

Appendix 1 – Examples of Early Proposals to Solve the Longitude Problem

Proposals using the scientific (astronomical) method

Early attempts involved the London mathematical community, especially the disciples of Isaac Newton. William Whiston (who had succeeded his mentor Newton as Lucasian Professor of Mathematics at Cambridge) and Humphry Ditton (Master of the Royal Mathematical School at Christ's Hospital) suggested anchoring station ships along the trade routes to fire rockets into the air to determine the exact position of points on the sea coasts. At midnight (Peak of Tenerife time) *“each ship would fire a star shell to burst at a fixed altitude. A compass would provide the bearing to the station ship. Distance from the station ship could be obtained either by noting the length it took the sound to reach the observer or by observing the angle subtended by the bursting star shell, which was set to explode at 6,440 feet”* (Force 1985, pp. 22-23).¹ Published in *The Guardian* in 1713, and then again in *The Englishman*, the Whiston-Ditton proposal was further developed in a book entitled *A New Method for Discovering the Longitude Both at Sea and Land* published in July 1714. The proposal, however, soon proved unfeasible and was abandoned for lack of support.

A sidereal or astral clock was suggested by Jane Squire in 1731, and refined in a second, enlarged publication in 1743. The thrust of her proposal was to divide the sky into more than 1.25 million ‘cloves’ or numbered spaces. Equipped with this astral watch, all a navigator had to do was to *“recognize the clove directly overhead in order to calculate his longitude from Squire’s prime meridian, which ran through the manger at Bethlehem”* (Sobel and Andrewes 1998, p. 68). Despite several attempts to convince the Astronomer Royal, Edmond Halley (who had replaced Flamsteed in 1719), the Speaker of the House of Commons and the first lord of Admiralty, she never persuaded the Board of Longitude to consider her proposal.

Proposals using the mechanical (time-keeping) method

The idea of using a clock to find longitude at sea originated with Jeremy Thacker, a writer and watchmaker, who also coined the word ‘chronometer’. He proposed a marine chronometer mounted on gimbals in a vacuum chamber, and published his idea in a pamphlet, *The Longitudes Examined*, in 1714. While his clock worked relatively well on land, it remained unable to resist rolling seas to keep time precisely enough, or to cope with changes in temperature: although *“the vacuum chamber provided some insulation against the effects of heat and cold, it fell short of perfection, and Thacker knew it”* (Sobel and Andrewes 1998, p. 71). Despite its failure, Thacker’s proposal was the best among those reviewed by the Board in its first year.

The Dutch mathematician and astronomer Christian Huygens, who had developed the mathematical theory of the pendulum, tried himself to pursue ideas for using a clock to find longitude at sea late in the 17th century, but with little success (Chandler 1996).²

¹ Whiston also advanced – though without much success – other two methods, one involving the inclination of dipping needles (1721), and one based on observation of eclipses of the moons of Jupiter (1738). For a more comprehensive discussion see Force (1985).

² While the majority of solutions submitted to the Longitude contest were based on astronomical or horological principles, a variety of unorthodox proposals reached the Board. One example was the “Powder of Sympathy,” created by an alchemist from Paris. The method suggested that a special powder be applied to a cloth and then placed on a wound of an animal causing the wound to close up but at the expense of extreme pain. His idea was to take a wounded dog on board after the dog’s wound had come in contact with a certain bandage with the powder on it. Every day at noon in Greenwich, some reliable party would place the “powder of sympathy” to the bandage

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previously on the dog's wound, and it would cause the wounded dog on board the ship to howl in agony thus signaling the time of noon for the captains to use. The dog was required to be wounded everyday so that the wound could not heal. Another example was Whiston and Ditton's lightship method. Their proposal involved the establishment of a string of lightships that were ordered to fire a star shell, specially timed to explode at an altitude of 6440 feet. This - they argued - allowed captains to calculate the distances between their own ship and the lightship through the means of the interval between the flash and the returning sound of the cannon (Johnson 1989).

Appendix 2 - Beyond the Longitude Case

We present two more contemporary examples of innovation, one successful and one unsuccessful, to illustrate the plasticity of our framework across different types of innovation and fields. The first is Coco Chanel's entry into the field of haute couture. Like Harrison, Chanel was a non-certified outsider: she had no formal education nor did she apprentice to a fashion house. As an orphan from a poor family, she spent her adolescence in a convent and, with the financial support of two friends, started her career as a milliner in Paris in 1909 designing hats. The real turning point in the recognition of her work was the outbreak of World War I (Cattani, Colucci, and Ferriani 2015). The war was the external shock that gave Chanel an opportunity to introduce a new style that challenged French haute couture, whose target audience was upper-class women and their need to change clothes several times during the same day. World War I left a large number of widows and single women to fend for themselves. They entered the workforce and were looking for clothes that were simple, functional and elegant (Morand 2008). It is during this period that Chanel entered and began to build her own identity. Challenging leading French designers' feminine silhouettes and cumbersome outfits, Chanel presented her clothes as "suitable for a new lifestyle that was being adopted by young women during and after the First World War" (Crane 2000, p. 150). By accelerating change, the war facilitated the entry into the world of fashion of Chanel, whose sober style matched the women's new and more casual lifestyle.

However, neither the war nor Chanel's unique stylistic perspective and skills alone seem sufficient to account for her success within the French haute couture. Her designs were highly innovative and more comfortable than the cumbersome outfits of established fashion designers, but Chanel did not have the "influence to draw attention to and promote consensus around her work" (Cattani et al. 2015, p. 121). Despite consumers' appreciation for her design and fabric innovations, she struggled to obtain recognition especially from critics and peers: fashion magazines neglected her presence on the haute couture scene until 1920s, and leading fashion designers dismissed her. In a rather derogatory manner Madeleine Vionnet (a leading designer at the time) used to call her "that milliner" (Charles-Roux 2005, p. 327), Paul Poiret "that boyish head" and later jested on her by declaring that she invented "the poverty of luxury" (Mackrell 1992, p. 17). To fully appreciate Chanel progression to the core of the fashion field one has to account for the role of influential audiences, whose view of the social world, beliefs and tastes were more attuned to her own (Bourdieu 1980). Perceived as a fashion iconoclast and a modern woman who epitomized the liberated woman of the 1920s, Chanel appealed to important representative from the French artistic avant-garde, who promptly endorsed the philosophy behind her revolutionary designs. For instance, in 1922 Chanel began a 14-year long artistic collaboration with French poet and playwright Jean Cocteau who entrusted her the design of the costumes for his theatrical productions. Similarly, she designed the costumes for Pablo Picasso's adaptation of Sophocles' Greek tragedy *Antigone* in 1927. She also established and maintained close contacts with other avant-garde artists such as Sergei Diaghilev (the founder of the Ballets Russes), Pierre Reverdy (poet) and Igor Stravinsky (composer). After WWI the avant-garde was a very receptive and supportive social space that helped Chanel push forward a new set

of aesthetic standards that emphasized geometric forms, the rejection of ornamentation for simplicity and comfort – a trend that was, in fact, increasingly observable in many decorative arts (Steele 1993).

The second and more recent example concerns the unsuccessful attempt to introduce the first electric car in the state of California in the mid-1990s (Shnayerson 1996). In 1990, the California Air Resources Board (CARB) passed the Zero-Emission-Vehicles (ZEV) mandate to combat urban air pollution by requiring the seven largest US carmakers to make 2% of their fleets emission-free by 1998, 5% by 2001, and 10% by 2003 if they wished to continue to sell cars in California. The mandate spearheaded the development of electric propulsion systems that had “hovered at the fringe of legitimacy since 1900s” (Christensen 1997, p. 206), forcing an unprecedented infusion of resources into finding viable solutions to drastically reduce emissions (Kemp 2005). Interestingly, the sudden regulatory impulse did not create entirely new approaches to electric propulsion, but altered the attention space of relevant decision-makers to solutions that had been anticipated – at least partially – many years before but, in the absence of exogenous pressures, had been ignored. Between 1997 and 1999 GM responded to this major regulatory change by marketing successive versions of EV1, the first mass-produced and purpose-design electric vehicle of the modern era (Anderson and Anderson 2010), and prototype zero-emission vehicles from Toyota, Nissan and Honda followed shortly thereafter. Despite the strength of its initial commitment – and positive customer reaction – CARB gradually watered down its ZEV regulation after 1999 via various amendments that greatly relaxed the original restrictive emission criteria, until the program was discontinued altogether in 2003, at which point all electric cars then on the road were recalled and production terminated. While multiple forces contributed to the reversal of CARB’s original mandate and the subsequent loss of momentum of the electric propulsion systems, commentators largely concur in locating the beginning of the shift in the Board’s orientation as coinciding with the appointment of Alan Lloyd as its Chairman in 1999 (Boschert 2006; Cefo 2009). Lloyd (whose chairmanship lasted until 2004), who had been known as a fuel cell partisan since his days as chief scientist at the South Coast Air Quality Management District, pushed for amendments to the ZEV. Early in 2003, Lloyd became the Chairman of the California Fuel Cell Partnership – a joint venture between several automakers and four major oil companies – an initiative for which he had been the driving force (Cefo 2009). By the end of the year, under Lloyd’s leadership (and after relentless pressures from automobile manufacturers) CARB’s drastically scaling back of the ZEV regulations contributed to GM terminating EV1 production. As Cefo points out (2009, p. 8): “Despite the existence of a viable zero-emission electric vehicle [...] the California Fuel Cell Partnership interest group controlled the Board through Lloyd, and no one stopped them [...]. Shortly afterwards GM sold the patents of the incredibly efficient NiHM technology to ChevronTexaco, who successfully mothballed the large capacity necessary for electric vehicles.”

Although these brief illustrations cannot encapsulate the complexity and more nuanced aspects of innovation journeys that unfolded over long periods and cutting across multiple actors and interests, they are nevertheless instructive as they bring to light stylized elements of the process by which marginal

ideas may or may not become mainstream. Like in Harrison's case, Chanel's successful efforts at novelty depended on the concatenation of her unique skills and outside perspective, but also macro and meso level forces that created a favorable scaffolding for her agency to unfold and gain impetus. The EV1 case, on the other hand, offers a useful counterpoint to Harrison's chronometer revealing how changes in audience orientations may shape the legitimization journey of novelty. Initially, after the exogenous change in regulations, the electric propulsion technology catalyzed the attention and could rely on a favorable audience structure: electric battery producers, environment friendly consumers and politicians all supported the introduction of EV1. But, over time, the resistance from other audiences – e.g., oil companies, traditional consumers, competitors, components manufacturers, etc. – with a vested interest in the traditional (gas-based) drive technology forced GM to terminate the production of EV1.

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