is always, by its very nature, an intersection of imitation rays, an original combination of imitations" (Tarde, 1902, p. 565). The result could be 'theoretical inventions' (which meet 'the need to believe, affirm or deny'), other 'practical inventions' (which meet 'the need to desire, want, and act') (Djellal & Gallouj, 2014, pp. 3, 8). Obviously his period of reference included the preceding *Times of Imitatio & Emulatio*[2]. The economists picked up on the *imitation-concept* and kept it alive far into the twentieth century (Godin, 2008, p. 37).

Then, early twentieth century scholars further developed the *combination-concept* of innovation. Abbott Payson Usher found *"the search for the unique inventor naïve and ill grounded"* (Usher, 2011, p. 530), and developed the synthesis-theory where the individual Act of Skill and the Act of Insight created the new combination (Figure 1). He did not discriminate between invention and innovation, unlike his contemporary Alois Schumpeter who saw Innovation as different from invention: *"Although most innovations can be traced to some conquest in the realm of either theoretical or practical knowledge,*

[2] The times from the middle Ages preceding the Industrial Revolution, characterized by the pro-industrial heritage of the feudal times; the guild system with its craftsmanship and apprenticeship.

there are many which cannot. Innovation is possible without anything we should identify as invention, and invention does not necessarily induce innovation, but produces of itself [...] no economically relevant effect at all." (Schumpeter, 1939, p. 80). For him 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).

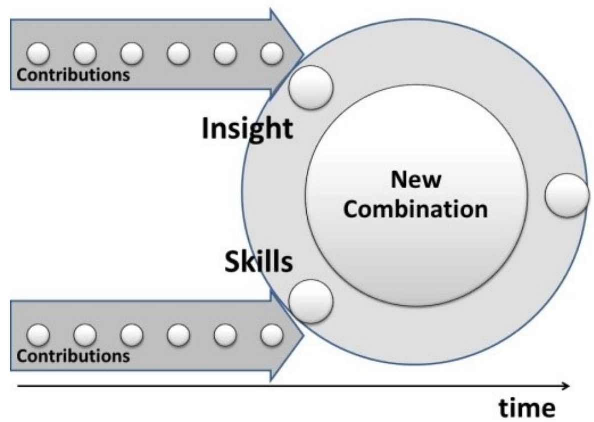

Figure 1: Synthesis-thinking where Innovation is the new combination: the result of the Act of Insight combined with the Act of Skills.

Schumpeter's definition reflects the combination-approach in invention-thinking at the beginning of the twentieth century up to the 1950s. It fitted with the *Times of Invention*[3] as the work of inventor-entrepreneurs such as Thomas Edison, Alexander Graham Bell and Guglielmo Marconi.

Over time the individual approach to innovation changed into the collective approach. By the mid-twentieth century innovation was seen as the result of a collective effort called research and the subsequent development activities (aka R&D): *"Innovation is the process of bringing invention into use"* (Schon, 1967, p. 1) and *"The process by which an invention or idea is translated into the economy"* (Twiss, 1980, p. 6). This concept stressed the importance of basic and applied research, creating inventions that were diffused by the development of innovations. In contrast to research resulting in discoveries and inventions, development activities seemed to be quite manageable. So innovation-scholars developed the *process-concept,* where innovation was seen as the result of a linear process of activities and thus developed their 'linear models of innovation': *"It is a complex series of activities beginning at first conception, when the original idea is conceived; [...]; and ending at first realization when an industrially successful product, which may actually a thing, a technique, or a process, is adapted in the marketplace."* (Globe, Levy, & Schwartz, 1973, p. 8). This view continued into the twenty-first century.

The result of all these views on innovation is a heterogeneous collection of definitions of the notion of innovation, as we have explored elsewhere (Kooij, 1988, 2013). From different points of view and

[3] The times of the Industrial Revolution characterized by their inventions (eg steam engine). Especially the second Industrial revolution with the invention of electric light, the cabled telegraph and telephone, and wireless telegraphy.

perspectives sociologist, anthropologists, economists and management-scholars looked at the process and its results; and they presented quite different views, theories, definitions and models.

3. Methodology framework

For clarity and simplicity, we would like to stay for the moment with defining innovation in the spirit of Schumpeter: *Innovation is the new combination that creates new products, markets, organizations and production methods.* In addition, realizing an innovation can be considered as the result of a process of human acts of creation. However, what mechanism constitutes that individual *Act of Creation,* apart from the observations of human curiosity, ingenuity, and creativity, is not that clear at all. The same goes for entrepreneurship, an essential part of the process of Morse's, Bell's and Marconi's inventions. Given the preceding 'tour d'horizon' of the innovation-concepts developing over time, we will now zoom in on the characteristics of their acts of creation.

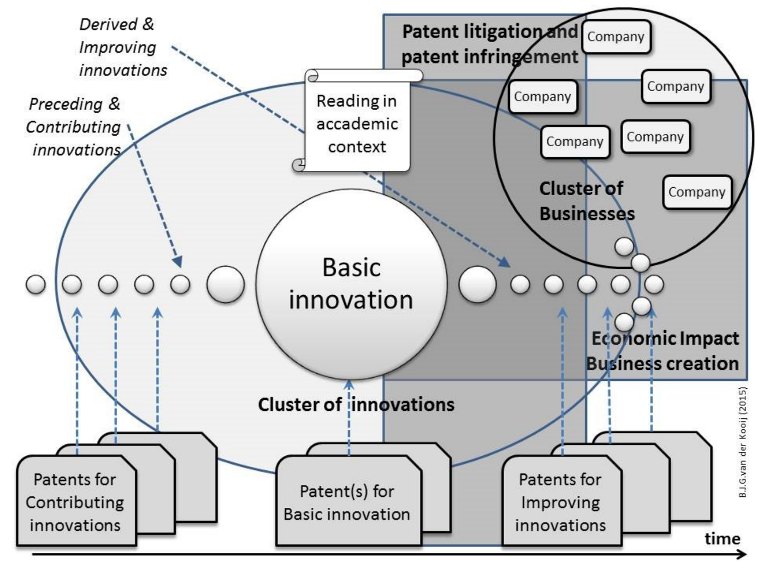

Figure 2: The Content of Innovation: the Cluster of Innovations and the Cluster of Business.

We will use the method of case studies, because it gives us the opportunity to describe the content and the context of the individual cases. For the content, we will use the construct of the *Cluster of Innovations*—with the basic innovation at its core—and the *Cluster of Business* that emerges from the invention (Figure 2). For the context of that cluster of innovations

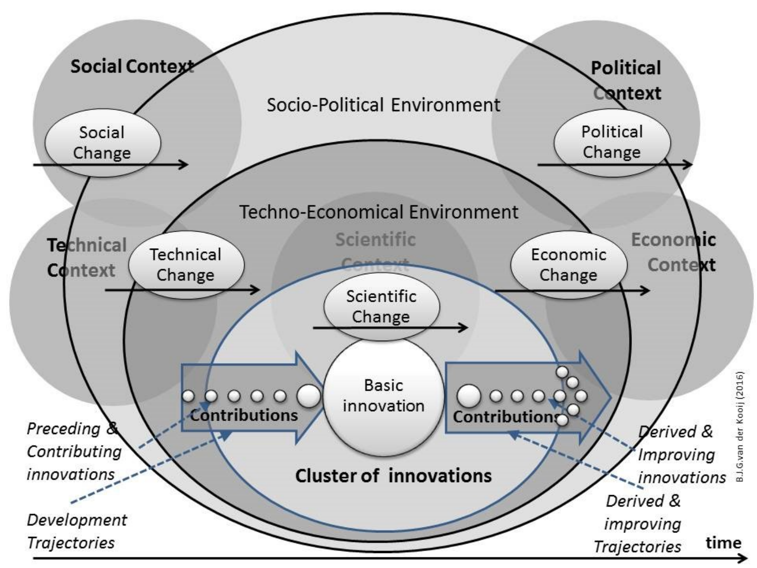

Figure 3: The Context for Innovation: the Socio-Political Environment and the Techno-Economic Environment.

we use the constructs of Change; technical, economic, political, social and scientific change, that each create their own specific contexts. We will combine those contexts into the Techno-Economical Environment and the Socio-Political Environment (Figure 3).[4]

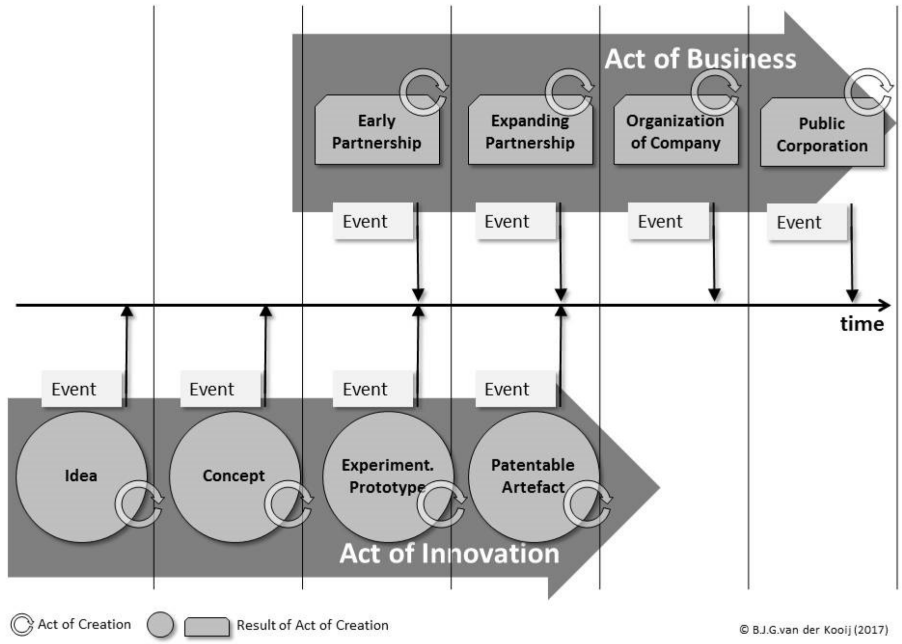

Figure 4: The constructs of the Act of Invention and the Act of Business.

In addition, let's investigate how those basic innovations arose. What did the inventors do to create their invention? So, zooming in on their activities— within their different acts of creation—we used the constructs of the *Act of Invention*[5] and the *Act of Business* (Figure 4). We define the Act of Invention as 'the total process of inventive activity that starts with an idea and results in a (patented) artefact,' and the Act of Business as 'the total process of entrepreneurial activity that starts around a (patented) artefact and results in an organization.' These Acts, by themselves, each constitute out of several Acts of Creation (circles in Figure 4). As an identifier for those activities we observe the *events* that are recorded by biographers and other scholars. Using this perspective, we analyzed the events around the inventor-entrepreneurs: Samuel Morse, Alexander Graham Bell and Guglielmo Marconi.

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[4] For more details of the methodology we refer to the introduction of each case study where our field of interest, focus of analysis, perspective, unit of analysis, and innovation-identifiers are described in detail.
[5] The word 'invention' used here for Morse's, Bell's and Marconi's contributions, would be replaced by the word 'innovation' in today's interpretation. Seen in the context of their impact the additive 'basic' would be used. So instead, in these cases, we would talk about their 'basic innovation' rather than invention. For pragmatic reasons we have stayed with the historic use.

Case studies

Based on the conceptual framework, we have created the operational models for our interpretation, and applied it in the following case-studies: the *Invention of the Communication Engine 'Telegraph',* the *Invention of the Communication Engine 'Telephone',* and the *Invention of Wireless Communication Engine*. Together they describe the early phases of the Communication Revolution. In each case study, we zoomed in on the Acts of Invention and the Act of Business. Let's have—in a quite condensed form—a look at those developments as they happened to be.

4.1 Morse's Act of Invention and Act of Business

On 15 November 1832 the steam powered packet boat Sully arrived in the harbor of New York. On board was the forty-one-year-old painter Samuel Breese Morse (1791-1872). He returned from England, France and Italy, after a two year stay to improve upon his painting skills. The long voyage had seen many discussions with his fellow-passengers. Among them was Dr. Charles T. Jackson, a Boston physician who was familiar with the latest European discoveries in electricity and electromagnetism. Jackson

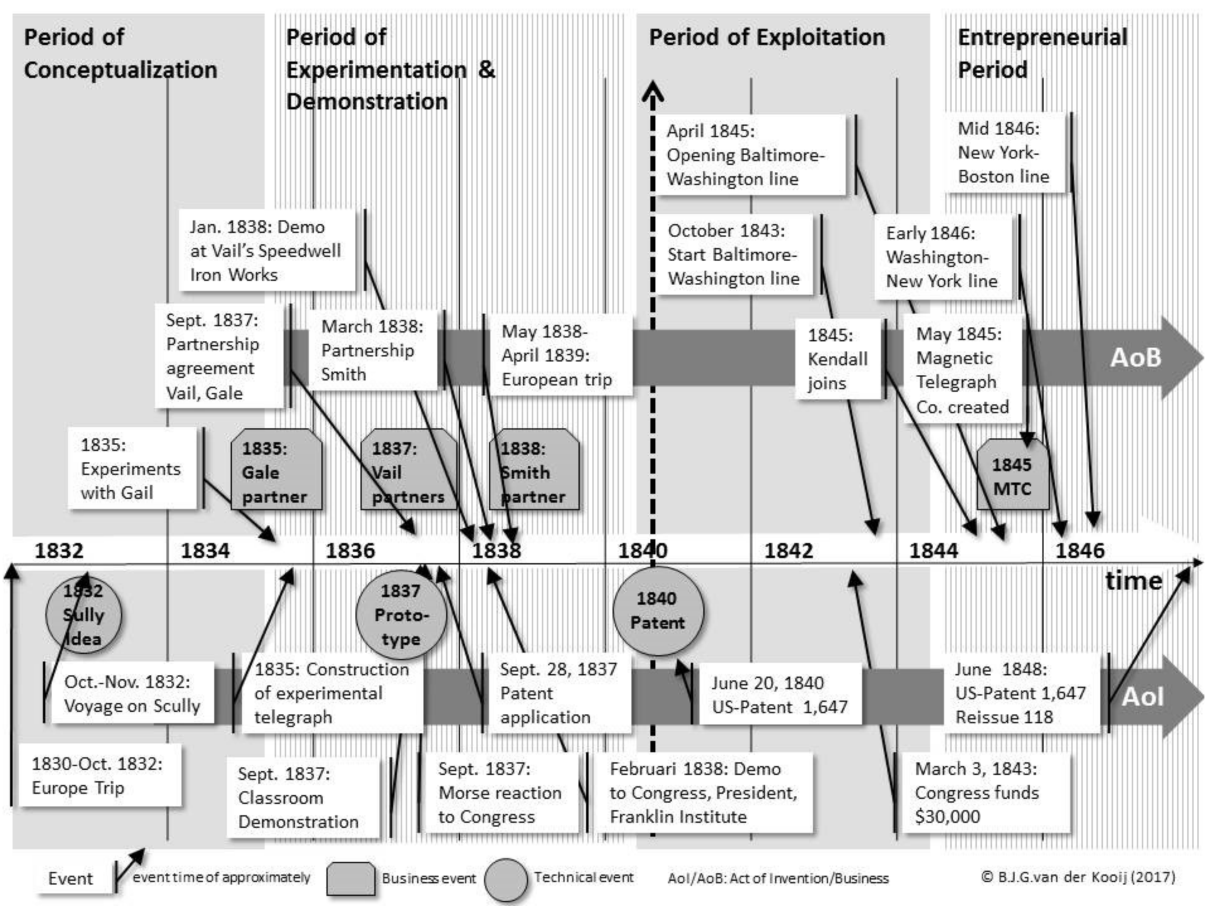

Figure 5: Timeline of the Samuel Morse's activities (1832-1846)

Figure created by author

remarked that electricity passed instantly through long wires, and that its presence could be detected by breaking the circuit and observing the resultant spark. Morse exclaimed that "if this is so and the presence of electricity can be made visible in any desired part of the circuit, I see no reason why intelligence may not be instantaneously transmitted to any distance.” (Hochfelder, 1998, p. 4). He became exited and, sketching and discussing, developed the idea of transmission over distance with the lightning speed of electricity.

Occupied by other activities—Morse became a professor of fine arts and finished several paintings—it took a while before he was able to convert his ‘Sully-idea’ into a first experimental telegraph in 1835. One part of his activities concerned the development of the hardware; based on an old canvas frame easel, he constructed in wood a clumsy prototype for the receiver. The other part was the development of the software; the Systems of Signs with codes that would grow into his famous code-system of ‘dots and dashes’. Continuing with improving his experimental apparatus, covering increasing distances, he demonstrated it to friends and colleges, and he went into partnership with professor Leonard Gail. In September 28, 1837, he filed his patent-application claiming an apparatus for ‘telegraphic communication at any distance’ establishing his priority-rights. In January 1838 he demonstrated his invention to the Vail-family, owners of the Speedwell Iron Works. The mechanically able son Alfred Vail went into partnership with Morse, and his brother George started financing him. In February 1838 he demonstrated his invention to members of Congress and the President. It interested congressmen Francis Smith enough to enter into the partnership with Morse, Gail, Alfred and George Vail. Morse went on a business trip to Europe, but his efforts to secure patent protection in Europe proved to be disappointing and futile. After returning disheartened, Morse had difficulties earning a living.

In June 20, 1840 he obtained his US patent № 1,647. Then, in December 1842, he made another effort to obtain the help of Congress—now with more success, as the Bill to finance an experimental line passed by a marginal majority. With the $30,000 funding he was able to start the erection of the first electric telegraph line between Washington and Baltimore in 1843. It was opened for business on April 1, 1845, to the public. To expand the lines, Morse had to find additional capital, so the joint stock company called Magnetic Telegraph Company was formed. It was the beginning of the telegraph network that eventually covered the East Coast. Within a decade, telegraphy conquered the eastern part of America. Protected by his patent, which was often infringed upon and led to his patent war, he created the monopoly of the ‘Morse System’. This pictures the timeline of Morse’s invention (Figure 5).

4.2 Bell's Act of Invention and Act of Business

In 1870 the Scottish family, Bell, emigrated to Newfoundland, Canada. The young Alexander Graham Bell (1847-1922) worked with his father, a well-known elocutionist, teaching speech to deaf people. As telegraphy was in its ascendancy, Bell came in touch with the new phenomenon of electricity. He was invited to start teaching in the technology-dominated city of Boston in April 1871 and opened there his School of Vocal Physiology and Mechanics of Speech in October 1872. Working by day, he devoted the nightly hours to experimenting with sound and electromechanical devices. That lifestyle took its toll and by 1874 he had only two students left; Mabel Hubbard (his future wife) and George Sanders. Both their fathers would go and play an important role in Bell's future.

In the autumn of 1874 he created a Musical Telegraph, a device consisting out of a magnet powered reed that reacted to an AC-current. He conceptualized the 'musical telegraph' which would create the frequency on one side of a line with a tuning fork, receiving it with a reed electromagnet on the other side. The Idea of 'Electric Speech' was born, in today's language, to transmit signals by using AC-currents of different frequencies. However, the lawyer Hubbard familiar with the telegraphic world, saw this idea

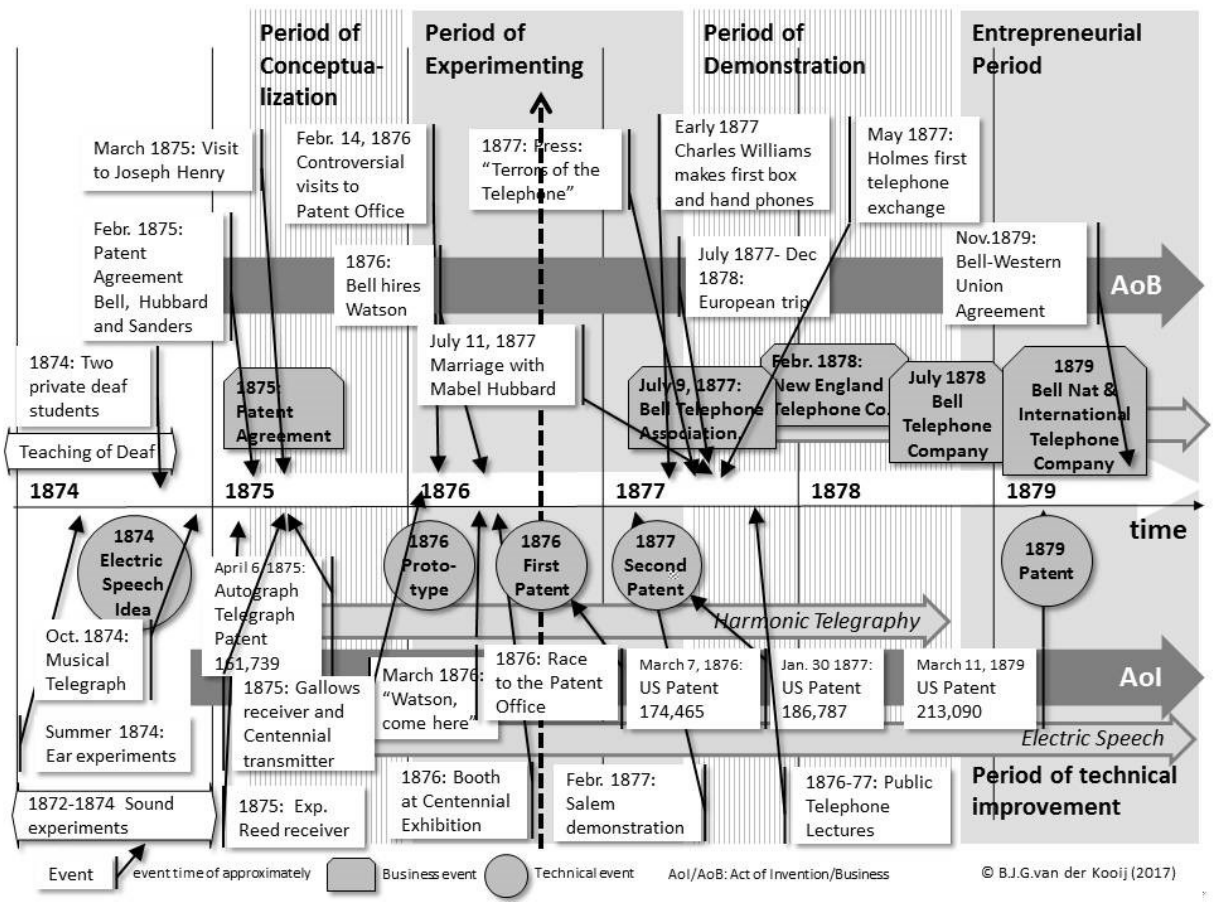

Figure 6: Timeline of Alexander Graham Bell's activities (1832-1846)

Figure created by author

as a means for solving the capacity problem of the telegraph industry, and breaking the monopolies of the large telegraph companies. The search for the harmonic telegraph was in full progress and Hubbard was excited by young Bell's idea. Including the entrepreneur Sanders he created an association based on a patent agreement, in 1875 to finance Bell's further work. Further experimenting resulted in a first patent and on April 6, 1875, Bell was granted US Patent № 161,739 for 'improvements in transmitters and receivers for electric telegraphs'. The patent was for an invention capable of sending several telegraphic messages simultaneously. To assist him with technical matters, in 1876 Bell hired Thomas A. Watson, a technician, to build prototypes in his laboratory. Despite Hubbard's and Sander's pressure to continue with the harmonic telegraph, he also progressed with his idea of electric speech, and created the 'membrane Gallows receiver' and the 'Centennial transmitter'. In March 1876 he made a working prototype and transmitted the now famous words: "Watson come here, I want to see you." He obtained his first telephone patent on March 7, 1876. As it was a broad patent it would become one of the most valuable patents of that time. He got the patent, but not without problems, as it had been a race to the Patent Office to beat his competitor Elisha Grey who had a similar invention.

Next Bell demonstrated his invention at the Centennial Exhibition (May-November, 1876) in Philadelphia. Among his visitors was the Emperor of Brazil, and his invention became the star of the exhibition. Public reception was quite different, and the press reported on the 'Terrors of the Telephone'. That changed after Hubbard organized demonstrations and Bell gave a series of telephone lectures. Independent operators such as E.T. Holmes created local networks with Bell's equipment. The manufacturing of telephone sets was done by a subcontractor, one Charles Williams. In the meantime Bell focused on developing his device, and obtained a new patent; this second telephone patent that would become the cornerstone for the Bell Monopoly. Bell's company was organized in July, 1877 after negotiations failed to sell his patent to the large telegraph company Western Union. Soon business picked up, and telephone sets were leased with a license to use the patented system, to independent parties. At that same time, in July 1877, Bell married Mabel Hubbard and went on a business-oriented honeymoon to Europe for a year-and-a-half. In England he gave many demonstration, including a personal demonstration to Queen Victoria, and furthermore he created the (British) Telephone Co. Ltd (Bell's patent). Bell also obtained patents for his invention in other European countries like Great Britain, Italy and Sweden. Getting patents and doing business in all these different countries proved difficult however, and his trip—from a business point of view—was not that successful.

Back in the US he was faced with the aggressively competing Western Union, which had entered the telephone market by creating its own company. Bell's business partners decided to act; the defense of the patent-priority in court and the creation of the New England Telephone Company to expand the business by themselves. It became a fight between David (the small Bell enterprise) and Goliath (the giant monopolist Western Union), that ended with a business agreement in November 1879. It was agreed that Bell would not go into telegraphy, and Western Union would stay out of telephony. This was the start of the Bell monopoly, in July 1878, for the newly organized Bell Telephone Company. A company that would be confronted with a patent battle of more than four hundred court cases. Now business quickened and additional need for capital resulted in the division into the National Bell Telephone and the International Bell Company in 1879. In the following years, Bell's System conquered the world. This pictures the timeline of Bell's invention (Figure 6).

4.3 Marconi's Act of Invention and Act of Business

In Italy the young Guglielmo Marconi (1874-1937)—second child of a mixed Italian-Irish couple—excited by the possibilities of electricity, had been experimenting in the attic of his home, Villa Griffone. After being confronted with Hertzian waves—electromagnetic waves explored by Heinrich Hertz—in January 1894, he conceived his "Hertzian wave" idea for an apparatus for distant action, such as the 'wireless' ringing of a bell. This was a simple idea that would grow into a concept: how to realize a system using 'electric waves' for action at a distance. It was during the holidays in the summer of 1895, in the Alps, that Marconi conceived the idea for a wireless communication system. He constructed a first experimental system and tested it on the Celestine Hill, next to his paternal house in Pontecchio near Bologna. His system worked. Thus he had, over the period of less than two years of thinking and tinkering in an experimental way, converted his initial idea into his experimental prototype of a rudimentary system of wireless communication: the wireless transmitter and receiver combination. Having realized that, he then pondered on what to do with his invention. With his background of a business-minded family (both in Italy as well in Ireland), the choice to commercialize his invention, one way or another, was not too surprising. Britain, currently the industrial 'Workshop of the World', seemed to be the country to do that.

After Marconi's arrival in England in early 1896, he was supported by his nephew Henry Jameson-Davis. He arranged for the young Guglielmo the first contacts with the Post Office—the British authority on telegraphy—and organized to obtain a patent. On 5 March 1896 the provisional specifications were filed establishing his priority right, and on 2 June 1897 the patent was granted. The Post Office had embraced Marconi's invention, especially after test on the Salisbury Plains in September 1896, but the British scientific community was appalled by the application of the patent. In the meantime, his helpful nephew Davis had found parties interested in investing in Marconi's invention and, in July 1897, the Wireless Telegraph & Signal Company was organized. Although by now the Post Office had withdrawn its cooperation, the further development of a wireless transmission system went quickly with George Stephen Kemp, former Post Office employee, serving as assistant for the next 36 years. From the first prototypes of the components, that were the subject of his patent claims, as well as the claim for the overall system, much effort was put into both the technical development and the market development. The technical experimenting went hand in hand with the public demonstrations, which focused on interest groups, as perceived by Marconi: the British aristocracy and the governmental decision makers within the Royal Navy, Army, and the Post Office. In addition, the widely published demonstrations created awareness among society's decision-making elite; Marconi's trump card was the excitement of novelty.

Then came the period of early manufacturing. From the early prototypes, Marconi now had to create a commercial product. First, there was an impromptu setup to create some quite crude wireless stations and wireless equipment; a lot of this work was done by subcontractors. However over time, as the

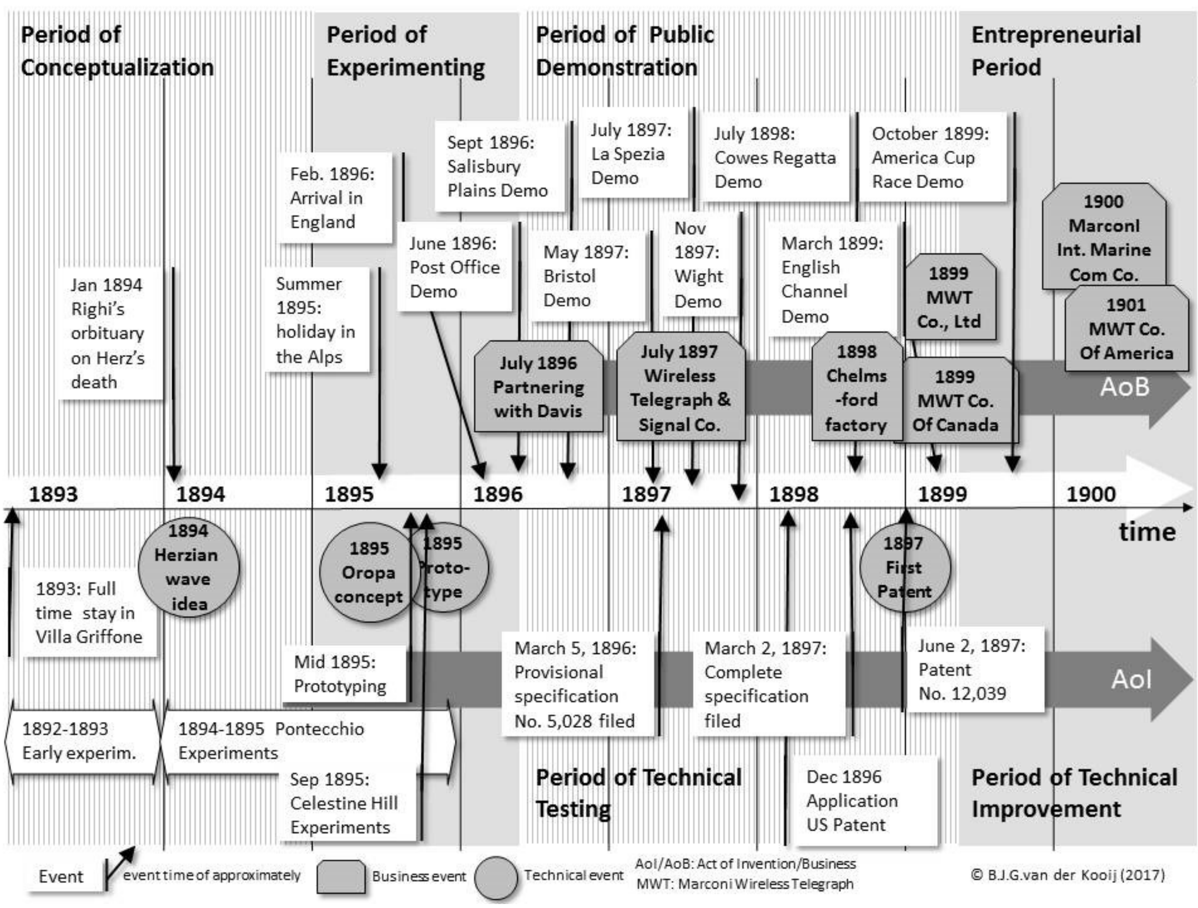

Figure 7: Timeline of Guglielmo Marconi's activities (1893-1898).

Figure created by author.

product design stabilized, larger volumes were needed, and standardization and interchangeability of parts became a necessity. In 1898 the Chelmsford factory was opened.

After the first contract with Lloyds' shipping insurance company, European business slowly picked up. He sold his equipment to the British, Italian and Japanese Navies and demonstrated it to European royalty. His experiment across the Atlantic Ocean and subsequent travels to America and Canada brought many business contacts. This resulted —after the reorganization into the *Marconi Wireless Telegraph Company, Ltd (1899)* and the creation of the *Marconi International Marine Communications Company,* Ltd. (1900)—in the creation of the *Marconi Wireless Telegraph Company of Canada* (1899) and the *Marconi Wireless Telegraph Company of America* (1901). It was the birth of the Marconi monopoly that would have to fight—next to the patent battle—many other battles; against competitors (eg the German company of Telefunken), governments (eg the British Monopoly on communication), and institutions (eg military institutions like the US Navy). This pictures the timeline of Marconi's invention (Figure 7).

4.4 The rise of Infrastructure

These General Purpose Engines (GPEs) created by Morse, Bell and Marconi marked the beginnings of the three phases of the Communication Revolution[6]. The first phase saw the GPE for coded information transmitted by cable, then in the second phase a GPE realized the spoken word transmitted by cable, followed by the third phase of a GPE that enabled wireless transmission of coded/spoken information. The common element was the communication infrastructure; first the cabled networks, later the wireless networks. Just as the development of the transportation infrastructure—i.e. the roads and canals—had contributed to the first British Industrial Revolution (1760-1850), where the railroad networks had emerged, the same was happening with networks in the Communication Revolution. The second Industrial Revolution (1850–1914) saw, next to the electricity distribution cables dotting the landscape and clothing the villages and towns, the rise of telegraph and telephone networks. Their development was the same. First appeared the local networks, then the regional networks. Then followed national networks spreading over the continents of the Old World of Europa and the New World of America, that soon became connected with a global spanning communication system. Their impact was the same. Where transportation networks had brought mobility to the people, and where the electricity networks brought power and light to the people, the telegraph and telephone networks

[6] The Communication Revolution did not stop here and saw more phases to come, such as the phase of broadcasting (radio and television), and the phase of mobile telephony with texting, speech and pictures/video.

brought communication to the people. In less than a century, by 1914, the world had changed as illustrated by the following.

Telegraph networks: After the Washington-Baltimore line opened in 1845, an abundance of local telegraph networks stretched over a thousand miles, by 1847, to the East Coast of America. By 1861 the US transcontinental telegraph line was completed. In Britain similar development with Cooke & Wheatstone's invention took place. By the 1850s miles of international submarine cables connected the British Isles with the European continent and by the 1870s there were transatlantic submarine cables connecting the continents. By the time Bell patented his telephone in 1876, a global telegraph network existed—using primarily the Morse telegraph—of more than 1,000,000 kms of wire and 50,000 kms of submarine cable, connecting more than 20,000 towns all over the world. (Huurdeman, 2003, pp. 88-90)

Telephone networks: After the first telephone exchange was created in 1878 at New Haven, Connecticut, USA, the local telephone networks with their mostly female-operated mechanical exchanges emerged rapidly, profiting from the telegraphic networks. By 1885 the American Bell Telephone Company had 134,000 subscribers. It was the start of massive expansion that not only happened in the US, but also in Europe, although in Britain the monopoly of the Post Office hampered its development, limiting the activities of private companies. That was different in Germany where Bell had applied for a patent. By the end of the century about 230,000 telephone lines were installed in a German network with a total length of 830,000 kms (ibidem, pp 173-174).

Wireless networks: For Marconi it was 'from zero to a hero' in less than a decade. By 1910 Marconi companies dominated wireless marine communications. In 1912 there were 13 overseas Marconi companies: as well as the United States and Canada, there were companies in France, Argentina, Russia, Italy, and Spain. Marconi had headquarters in Brussel, Paris, Rome, Madrid, and Buenos Aires. A network of dozens of stations covered all continents, from North and South America to Europe, Asia, Africa and Australia.

4. Brothers in Arms: Morse, Bell, and Marconi

The preceding analysis has painted in rough brushstrokes the different inventions of the communication engines by Morse, Bell and Marconi. This outlines the total process from idea to concept and archetype which we call the *Act of Invention*, that starts with the birth of an idea, subsequently turns that idea into a concept and archetype, and ends with the blessing of the Patent Office. It is accompanied with the *Act of Business* that started early cooperation with non-technical parties (supplying finance, from family and banks to private investors). Next to be followed by the formal creation of a legal organization, and results later in a massive structure of many public corporations that dominate the market for a considerable time. And at the core of these developments we find three men.

At the end of the nineteenth century the young Guglielmo Marconi found himself in a similar situation to that of Samuel Finley Morse some sixty years earlier,[7] and to that of Alexander Graham Bell some two decades before. Morse, American born, had travelled Europe extensively. The young Bell, of Scottish origin, had left Britain with his parents for Canada and then America. He had immigrated to the New World of opportunity. The young Marconi was an Italian who'd accompanied his British mother back to England. He was entering the Old World, where Britain was at the peak of its imperial powers and considered to be the 'Workshop of the World'. But there was much more that the inventors had in common[8]:

No formal education *in electricity:* None of these men were solidly educated in the emerging field of electricity, but they were fascinated enough by the phenomenon to acquire the knowledge, knowhow, and hands-on experience needed to create their first rudimentary archetypes.[9] Morse was a painter fascinated by the new phenomenon. Bell was a teacher of the deaf, and Marconi a young, self-educated man fascinated by electric waves. For them, electricity was a challenge.

Driven by fascination: All three men had the spark of an 'idea' that they transformed, with a lot of experimentation and in their own workshops, into early artefacts. Morse worked in the Vial's Speedwell Iron Works facilities of his financial backer, Bell in his workshop in the cellar of the Sanders' house where he lodged, and Marconi had his workshop in the attic of his parents' house, Villa Griffone. Their fascination with electricity led them on a path of discovery and experimentation.

Developing a system: Each inventor developed his original idea—similar to a mental image of something to become—into a 'concept of communication over distance using electricity': the system of coded information by Morse, the system of electric speech by Bell, and the system of wireless transmission by Marconi. All three seemed to be quite aware of the magnitude of their vision. Bell feared others

[7] We have excluded the contribution of Cook and Wheatstone, as their needle telegraph proved to be a dead-end technology. Nevertheless, quite a few similarities could be found in their case: such as the use of technical assistance, where the businessman Cooke started working together with the electrician Wheatstone.

[8] One has to realize that finding the common denominators neglects all the differences that could also be found.

[9] Bell was quoted as saying: 'Had I known more about electricity, and less about sound, I would never had invented the telephone' (Casson, 1910, p. 27).

would steal his idea, and Marconi was quite afraid someone else might have done something similar at the same time he was busy experimenting.[10]

Simple basic concepts: The concepts, on which their inventions were founded, were surprisingly simple. For Morse, it was a DC electromagnet commanded at a distance by a switch, (later to become the telegraph key). Using a marker, that action would be recorded at a distance on a moving strip of paper: the dots and dashes. For Bell, it was sound that initiated a variable resistance (in the microphone) creating an alternating current travelling through a wire that moved the coil and membrane (of a loudspeaker) creating the 'electric speech'. For Marconi, it was the burst of electric sparks creating electric waves that carried the dots and dashes to be detected by a receiver. All were applications of electricity in its most simple form.

New Art: As simple as they may now seem, their concepts were 'new to the world'. Morse was working on the use of electric devices in distant writing that others before him—eg Weber and Gauss in Germany—had initially explored also, but had failed to commercialize seriously. He created a new system of *coded telegraphy* of hardware (the receiving apparatus), software (the Morse code), and the network of copper cables. Bell, also building on the insights, experience, experiments, and early apparatus of many others, created a system for electric speech: the *speaking telegraph*. It was a network of equipment (i.e. the telephone equipment with microphone and earphone) and infrastructure (i.e. the copper cables spanning the globe and the exchange stations interconnecting them). Marconi, in a similar way, using the contributions of many others, created a system for cable-less transmission: literally the *wire-less telegraph*. It was a network of equipment (the Marconi sets on board ships) and infrastructure of (coastal) wireless stations around the globe, transmitting those messages 'without wires'. In terms of novelty, as required by the patent-issuing institutions, each of them created a new art.

Technical assistance: The further technical development of their respective inventions, into a working system, also shows quite a bit of similarity. Being a painter, Morse was assisted by Alfred Vail, a skilled mechanic building his prototypes. The teacher of the deaf, Bell, was assisted by the mechanically skilled Thomas A. Watson. Marconi got a lifetime assistant in George Kemp, the former technician of the Post Office. Vail assisted Morse in his first experimental transmission over two miles at the Speedwell Iron Works and deciphered the famous historical sentence: ''A patient waiter is no loser." Watson was there at the magic moment when Bell called for him over the experimental

[10] Marconi was quoted as saying: 'My chief trouble was that the idea was so elementary, so simple in logic, that it seemed difficult to believe no one else had thought of putting it into practice' (Dunlap, 1941, p. 12).

telephone line in March 1876: "Watson, come here. I need you." Kemp was there when Marconi asked him on May 13, 1897, over the wireless telegraph line in Morse code: "Can you hear me?"

Entrepreneurial assistance: Each inventor had transformed an idea into a physical archetype. In that process, each had obtained the help of relatives and friends. Morse was financially supported by Vail's father, Judge Stephen Vail owner of the Speedwell Iron Works, and his son Alfred Vail building the instrument and paying for the patent, with whom he created a partnership. Bell was supported by Gardiner G. Hubbard (later his father-in-law) and (business) friends like Thomas Sanders coughing up early 'angel financing'.[11] In the process creating in July 9, 1877 the *Bell Telephone Company* (with Hubbard as a trustee). Marconi's early work was supported by his father, who seed-funded his son, and this was followed by the angel funding of the Jameson clan and their merchant contacts when, in 1897, the *Wireless Telegraph and Signal Co. Ltd*. was organized. In all of this, his 20-year-older nephew, Henry Jameson Davis, was his fierce supporter.

So, all three men had quite a lot in common on the personal level of their activities and the technical and entrepreneurial people in their close environment. In addition, there were other factors that created a comparable context for their work:

Antagonistic scientific environment: Although in the Morse case, the technically educated people (eg Joseph Henry) recognized the value of his invention, that appreciation was not the case with Bell and Marconi. Only Morse was encountering a stimulating environment, where the American Congress—true, it took some years—even funded his first experiment with the Washington-Baltimore line. But Bell and Marconi were confronted with an uninterested, sometimes even hostile scientific community. In capitalistic America, obsessed by the enterprises creating railroad empires, Bell was faced with the telephone conspiracy and other scientific inventors like Elisha Gray claiming priority. Marconi was facing the hostile British scientific community with Oliver Lodge—also claiming priority—as its major exponent; and the engineers from the British Post Office were—to put it mildly—not that enthusiastic at all when Marconi created his company.

Creating broad awareness: Morse was received by scientists, engineers, and those in political power. He gave demonstrations before his fellow people at the university where he worked, and to (skeptical) members of Congress and the President. In addition, Morse travelled and gave many demonstrations to an (enthusiastic) public. In contrast, Bell and Marconi were opposed by people in political power who—not too unusually—were not really interested, did not share the inventors' visions, and had to

[11] Financing developments before a company is organized requires informal seed funding. 'Angel funding' is the present-day expression for the early start-up capital of a company.

be convinced by example. Bell undertook a massive campaign of lectures to show his invention 'to the people' (and British queen). Marconi did the same by involving the 'monarchy and aristocracy' in the enormous publicity he created with his public experiments and the help of a sympathetic press.

Hostile business environment: All three inventors officially became entrepreneurs when they organized their respective companies. For Morse and Marconi, the alternative had been selling their patented invention to the government (i.e. the Post Offices). For Bell and his partners in the association, that was never an option in capitalist America. The alternative of selling it to a telegraph company like Western Union failed, due lack of interest from that side. Bell and Marconi were facing a hostile business environment: namely the vested interests of the monopolies in telegraphy. Bell had to fight a David-Goliath battle with the telegraph monopoly of the mighty Western Union. Marconi had to face the state monopoly of the British Post Office and the opportunistic British War Office, Army, and Royal Navy, as well as the British telegraph-service industry. In America, the fierce business opposition came from the telegraph establishment. These were all parties that had something to lose from the new inventions.

System developers: Despite the lack of interest (Morse) and opposition (Bell, Marconi) all three inventors, with the help of early 'angel investors' financing their ambitious projects, created communication systems that succeeded in business. Morse created a system that was widely adapted, but did not create a range of companies based on his patent rights, because the *Morse system* was widely copied. Bell created the patent-protected *Bell system* used by many companies (the Bell companies), that licensed his patents and used his equipment for telephonic communication. Marconi created the similar well-protected *Marconi system,* also used by many companies licensed to his patents and using his equipment for wireless communication.

Morse, Bell, and Marconi were children of their times: Morse, in the pioneering days of electricity, and Bell and Marconi, both active in the time that electricity had found its way into rapidly maturing communications. Thus their consequential technical and entrepreneurial activities also show quite a similarity.

Right time, right place: Morse's work was in the dawn of electricity; its novelty spreading like a wildfire. For Bell, it was the more mature time of electricity when telegraph engineers were eagerly looking for ways to improve upon the efficiency of telegraphy: the hunt was for multiplex-telegraphy, in which several messages could be transmitted at the same time (eg in the United States by Western Union). For Marconi, it was the time of the search for alternative ways of transmission without cables (as was explored in Britain by the Post Office). One could say, the times were ready for their inventions.

Patent protection and defense: For all three men, protecting their invention by a patent was important. In 1840 Morse was granted US Patent № 1,647, which he had applied for in 1837, but he failed to get European patents. Bell was granted US Patent № 174,465, dated March 7, 1876, and obtained GB Patent № 4,765 also in 1876 in Britain. In Europe he only managed to obtain some patents (eg Italy, Sweden). Marconi was granted the British Patent № 12.039 on June 2, 1897, and got a range of similar patents all over the world. Securing the patent rights of their respective inventions was just a beginning and it put them all of them on the path of massive litigation. The ensuing patent wars were about the commercialization of the patents they had obtained: the respective *Morse monopoly*, the *Bell monopoly*, and the *Marconi monopoly*. Morse was seriously challenged by individuals like Jackson and O'Reilly and had to go to court a dozen times. Bell fought for his patent protection in over 400 court cases. Marconi was involved in more than 30 court cases and faced powerful state institutions such as the military.

Inventor-entrepreneurs: All inventors tend to be faced with technical, organizational, and marketing issues of some magnitude. This resulted in a wide range of activities that illustrates the intellectual broadness of the inventor-entrepreneurs. All were curious, ingenious, creative, and determined, entrepreneurial people able to combine the *art of invention* as well as the *art of business*. They had a vision, they had the guts and endurance, and they created and exploited their inventions that changed the world. With help, they were all involved in the early entrepreneurial exploration of their inventions, both by selling patent licenses, as well as their equipment. Morse did not consider himself as a businessman; he hired professionals and licensed the manufacturing to others. He did not reap the fruits when his Morse system became widely adopted in Europe, where he was without patent protection. By 1881, half a decade after his invention, both Thomas Watson and Alexander Bell, being financially independent by that time, had left the company and gone their own ways. Only Marconi stayed strongly involved in his company for a longer time—until the Great War impacted his life and the future of his company.

From these observations, one can see that although each of the inventions took place in its own timeframe and geographic location, it was dominated by its specific socio-political and techno-economic contexts. However, apart from their individual personalities, the three inventors were quite similar in their work. Which became more obvious when we looked in more detail at how their inventions came to be in existence, during their Acts of Invention and Act of Business.

5. Conclusion

Surely the development of each of these communications engines is unique; not only by content and context, but also by the personalities involved. However, the cases studies also show that they had much in common. For one thing, they shared a fascination for, and were challenged by the new possibilities of electricity. They were also conceptual thinkers, who envisioned how their ideas could be used and they had the endurance and entrepreneurial orientation to bring a working system to the market—a market where the respective inventions fulfilled an obvious need. Their contributions started with a range of activities of a technical nature. Looking at the total Act of Invention, we can observe the following (Figure 8):

Conceptualization: Stimulated by specific events, developments, meetings, etc. (in short 'external inputs'), there is the moment that an 'idea' is created. The inventor in the making recognizes a technical possibility, and the entrepreneur in the making recognizes an opportunity to fulfil a need, something like: 'If we could combine … and … we could make … and sell it as….'. Following the early idea, the mental picture matures into a concept of specific functionality. In the case of

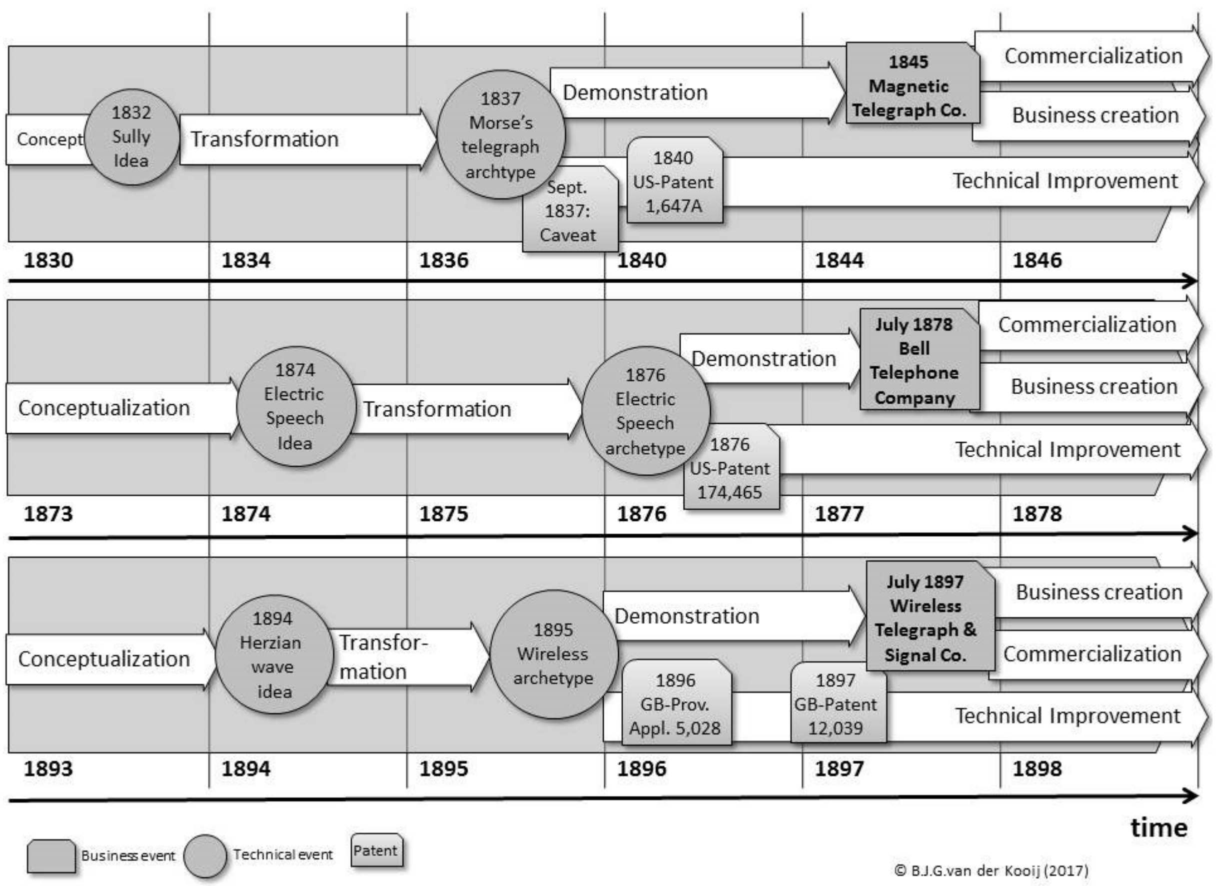

Figure 8: Combined timelines for Morse's, Bell's and Marconi's inventions.

Figure created by author.

telegraphy, Morse had his ‘Sully idea’ (1832). In the case of telephony, Bell had the ‘Electric speech idea’ (1874), and Marconi had his ‘Hertzian wave idea’ for wireless telegraphy in 1894.

Transformation: Following the first conceptualization comes the transformation of the rough outline of the first ‘idea’ into a working model, often a lengthy and random process of many prototypes that ultimately results in functional and working archetypes. That experimental and evolutionary process of trial and error results in a patentable object that the inventor considers to have novelty. He files as extensive a patent specification as possible and makes a broad claim. When officials in the Patent Office agree with him on the novelty, he is granted a patent protection for his claims. The more fundamental the patent is, the more it can be the cause of many disputes and controversy. Morse became embroiled in the Great Telegraph Patent Case after he was granted his ‘1,647’ pioneering patent in 1840. Bell was faced with the Telephone Patent Conspiracy and later with massive litigation after his ‘465’ patent in 1876. Marconi was opposed by the British scientific community (Lodge et al), who claimed priority, and later had to fight his ‘039’ patent rights extensively.

Technical Improvement: As the first patented archetype was inevitably an immature and unproved product, a lot of attention had to be paid to the technical improvement. This resulted in a constant process of experimenting, and in new patents protecting those improvements. Bell got his second telephone ‘787’ patent in 1877, which created the Bell monopoly. Marconi was granted his ‘7,777’ patent for his syntonic telegraph, which created the Marconi monopoly.

At a given moment in time, depending on the context, the chain of activities is complemented by further activities of a different nature. Looking at the total Act of Business, we can observe the following:

Demonstration: When the invention has obtained patent protection, not only the inner circle of the technical community, but also the general public and specific interest groups (being future clients) can be informed. Depending on the novelty, this can take some time. Cooke and Wheatstone demonstrated their invention to the railroad companies, which they saw as potential users. Morse demonstrated his invention to Congress to obtain funding for a first telegraph line. It took him some five years before he succeeded. Bell showed his invention at the Centennial Exhibition of 1876, and gave a range of telephone-lectures. Marconi demonstrated his invention to the Post Office, British military and European royalty, soon creating massive publicity in the general press.

Commercialization: The archetype is protected by a patent, broad claims are made, experiments improve the product and system, and demonstrations show its feasibility. That unavoidably arouses competing interest in the business community. Moreover, angel funding is depleted by now, and additional experimenting and demonstration have to be funded, so commercialization of the patent rights becomes an issue. The choice is twofold: either one sells the patent rights to another party, or one decides to implement a commercial organization on one's own. Remarkably, the inventor-entrepreneurs of the Communication Era all chose the latter. Morse started the *Magnetic Telegraph Company* in 1846. Bell, stimulated by his father-in-law, created the *Bell Telephone Company* in 1878, and Marconi created the *Wireless Telegraph and Signal Co* in 1897.

Business creation: In the second half of 1840, in America, the Telegraph Boom started to emerge. Responding to the demand, Morse licensed his invention (and equipment) to a chain of telegraph-providers. These Service Providers were supplied by (licensed) equipment manufacturers. By the time his patent-protection ended, an industry had emerged with the equipment manufacturers, as well as the service providers. The same was the case with the US Telephone Boom in the second half of the 1890s, when the telephone market in the US surged with two-digit percentages. Responding to demand, independent service providers (i.e. non-Bell companies) had emerged and other equipment manufacturers made telephones and exchanges. At the same time Marconi's invention was causing the Wireless Boom of service-providers in business. This boom was accompanied in the early 1900s, in America, by the 'Wireless Hype', with its massive stock fraud, which infected the emerging industry.

The above described developments of the General Purpose Engines saw the GPT-Electricity spawn into new applications; those of that made communication at a distance possible. They all started with a few simple 'ideas' that would come to dominate the lives of Morse, Bell and Marconi in ways and on a scale they could never have imagined, not even in their wildest dreams.

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