Deconstructing the Outsider Puzzle: The Legitimation Journey of Novelty

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Abstract

The proposition that outsiders often are crucial carriers of novelty into an established institutional field has received wide empirical support. But an equally compelling proposition points to the following puzzle: the very same conditions that enhance outsiders' ability to make novel contributions also hinder their ability to carry them out. We seek to address this puzzle by examining the contextual circumstances that affect the legitimation of novelty originating from a non-certified outsider that challenged the status quo in an established institutional field. Our research case material is John Harrison's introduction of a new mechanical method for measuring longitude at sea – the marine chronometer – which challenged the dominant astronomical approach. We find that whether an outsider's new offer gains or is denied legitimacy is influenced by (1) the outsider's agency to further a new offer, (2) the existence of multiple audiences with different dispositions towards this offer, and (3) the occurrence of an exogenous jolt that helps create a more receptive social space. We organize these insights into a multilevel conceptual framework that builds on previous work but attributes a more decisive role to the interplay between endogenous and exogenous variables in shaping a field's shifting receptiveness to novelty. The framework exposes the mutually constitutive relationships between the micro-, meso-, and macro-level processes that jointly affect an outsider's efforts to introduce novelty into an existing field.

Key Words: Outsiders; Insiders; Jolts; Audiences; Agency; Legitimacy; Novelty; Field; Historical Study; Longitude; John Harrison; Chronometer.

Introduction

An established sociological tradition treats outsiders – i.e., actors who are not active players in the field and so are unconstrained by its conventions – as crucial carriers of novelty (Coser 1965; Merton 1972). What has received less attention, though, is the problematic process by which outsiders and, in particular, non–certified outsiders – whose expertise lacks formal certification (e.g., a university degree) – succeed in entering into an institutional field and building legitimacy around their novel offers. This process almost by definition is puzzling precisely because the same social position that enhances outsiders' ability to depart from prevailing social norms also signals their lack of crucial markers of credibility to attest to the legitimacy of their offers. Outsiders possess what Merton (1973, pp. 518-519) called *focused naïveté* – i.e., "a useful ignorance of prevailing assumptions and theories that allows them to attack problems generally regarded as impossible or uninteresting by specialists" (Gieryn and Hirsh 1983, p. 91) – and so may be less likely to pre-empt a line of inquiry merely because it runs counter to received wisdom. Yet they have no (or only limited) social ties to field insiders, and no power or status within the particular field they seek to challenge: most notably, they lack experts' authority and trust. How do they then stake out ground in the insiders' own terrain?

At least three research traditions offer cues to address this puzzle. One familiar class of explanations focuses on individual attempts at introducing novelty. This work primarily advances *actor–centric* accounts of extraordinarily skilled individuals whose acumen and social skills enable them to "innovate upon received cultural categories and conditions of action in accordance with their personal and collective ideals, interests, and commitments" (Emirbayer and Goodwin 1994, p. 1442). Another recent line of inquiry points to fields' particular *structural features* that can make them more or less permeable to the reception of novelty and their subsequent reconfigurations (Padgett and Powell 2012). Studies in this tradition have drawn attention to the structural fragmentation of the field (Sgourev 2013) or the extent to which the social audiences in charge of channeling critical material and symbolic resources are receptive to new offers (Cattani, Ferriani, and Allison 2014). Other established explanations rely on the role of *exogenous shocks* in subverting the social order of an existing field and creating pathways for the entry of new players (Sine and David 2003). Specifically, some scholars have noted that in response to transient large-scale perturbations field actors may become more permeable to new offers and engage in search processes to identify alternatives.

Working at different levels of analyses – micro, meso and macro – each of these approaches has produced important insights into how novelty emerging at the margin of a given field may take root and propagate. However, each approach also confronts the limits arising from its specific theoretical and analytical concerns (Garud, Hardy, and Maguire 2007; Johnson and Powell 2015). Agency-centric explanations emphasise the superior motivations and skills of some peripheral actors who advance offers that deviate from the field's normative expectations, but do not explain the circumstances that precipitate the same actors to do so. By overstating the ability of these individuals to attain legitimacy for their claims studies in this tradition have deflected attention away from those actors that ultimately confer legitimacy, and whose reactions may affect the success or failure of attempts at innovation, sometimes irrespective of an individual's specific actions. Explanations emphasizing exogenous shocks, on the other hand, shed light on the conditions that may precipitate outsiders' entry into the field but do not exhibit much analytical power in explaining the process by which some outsiders succeed while others do not. Meso level accounts have contributed greatly to bridging the gap between micro- and macro-explanations by showing that the openness of a social system towards novelty is as much a part of the phenomenon to be explained as the generation of novelty itself (Padgett and Powell 2012). Yet we still have limited understanding of why and under what conditions an institutional field's openness to novelty changes in time and space, sometimes resulting in dramatic twists and turns in the legitimation journey of novelty from the moment it arises to the time it takes hold.

We argue that the relative lack of dialogue between these lines of scholarship has hindered multilevel investigations of the process by which novelty emerging at the margin of a given field may succeed in gaining traction and moving towards its core. At the same time, these literatures provide powerful insights that we leverage to expose the mutually constitutive relationships between the micro-, meso-, and macro-level processes that jointly affect an outsider's efforts at innovation. To this end, we present a historiographic analysis of John Harrison's development of the marine chronometer, which – as an alternative to the lunar method, the traditional astronomical approach for calculating longitude at sea – set new standards for time-keeping precision, had a major impact on navigation at sea and helped cement Britain's position as a world sea power. In 1714, a few years after the worst maritime disaster in UK history, when an inaccurate longitude calculation had caused the wreckage of a British squadron off the Isles of Scilly with the loss of 2,000 lives, British Parliament announced three extraordinarily large rewards to stimulate scientific and technological advances in this extremely critical matter. It appointed a committee – the Board of Longitude – whose constituents included members of the astronomy community (mostly academics from Oxford and Cambridge universities), politicians (Members of Parliament), and the Navy's highest-ranking officers, which was charged with evaluating the various solutions proposed to the longitude problem. Amid competition from some of the most brilliant minds of the time, the solution came from an outsider, John Harrison – a self-taught craftsman of humble origins from an obscure village in the Lincolnshire and without formal academic education – who challenged the leading academic community with a novel approach to tackle the longitude problem. John Harrison's fifty-year-long quest for measuring the longitude, a very accurately documented yet unfamiliar story in organizational scholarship, affords an analytic window into the recursive relationships between an outsider's attempts to push forward novelty and key meso- and macro conditions that shape them.

We use this case material to develop a strategic narrative (George and Bennet 2005), that is an account of actors and events based on a subset of historical facts that permits us to systematize existing knowledge in a way that promotes theoretical advancement. In so doing, we start with a theoretical agenda and we then move from theory to evidence in order to develop new insights. Our account is intended to sharpen, illustrate and ground our arguments, not to provide an empirical test (David, Sine, and Haveman 2013). In particular, our analysis exposes key contextual circumstances that affect the opportunities facing outsiders and the constraints to their efforts. We organize these insights into a multilevel process model that builds on previous work in important regards but attributes a more decisive role to the interplay between endogenous and exogenous variables in shaping an institutional field's shifting receptiveness to novelty. The framework helps explain the conditions under which an outsider, located at the margins of the field, may garner resources and have impact despite the lack of credentials and disengagement from the centres of power.

The Outsider Puzzle

The proposition that outsiders often are crucial carriers of novelty into an established institutional field has received wide empirical support. As early as 1667, Royal Society historian Thomas Sprat called attention to the connection between being an outsider and the ability to innovate in a particular field: a glance from an angle, he argued, can reveal a new aspect of nature (Harman and Dietrich 2013). Subsequent elaborations of this basic idea encompass a rich research tradition that highlights the role of socio-structural conditions in shaping marginal actors' propensity to engage in innovative rather than conforming behavior (e.g., Veblen 1919; Coser 1962; Simmel 1971; Leblebici et al. 1991; McLaughlin 1998). As they are structurally distant from the influence of prevailing social norms, outsiders are more likely to advance ideas that challenge the status quo: with the "least opportunity for full participation in the most valued activities of their own society, they may be stimulated to make new responses which depart from the habitually required" (Coser 1962, p. 179).

The logic behind the proposition that outsiders are the originators of novelty is relatively straightforward and grounded on extensive historical evidence. But an equally compelling proposition points to the following puzzle: the very same conditions that enhance outsiders' ability to make novel contributions also hinder their ability to carry them out. Consider this passage from James March's discussion on heresy and non-conformist genius: "… the genius is an *outsider* with respect to the institution, is badly socialized and therefore spells trouble, but has deviant understanding of the world that ultimately turns out to be right" (reported in March and Weil 2005, p. 35, emphasis added). The intuition expressed in this passage captures two related problems concerning the impact of outsiders' novel contributions.

First, novelty is truly consequential when its originators can mobilize attention and resources, persuading powerful field members to support their innovative efforts. By definition, however, outsiders are strangers to the field they target, which makes it particularly difficult for them to secure the support needed to promote their offers and instigate change (Sgourev 2013). Second, outsiders are perceived as a threat (they "spell trouble"). Their solutions make it possible to explore unknown, though potentially very rewarding, paths that are typically incompatible with the paradigm they challenge – thereby eliciting strong, sometimes even vehement, reactions from field incumbents (Barber 1961; Fligstein and MacAdam 2012; Cattani et al. 2014). Indeed, "the paradox in this situation is less about how such actors come up with ideas for change; rather, it relates to how these peripheral, marginal actors get other field members to adopt them" (Hardy and Maguire 2008, pp. 5-6). How can then outsiders succeed in building legitimacy around their novel offers if they have limited or no credibility in the eyes of field insiders?

Theoretical Orientation

Following the lead of prior research, we organize our response to the previous question in terms of the three interrelated classes of explanations introduced previously. Our goal is to assess the contribution of each of these perspectives to the outsider puzzle and, at the same time, expose their explanatory limits. We argue that while each of these perspectives working at different levels of analysis – the micro-, meso-, and macro-level – is useful in and of itself, their independent adoption constraints our ability to produce a compelling and accurate account of how novelty may emerge and successfully move from the margins to the core of the field. In short, we seek to develop a multilevel explanation of this process, to which we now turn.

Micro-level: The Role of Agency

A voluminous literature suggests that one way outsiders may succeed in carrying out their efforts to introduce novelty is through entrepreneurial agency – i.e., individual actors' ability to use social skills to overcome skepticism and persuade others to believe in the claims they advance about the benefits of their innovations (Beckert 1999; Fligstein 2001). Eisenstadt (1964, 1980) was the first to coin the term "institutional entrepreneur" in his attempt to integrate agency and historical context. Inspired by Weber's (1922/1978) idea of individual carriers of charisma (i.e., charismatic leaders), he focused on exceptional individuals capable of igniting social or technical change. Subsequent research in this area has benefited particularly from the work of neo-institutional scholars who treat institutional entrepreneurs as purposive, self-interested actors whose acumen and creativity allow them to recognize problems and take advantage of enabling conditions to push forward their novel solutions to those problems. Scholars have emphasized how some individuals are endowed with unique abilities and features that 'normal' actors do not possess (DiMaggio 1988). A sizeable portion of this literature is also concerned with the analysis of the strategies that individuals deploy to sustain novelty (Aldrich and Fiol 1994; Lawrence 1999; Greenwood and Suddaby 2005). These strategies include mobilizing resources, forging new inter-actor relationships or concocting legitimating accounts of novel offers that typically combine normative and interest-based appeals (Hardy and Maguire 2008).

The agentic perspective offers important insights into how individuals may pose successful challenges to the status quo of an existing institutional field. Yet it also presents some theoretical difficulties when applied to the case of outsiders. Because studies in this vein conventionally focus on resource rich field insiders – e.g., Cosimo de' Medici (Padgett and Ansell 1993) – they overlook the simple fact that superior political or social skills unlikely belong to the repertoire of tools available to outsiders, especially non-certified outsiders. As Clemens and Cook (1999, p. 460) noted, in our efforts "to appreciate human agency, we should beware of assuming every actor a Cosimo de Medici." Likewise, the ability to frame the unknown in such a way that it becomes believable (Aldrich and Fiol 1994) implies "using powers of persuasion and influence to overcome the skepticism and resistance of guardians of the status quo" (Dees and Starr 1992, p. 96). The effective use of rhetorical strategies thus requires manipulation of institutional vocabulary. But since outsiders who are non-certified members of a given field are also foreign to its conventions, it is not clear how they can skilfully manipulate this vocabulary and effectively mobilize resources and attention. Framing the problem in these terms portrays outsiders as confronting seemingly insurmountable obstacles in their struggle to gain legitimacy for their novel ideas, particularly when they face an entrenched value system. Under such circumstances, the barriers to mobilization erected by insiders are typically so daunting that "many opportunities for successful challenge die before they produce change" (Fligstein and McAdam 2012, p. 107).

These observations suggest that the success of outsiders may have less to do with purposive action and elaborate framing strategies than with the occurrence of external changes that enhance the field's tolerance for deviance, which is often the result of particular circumstances that throw established institutions into a state of indeterminacy. As March (in March and Weil 2005) perceptively noted: "Heresy only overcomes intolerance when institutions are desperate" (p. 36). Because outsiders' dispositions and position-takings typically clash with the field's prevailing expectations and norms of production – Bourdieu notes – they cannot succeed without the help of external changes. These changes may take two forms: they may be "political breaks such as revolutionary crises, which change the power relations within the field … or deep-seated changes in the audience of consumers who, because of their affinity with the new producers, ensure the success of their products" (Bourdieu 1993, pp. 57-58). These observations point to an alternative yet complementary approach to agentic explanations, one which seeks to embed individual innovative efforts within field-specific dynamics that shape the field's receptiveness to novelty. We now turn to these two sources of change.

Meso-level: The Role of Audience-Mediated Legitimation Processes

The understanding of legitimacy as an audience-mediated general social process offers an additional angle to the analysis of the process by which new offers that challenge the prevailing wisdom of a specific field come to be accepted or rejected. As Johnson and colleagues (2006, p. 57) explain, the legitimacy of any social object (e.g., idea, product, technology or organizational form) depends on "the implied presence of a social audience, those assumed to accept the encompassing framework of norms and values, and, therefore, the construal of the object as legitimate." Implicit in this view is a notion of resource asymmetry, with audience members having control over the material or symbolic resources on which actors depend for gaining legitimacy (Zuckerman 1999, p. 1402). Audiences are therefore in a critical position to determine if and under what conditions novelty is taken up and supported. This understanding of legitimacy as "a relationship with an audience" rather than a possession of the actor (Suchman 1995, p. 594) is of particular relevance to the understanding of field dynamics and we take seriously Bourdieu's suggestion that "all the homologies which guarantee a receptive audience and sympathetic critics for producers who have found their place in the structure work in the opposite way for those who have strayed from their natural site" (1993, pp. 95-96). In Bourdieu's perspective the existence of a 'homologous' (i.e., receptive) social space is, in fact, a critical condition for enabling outsiders to marshal credibility resources and increase their chances to advance offers that are contentious relative to the field's prevailing expectations (Cattani et al. 2014). Empirical accounts consistent with this view include Sgourev's (2013) analysis of the rise of Cubism where it is shown that the fragmentation of the 20th century Parisian art market resulted in an increasing taste for experimentation among relevant social audiences that were therefore more attuned to Cubism's radical novelty, which was emerging at the margins of the French art world. This suggests "that disconnected actors may be successful in innovation not because of the specific actions that they undertake but because of the favourable interpretation of these actions by members of the audience" (Sgourev 2013, p. 1611). Another illustration of this point can be found in Anand and Watson's (2004) analysis of the Grammy awards assigned by the National Academy of Recording Arts and Sciences. The Academy initially opposed recognition of progressive genres such as rock-and-roll and rap. As newer and younger audience members – more attuned to the emerging novel musical styles – joined the National Academy of Recording Artists and Sciences (NARAS), "political struggles for the inclusion of more progressive genres broke out" (Anand and Watson 2004, p. 70), which eventually led to the recognition of peripheral groups' assertions about their relevance and centrality to the field through the institution of specific awards for them.

Shifting the focus on social evaluation and the mediating role of social audiences in shaping legitimacy struggles opens up the possibility of theorizing on the reasons why fields may differ in their disposition towards novelty, irrespective of the amount of resources supporting it. Yet, by focusing on the receiving end, i.e., the audience level, this perspective has deflected attention away from sources of novelty that operate at the individual level and affect individuals' efforts to advance their novel offers. This, too, is a limitation. For, while the individual may not be as important as it is often assumed, it is also untrue that novelty can emerge without the contribution of individuals or that all individuals have the same likelihood of producing novelty – as agency-oriented explanations discussed earlier emphasize. What is more, the vast majority of this scholarship treats audiences as homogenous entities overlooking the fact that the way audiences respond to novel offers may vary – sometimes dramatically – depending on their particular disposition or orientation towards the field (Cattani et al., 2014). That brings us back to Bourdieu's earlier reminder about the importance of taking macro-level sources of change into account.

Macro-level: The Role of Exogenous Jolts

Although the field's social structure is typically highly resistant to outsiders' challenges, such a resistance may not be strong enough to forestall convulsive moments following exogenous shocks or other dramatic events that suddenly alter existing relations in the field, setting in motion "a period of prolonged and widespread crisis in which actors struggle to reconstitute all aspects of social life" (Fligstein and McAdam 2012, p. 32). This kind of events, also known as environmental jolts (e.g., social upheavals, technological disruptions, large-scale accidents, regulatory changes), represent significant turning points in the evolution of an institutional field and play a key role in fostering transformative change (Meyer 1982). It is during these convulsive moments that "new logics of action come into existence" (Fligstein and McAdam 2012, p. 4) that may reshuffle control over resources and provide certain actors with avenues for action. Organizational analysts have accumulated considerable evidence on how exogenous jolts cause indeterminacy and hence create impetus for advancing new lines of action (e.g., Meyer 1982; Davis, Diekmann, and Tinsley 1994; Fox-

Wolfgramm, Boal, and Hunt 1998; Garud, Jain, and Kumaraswamy 2002). It has been shown that jolts can alter the intellectual climate (Kuhn 1970) and raise awareness of extant and alternative logics, opening the way for the entry of new players into the field (Sine and David 2003; Corbo, Ferriani, and Corrado 2016). Breaking an existing paradigm requires an accumulation of anomalies concerning both fundamental theoretical assumptions and experimental results (Kuhn 1970; Constant 1973). By exposing these anomalies and the need to find a solution to them, exogenous jolts may precipitate revolutionary change.

In short, explanations based on external shocks offer a useful conceptual toolkit to complement the other two perspectives and address some of their limitations. Such explanations complement agentic perspectives by showing the levelling of the playing field that typically occurs in the aftermath of dramatic events that are perceived as clear and distinct ruptures in extant field practices and routines. They also complement audience-based accounts by highlighting the role that shocks often play in changing the field's attention space and sensitizing social audiences towards alternative lines of action. Yet this toolkit is limited in its ability to account for the *process* by which outsiders achieve legitimacy for their novel offers. In this respect, we agree with Croidieu and Kim's observation that the occurrence of external shocks "does not always reveal the exact mechanism through which change unfolds in society" (2017, p. 34; on this point see also Padgett and Powell, 2012, p. 26). Shocks, in other words, provide outsiders with a port of entry into the field, but cannot fully account for their subsequent legitimation journey to the core. This is a shortcoming, however, that agency- and audience-oriented perspectives are well-equipped to tackle. The analysis of the tortuous process by which John Harrison's novel solution to the longitude problem originated from the margins of the field and then became the established approach for measuring longitude at sea provides an opportunity to elaborate a conceptual synthesis that considers the interdependence between micro-level efforts, and meso- and macro-level dynamics that are largely independent of those efforts, and yet play a critical role in shaping their outcome.

RESEARCH DESIGN

Our strategic research material is John Harrison's invention of the marine chronometer, which – as an alternative to the lunar method, the established and widespread astronomical approach for calculating longitude at sea – had a major impact on navigation at sea and helped consolidate Great Britain's role as a world sea power. But, despite the promise of his solution, Harrison faced strong resistance from an academic orthodoxy that was strongly committed to the lunar-distance method. Only after years of struggle was his solution accepted as the most accurate method for measuring longitude at sea. We use an historical approach to examine the interplay between environmental jolts, social audiences, and individual agency in shaping the process of finding a proper solution to the longitude measurement problem. The use of a historical case method is well suited to analyze a rare event which displays complex dynamics and context-specific meanings (Hargadon and Douglas 2001; Cattani, Dunbar, and Shapira 2013; Sgourev 2013). Besides, this method allows for the necessary distance needed to observe how the complex interplay between the forces and actors involved unfolded over time (Kieser 1994). Rather than aiming to produce universally generalizable results, this research seeks to demonstrate the potential of its theoretical approach. By analyzing the introduction of a new technology for measuring the longitude at sea (i.e., a marine chronometer), we can understand how it was effected; who did what and why; what political, social and institutional reactions the new technology provoked; and how, why, and to what extent it gained acceptance.

Our historical analysis is based on Longitude histories and archival documents. Several bibliographical sources and publications (Gould 1935/1978; Quill 1966, 1976; Landes 1983; Howse 1989, 1996 and 1997; Sobel 1995; Andrewes 1996a, 1996b; Siegel 2009; Dunn and Higgitt, 2014) describe the discovery of the solution to the longitude problem in great detail and offer important contextual information. Although historical cases offer opportunities to examine and evaluate social processes in ways that other methods (e.g., cross-sectional and large-sample longitudinal studies) cannot, accounts that 'look back' often neglect the concrete details that constitute and shape actions in favor of more abstract accounts that highlight the 'spirit of the times.' Fortunately, the minutes of the Board of Longitude document in rich detail many of this public institution's remarkably wide-ranging activities over more than a century (1714-1828), well beyond the period covered in our analysis. These minutes provide records of meetings, members' attendance, details of relevant Acts of Parliament, salaries, correspondence with inventors, accounts of chronometer trials, outlines of impractical proposals, the log-books of several ships, and the astronomical observations of Captain Cook's voyages. This collection of unique contemporary data gave us the opportunity to examine the key steps and decisions shaping the legitimation of Harrison's chronometer through the eyes of those involved, and to identify precisely when those steps occurred and how those decisions were actually made, so reducing significantly the risk of retrospective sense-making. The Board records further include papers relating to other issues of navigation such as records, notably logs of scientific observations, relating to some major voyages of discovery (e.g., the search for the North West Passage), and administrative Board papers that are not directly relevant to the Longitude story. Originally archived at the Royal Greenwich Observatory (ref. RGO 14/1-68) and at the Public Record Office (ref. ADM 7/684), the Board of Longitude records are now fully digitized and, therefore, can be searched online through the University of Cambridge's Digital Library. This greatly simplified the selection of the relevant minutes. We identified all the minutes that deal explicitly with the longitude problem by searching for those minutes in which the words 'longitude,' 'chronometer', 'timekeeper' or 'Harrison' (both John and his son William) were mentioned.[1] These minutes proved particularly important for our historical analysis as they shed light on key events and/or decisions such as the trials the Board arranged to test Harrison's sea chronometers, the evaluation of those trials, the payments made to Harrison for his work on his chronometers, turnover among Board members, etc. Other relevant contemporary sources used in the analysis include excerpts from the *Journal of the House of Commons* – e.g., the 1714 Longitude Act or other decisions by British Parliament concerning the longitude and/or John Harrison.

We also looked at John Harrison's 1763 pamphlet – *An Account of the Proceedings in Order to the Discovery of the Longitude* – in which he expressed his personal view on the longitude controversy and lamented some Board members' conflict of interest – e.g., when Nevil Maskelyne, who was a contender for the final reward, was appointed Astronomer Royal and hence became ex officio a member of the Longitude Board. Finally, we analyzed the thirteen documents and the pamphlet written by William Wildman, Viscount Barrington, who was Treasurer of the British Navy in the years 1762 to 1765. This position made him an ex officio Commissioner of Longitude and allowed him to attend eight meetings during a key period in the Board's negotiations with John Harrison.[2]

[1] A list of relevant Minutes of the Board of Longitude meetings is available from the University of Cambridge Digital Library at http://cudl.lib.cam.ac.uk/view/MS-RGO-00014-00005/20 under "Contents."

[2] These documents, known as The Barrington Papers are today preserved at the National Maritime Museum, Greenwich (London).

Our goal is to use the historical material derived from these sources to illustrate and sharpen our conceptual framework and not to provide an empirical test of it (David et al. 2013). In this sense, we employ the longitude case not merely as illustration, but as an inspiration for new understanding. We have bracketed the events shaping this journey into a chronological narrative of successive periods, which we intend not as phases in a predictable sequential process, but, simply, a way of structuring the description of events so that distinctive patterns in events can be observed more clearly (Langley 1999, p. 703). Our choice of a chronological account is premised on the notion of social temporality, i.e., it is impossible to understand the outcomes of a given act without understanding the social context in which that act takes place. If the social context in which actions are carried out is temporally heterogeneous, then chronology is important because it "tells us within what historical context we must place the actions… we are attempting to interpret or explain" (Sewell 2005, p. 11). This history- and field-sensitive account helps to unveil the reasons why the same innovative effort may be opposed at one time, but praised and seen as legitimate at another, or vice versa.

In the following section, we review the exogenous event (the wreckage off the Isles of Scilly) that precipitated the search for a solution to the Longitude problem and led to the emergence and development of the sea chronometer. We then examine John Harrison's legitimation journey by looking at how relevant social audiences resisted and/or supported his ideas and the particular actions Harrison took to navigate the opportunity structure which emerged in the aftermath of the exogenous shock and as a result of subsequent changes in the audience structure and orientation.

THE LEGITIMATON JOURNEY OF HARRISON'S CHRONOMETER

The Longitude Problem

The quest for the accurate measurement of longitude had been an unfathomable puzzle for astronomers since Ptolemy in the II century AD. But it became a more urgent scientific and practical issue after the discovery of the New World, when oceanic navigation replaced coastal navigation. Yet, without being sure of their ships' longitude navigators were still basically reliant on a combination of their compasses, available charts, and 'dead reckoning' to supplement their accumulated experience and instinct in keeping them safe and on course for their destinations.[3] By the period we examine, two fundamental theoretical methods had been long established: the dominant one involved observing some astronomical phenomenon, and the other exploiting the fundament link between longitude and time.[4] The former case required using a telescope to compute the time of occultations or appulses of the moon or a star as a means of determining time at sea. In the latter, all seamen need to know to find the longitude is the time at another location on earth, usually the home port. Carrying on board a timekeeper set on the time at the home port, the longitude can then be determined by computing the difference between this time and the local time at sea – which can be ascertained by establishing the local noon from the highest elevation of the sun (Taylor 1962). But, in practical terms, each method suffered from several shortcomings. Astronomical knowledge of the stars' position in the sky was not yet well-enough developed to allow for precise measurement of their distance from the moon (and at sea clouds often hindered observation of either). Until Harrison, timekeepers that could withstand the vagaries of navigation remained a little more than a theoretical possibility: variations in atmospheric pressure, humidity and temperature made for an extremely testing environment in which to try to keep very sensitive horological mechanisms functioning.

Exogenous Shock and Momentum for Change: The Longitude Act

An event occurred in 1707 that threw this problem dramatically into popular awareness. At 8pm on 22 October, as the British fleet returned from its campaign against France, its flagship HMS *Association* and three other warships (HMS *Eagle*, HMS *Romney* and HMS *Firebrand*) were wrecked on rocks off the Isles of Scilly, off the south-west tip of Cornwall, causing the death of nearly 2,000 men. The main cause of the disaster was later attributed to be the fleet's inability to ascertain its longitude accurately.[5] The newly formed Kingdom of Great Britain was not alone in its desire to solve the problem: in France, for instance, the Académie Royale des Sciences, founded by Louis XIV in 1666 and charged (among other things) with the advancement of the

[3] To carry out a 'dead-reckoning' measurement of a ship at sea, the captain would throw a log overboard and observe how quickly the ship receded from this temporary guidepost, also taking into account the direction of travel, by means of stars and/or a compass, and the length of time the procedure took, by means of a sand-glass or pocket watch. This procedure always resulted in significant measurement errors (Andrewes 1996b).

[4] Since the earth rotates every 24 hours, every hour by which a specific time (say local noon) differs from noon at a Prime Meridian represents 15° difference in latitude. The relationship is so fixed as to have been characterized popularly in the phrase "Longitude is time, time is longitude" (see, e.g., http://www.longcamp.com/longitude.html).

[5] William Whiston, Newton's disciple and successor in the Lucasian Chair, wrote a letter to the press declaring that all men might have been saved had longitude been found (Taylor 1962).

science of navigation and the improvement of maps and sailing charts, reserved one of its two *Prix Rouillés* (royal prizes) from 1715 for advances in navigation. By revealing the inadequacy of extant methods for measuring longitude at sea, in fact, the 1707 disaster gave innovators – both insiders and outsiders – the impetus to advance new alternative solutions to the longitude problem.

In 1713, William Whiston (Lucasian Professor of Mathematics at Cambridge) and Humphry Ditton (Master of the Royal Mathematical School at Christ's Hospital) presented their proposal before Parliament (see Appendix 1). By tapping into the emotional resonance of the Scilly's tragedy and a growing national interest in maritime trade, the Whiston-Ditton proposal and their supporters played a key role in prompting the formation of a parliamentary committee and the passage of the Longitude Act on July 8, 1714 (Turner 1996). With the Longitude Act, the British government established three huge rewards – till then the greatest rewards offered to solve the longitude problem – for different degrees of accuracy attained by any methods/techniques that led to a solution (Quill 1966, 1976).[6] The first reward (£20,000) was for a method accurate to within one-half of a degree; the second (£15,000) for a method accurate to within two-thirds of a degree; and the third (£10,000) for a method accurate to within one degree.[7] The Act further stipulated that the proposed methods should be tested on a ship sailing "[...] over the ocean, from Great Britain to any such Port in the West Indies ... without losing their Longitude beyond the limits before mentioned" and should be "tried and found Practicable and Useful at Sea" (Journals of the House of Commons, 1714). The Act stated that the rewards were open to any proposals, irrespective of their proponents' nationality or academic credentials, but did not clarify whether these two requirements, of accuracy and practicality, were to be considered as being distinct; or whether the second would be implicitly satisfied if the proposed method was successfully tested on a transatlantic voyage.

The Longitude Act also established an ad hoc committee – later known as the Board of Longitude – and gave it the formal authority to evaluate the suitability of proposed solutions and pass its recommendations about which solution to reward back to the government. In effect, the Board was tasked

[6] It is important to note that the Longitude Act only addressed the determination of longitude at sea. Determining longitude reasonably accurately on land was, by the 16th century, possible by a well-established method using the Galilean moons of Jupiter as an astronomical clock. The moons were easily observable on land, but numerous attempts to reliably observe them from the deck of a ship resulted in failure (Dunn and Higgin 2014).

[7] The full reward of £20,000 was "a princely sum – the equivalent of perhaps $5.5 million today" (Siegel 2009, p. 10). It is worth noting that this is one of the first cases of broadcast search (Jeppesen and Lakhani 2010).

with defining a standard, scientifically validated, method for measuring longitude at sea. The Board comprised twenty-three members ("Commissioners for the Discovery of the Longitude at Sea") representing the three main constituencies (here, audiences) interested in finding a solution to the longitude problem: the government, the navy and the astronomers' community, including Sir Isaac Newton who was considered the leading British authority on the determination of longitude.[8] While for major awards – i.e., the three rewards for different degrees of accuracy – a majority vote of the Commissioners was required, a quorum of five commissioners was sufficient to award up to £2,000 if a proposal had promise. In order to establish whether any given proposal was the correct solution to the longitude problem, the commissioners could decide which trial was most suitable for testing the validity of that proposal. But the last say on whether the results of the trail should be regarded as conclusive, fell within the astronomers' area of expertise. The Longitude Act spurred feverish searches for solutions to solve the longitude issue leading to a proliferation of proposals, both within and beyond the astronomers' community (see Appendix 1). Most of the proposals fell within the realm of science, but there were also proposals that stood outside of it.

The preliminary examination of a proposal was left to experts, particularly the Astronomer Royal. The failure of the early proposals to solve the longitude problem reinforced Isaac Newton's skepticism about solutions outside the realm of astronomic science. In a letter to Josiah Burchett (the Secretary of the Admiralty) in October 1721 in response to an early proposal to use a clock to find longitude at sea, Newton stressed how the solution was to be found "not by Watchmakers or teachers of Navigation … but by the ablest Astronomers." He reinforced his position on the matter in a second letter to Burchett on 26 August 1725:

> *"And I have told you oftener than once that the longitude is not to be found by Clock-work alone. Clockwork may be subservient to Astronomy but without Astronomy the longitude is not to be found. Exact instruments for keeping of time can be useful only for keeping the longitude while you have it. If it be once lost, it cannot be found again by such instruments. Nothing but astronomy is sufficient for this purpose. But if you are unwilling to meddle with astronomy (the only right*

[8] The Board included: the President of the Royal Society (Britain's scientific academy), the Astronomer Royal of Greenwich, the Savilian Professor of Mathematics at Oxford, the Lucasian Professor of Mathematics at Cambridge and the Plumian Professor of Mathematics at Cambridge; the Speaker of the House of Commons, the First Commissioners of Trade and of the Navy plus ten named Members of Parliament; and the Lord High Admiral of Great Britain, the Admirals of the Red, White and Blue Squadrons and the Master of Trinity House (the official authority for lighthouses in British territorial waters).

method and the method pointed at by the Act of Parliament) I am unwilling to meddle with any other methods than the right one.'[9]

Newton's belief in the primacy of astronomy in solving the longitude problem had a lasting influence on the struggle for legitimacy of solutions based on other technologies or methods.

The Challenge of a Mechanical Solution: John Harrison the *Outsider*

The Board did not meet for 23 years[10] after its institution and when it was convened for the very first time (on 30 June 1737, some ten years after Newton's death) it was not to consider an astronomical solution at all, but to examine a new chronometer made by John Harrison, an outsider (Bennett 1993). A carpenter (and son of a carpenter) from an obscure Lincolnshire village, Harrison repaired clocks in his spare time, and biographical sources report that, while not illiterate, he had had no formal education (Dash 2000). As Alwine noted (2011, p. 1277): "He was an entrepreneur without any formal training in clock making but applied what his father taught him about woodworking and carpentry to his clocks." In 1712, a clergyman who visited Harrison's church to direct its choir gave him a book – a lecture on natural philosophy delivered by the Cambridge mathematician Nicolas Saunderson – which, together with Isaac Newton's *Principia*, proved fundamental to Harrison's self-taught knowledge of physics and astronomy (Landes 1983). By the end of 1713 (when he was still only 20) Harrison had completed his first pendulum clock – which is still running at the Worshipful Company of Clockmakers in London – and followed it up with other clocks during the 1720s, concentrating on perfecting their accuracy. He conceived a frictionless design – called 'grasshopper escapement' – that reduced frictions and proved then crucial for the success of Harrison's early chronometers. The oils available at the time were the curse of clockwork, causing mechanisms to run inconsistently and break down. From his understanding of the properties of woods, however, Harrison "realized that the tropical hardwood lignum vitae, which contains a natural lubricant, could be used for the

[9] Both letters are included in Isaac Newton's correspondence, published in H. W. Turnbull et al. (1959-77), Vol. 6, no. 1137: 212. Cambridge: Cambridge University Press.

[10] During this long period of time, longitude authorities and individual Commissioners most often directed projectors to the Astronomer Royal and/or to accumulate expert opinions and proof of success through publication and trials. Isaac Newton, in particular, said that the Commissioners should not bother meeting at all until a proposal had accumulated sufficient proof of success (*Papers on Finding the Longitude at Sea,* Cambridge University Library, Department of Manuscripts and University Archives, MS Add.3972).

bearings and would allow him to dispense with oil entirely" (Dunn and Higgitt 2014, p. 77). As Harrison later wrote, "*I find by experience that these Rolls of Wood move so freely as to never need any Oil*" (Harrison 1730, pp. 2-3).[11]

Harrison first heard about the Longitude reward in the early 1720s (Quill 1966), and believed the problem would be solved if a chronometer could be developed that would withstand a marine environment over a long voyage and still retain sufficient accuracy. In 1730, after preparing drawings and a summary description of his ideas, Harrison traveled to London to submit his ideas to and seek financial assistance from the Board of Longitude. The established practice was that proposals aimed at solving the longitude problem were first examined by the Astronomer Royal, Edmond Halley. Thanks to a letter of introduction from a friendly cleric, Harrison presented himself to Halley at his Greenwich Observatory residence in a meeting that proved a critical turning point for him (Quill 1966). Halley referred Harrison to George Graham – at the time regarded as one of England's finest watch maker and Halley's instrument maker (Bennett 1993). Realizing that Harrison was not only very knowledgeable about clock-making, but had also discovered a way to compensate for the effects of temperature differences on metals, Graham personally loaned Harrison money to help him build a clock. Harrison returned to London in 1735 with his first maritime chronometer 'Harrison Number One' (labeled H1), which he had tested on barges in the Humber estuary (Taylor 1968). Concerned about the Board's possible reaction to Harrison's proposal, Graham (a Fellow of the Royal Society) arranged to have Harrison present his work to the Royal Society before approaching the Board of Longitude directly (Quill 1966; Landes 1983). The Fellows were so impressed by the demonstration that in 1735 five of them – Edmond Halley (Astronomer Royal), James Bradley (Savilian Professor of Astronomy at Oxford), John Machin (Gresham Professor of Astronomy and Secretary of the Royal Society) and Robert Smith (Professor of Astronomy at Cambridge) as well as George Graham himself – signed a certificate of endorsement to the Admiralty (drafted by Graham) stating that H1 deserved public encouragement and should undergo a thorough trial.

In 1736 Harrison sailed to Lisbon on HMS *Centurion* and returned on HMS *Orford*. The trial was successful: at the end of the homeward voyage, HMS *Orford's* navigation officer publicly praised the H1 chronometer for its accuracy, after Harrison had correctly identified a significant landmark on the Cornish

[11] "John Harrison, Clockmaker at Burrow; Near Barton upon Humber; Lincolnshire. June 10. 1730," MS. 6026/1, sect. 5., Library of the Worshipful Company of Clockmakers, Guildhall Library, London.

coast which the navigator's dead-reckoning calculations had miscalculated by more than sixty miles.[12] While this trial was not the voyage to the West Indies demanded by the Board, it demonstrated the soundness of Harrison's work. In fact, the Board's first meeting (30 June 1737 – a year after H1's sea trial) was not to discuss arranging a full trial to discover whether H1's performance qualified it for a reward, but to consider Harrison's request for funding to build a second, improved, chronometer.[13] The Board was impressed enough to grant Harrison £500 for further development, one half to be paid immediately and the other when he presented his new machine (H2). This marked the start of a long period of experimentation during which Harrison slowly but steadily perfected his chronometer design. Harrison began work on H2 in 1737 and completed it by 1739. On 16 January 1741, Harrison presented H2 in front of the Royal Society, which put H2 under test. The result of these experiments was that "(*as far as it can be determined without making a Voyage at Sea*) the Motion of the Machine is sufficiently regular and exact for finding the Longitude of a Ship within the *nearest Limits proposed by Parliament*, and *probably* much *nearer*" (italics in the original).[14] H2 was never tried at sea because of England was at war with Spain around this time. Though larger and heavier, H2 shared the same basic design as H1. The Royal Society again proved very supportive of Harrison's effort and twelve of its most prominent members – including the President Martin Folkes – publicly endorsed Harrison by giving him certificates that he was allowed to show to the Board of Longitude when asking for financial support (Smiles 1885, p. 93). One of these certificates, signed by the twelve members, stated:

> *"Mr. Harrison's machines, even in their present degree of exactness, will be of great and excellent use; as for determining the Longitude at sea, as for correcting the charts of the coast"* (Quill 1976: 12).

By means of this certificate, the Royal Society intended to remind the Board of Longitude that Harrison's machine represented a solution not only to a long-searched scientific problem, but also to a pressing economic and military issue. Solicited by the Royal Society, the Board granted Harrison another £500, which

[12] Roger Mills, master of the Orford, gave Harrison the following certificate: "When we made the land, the said land, according to my reckoning (and others'), ought to have been the Start; but, before we knew what land it was, John Harrison declared to me and the rest of the ship's company that, according to his observations with this machine, it ought to be the Lizard - the which, indeed, it was found to be, his observation showing the ship to be more west than my reckoning, above one degree and twenty-six miles" (in Gould 1923, p. 52).
[13] Among the eight commissioners who convened to judge H1 were several of Harrison's supporters, including Edmond Halley, Admiral John Norris (head of the fleet sailing to Lisbon), and James Bradley and Robert Smith (the Savilian and Plumian Professors of Astronomy at Cambridge and Oxford respectively) who had both, with Halley, signed the Royal Society's letter of endorsement two years earlier. The other members were the president of the Royal Society (Hans Sloane), Sir Charles Knowles of the Admiralty and two politicians (Sobel 1995).
[14] Folkes et al. (1741). Some account of Mr Harrison's Invention for determining the Longitude and for correcting the Charts of the coasts, delivered to the Commissioners of the Longitude, January 16, 2.

he used to develop H3. Indeed, Harrison deemed the design of H2 unsatisfactory: the bar balances did not always counter the motion of a ship, a deficiency that could be corrected if the balances were circular. He then proceeded to work on a third, improved construction (H3). Although this version of the clock was almost complete in 1741 (Andrewes 1996a, p. 219), it did not reach the exactness required by the Board of Longitude: because Harrison did not fully understand the physics behind the springs used to control the balance wheels, the timing of the wheels was not isochronous, a problem that affected its accuracy. Yet it represented a significant enough improvement over H2 to induce the Royal Society to continue to support Harrison. For instance, in a lecture held at a meeting of the Royal Society in 1752, Scottish scientist and Fellow of the Royal Society James Short read a paper in which he praised Harrison's innovation concerning, in particular, the mechanism that compensated for temperature variations.

> "*[…] he also made a drawing of a clock, in which the wheels are disposed in a different manner from those then in use; which drawing I have seen, signed by himself in the year 1725... two of these clocks were finished in 1726*."[15]

Interestingly, H2 took four years to build and H3 seventeen: while neither was trialed at sea, each allowed Harrison to experiment and test new solutions to the friction and temperature change problems (Gould 1935/1978). Struggling to improve H3's performance, around 1751–52 Harrison designed a pocket watch (later known as H4) with a radically new type of balance (Andrewes 1996a, p. 222). After presenting H3 to the Board in 1757, Harrison announced his intention to work on a smaller clock, and in 1759 completed H4, which was entirely different from the others: it measured only 5.2 inches in diameter and could be held easily in the hand; it also made use of jeweled bearings, which helped minimize the effect of friction on the clock's internal mechanisms and improve its accuracy (Figure 1).

<Insert Figure 1 about here>

"From the Outside In": Entry and Progression to the Core

By shaking the foundations of an institutional field and rendering "practices that were once taken for granted as 'the way things are done' vulnerable to reform or replacement" (David and Sine 2003, p. 187), environmental jolts prompt actors to search for causes and solutions. Clearly, the inaccuracy of extant methods for measuring longitude at sea and the resulting errors in navigation, culminating in the disastrous

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[15] A letter of Mr. James Short, FRS, to the Royal Society and concerning the inventor of the "Contrivance in the Pendulum Clock." Philosophical Transactions of the Royal Society, 1752, vol. 47 no. 88, p. 519.

shipwreck off the Isles of Scilly, generated a momentum for change. By revealing the inadequacy of extant methods, the 1707 disaster induced British Parliament to establish a grand innovation reward. The reward gave impetus to innovators – insiders and outsiders – fostering a variety of proposals, some of which challenged the dominant astronomical approach and the corresponding techniques used to measure longitude at sea.

As Constant (1973, p. 554) noted, a technological anomaly – which may in turn lead to revolutionary change – most commonly results from functional failure. Because of this functional failure either "the conventional paradigm proves inappropriate to 'new or more stringent conditions' or an individual assumes intuitively that he can produce a better or a new technological device."[16] The 1707 disaster suggested that the telescope had reached a performance ceiling that advances in astronomy could only ameliorate incrementally and in any case would have been insufficient to solve the problem with the required accuracy. The need to redefine available solutions created a sort of *solution bazaar* whereby "decision makers shop for appropriate solutions and entrepreneurs with solutions […] sell themselves as the best alternative to decision makers' needs" (David and Sine 2003, p. 187). It is against this backdrop that, while questioning the primacy of the astronomical approach, Harrison's invention did not face outright rejection when was first proposed to the Longitude Board.

Figure 2 illustrates this idea by suggesting that the external shock created an entry point for Harrison, enabling his change of status from outsider to legitimate and visible (albeit still peripheral) contestant. Building on social psychological literature we then conceptualize his subsequent attainment of legitimacy as a social process involving the gradual formation of consensus (Baumann 2007; Zeldtich 2001). This understanding of legitimacy implies that a given social object can be highly legitimated (diffuse consensus among relevant audiences), somewhat legitimated (mixed consensus among relevant audiences), or lack legitimation (no support from audiences). Accordingly, in Figure 2, we describe the outcome of Harrison's legitimation journey as continuous (rather than dichotomous) by showing Harrison's transition across 'layers of legitimacy' over time, with different audiences manifesting their support or resistance.

[16] Unlike the presumptive anomaly, the technological anomaly occurs "when scientific insight or assumptions derived from science indicate either that under some future conditions the conventional system will fail (or function badly) or that a radically different paradigm will do a much better job or will do something entirely novel" (Constant 1973, p. 555).

<Insert Figure 2 about here>

If the exogenous shock precipitated the entry of John Harrison into the field (Figure 2 sub a), it was the subsequent encounter with George Graham and the Royal Society that fueled his legitimacy progression throughout the late 1730s and 1740s (Figure 2 sub b). Outsiders bring with them a new language and in order to express their innovative ideas they "must engage in a process of translation" (Harman and Dietrich 2013, p. 15). Graham was a horologist and so in a position to understand and even appreciate the promise of Harrison's novel horological approach. Likewise, by its very nature and composition the Royal Society displayed a particularly favorable and open-minded orientation towards problems of practical utility. In fact, "many if not most (Royal Society members) were less interested in recondite speculation than in discovering a satisfactory way to measure longitude" (Coser 1965, p. 5). To appreciate this supportive attitude, it is important to observe that since its foundation the Royal Society admitted a plurality of knowledgeable individuals, not necessarily academicians, such as technicians and instrument-makers (e.g., watch-makers like George Graham). In the early days of the Society, about one-third of the Fellows consisted of "scientific men of eminence and merit, the remainder being made up of those who might be interested in the new philosophy and its aims, but who did not devote themselves seriously to the advancement of natural knowledge" (Lyons 1939, p. 108). As Coser (1965) pointed out, the Royal Society was truly an assembly of curious minds strongly devoted to the new experimental procedures and fascinated by problems of practical utility (see also Sorrenson 1996). This attitude stood in sharp contrast with the speculative rigor of natural philosophers like Thomas Hobbes who ridiculed the experimentalists of the Royal Society by comparing them to "quacks", "mechanics", and "workmen" (Shapin and Schaffer 1985, pp. 125-139; Shapin 1989). Given its interest in experimentalism and mechanical questions (Stewart 1992), the Royal Society proved particularly helpful during the early phase of Harrison's legitimation journey. Following the initial intercession by George Graham, the Royals Society demonstrated its helpfulness in many ways. It provided Harrison with the resources to start working on H1. It endorsed him with the Admiralty to conduct the first unofficial sea trial of H1 onboard H.M.S. Centurion sailing to Lisbon. Finally, the Royal Society signed the certificate which opened the door to the Board of Longitude for Harrison in 1737. A further certificate was signed by twelve members of the Royal Society in 1741.

At this stage, Harrison's credibility had grown to the point that he fully entered into the attention space of the Board of Longitude commissioners. From the late 1730s until the early-1750s, the commissioners, both the astronomers and the Navy, were also supportive, so contributing to further enhancing Harrison's reputation. For instance, the Admiralty had been so impressed by the performance of H1 on the return voyage from Lisbon to release an affidavit in which Roger Mills, the Master of H.M.S. Orford, admitted his own mistakes (see footnote 9 on p. 18) and praised instead the accuracy of the timekeeper. Next, during the years he worked on H1, H2 and H3, Harrison appeared before the Board on several occasions, every time receiving public funding to continue his experimentation (Table 1). During this period, in his role as Astronomer Royal, Halley was an *ex-officio* member of the Board and – as the key expert and authority in matters concerning the longitude – his word sealed the final decision on the proposals submitted to the Board. Harrison's reputation reached its apex on 30 November 1749, when the Royal Society conferred its Copley Gold Medal (the highest award it granted for work in any field of Science) on him for his contribution to the measurement of the longitude (Quill 1976). Although his chronometers did not yet qualify for the final reward, by the mid-1750s the mechanical (time-keeping) method had emerged as the most promising solution to the longitude problem.

<Insert Table 1 about here>

Notwithstanding the key role of the Royal Society in supporting Harrison's progression to the core, it is also important to stress his unrelenting agency and ingenuity. Having entered the arena of contestants, in multiple occasions Harrison travelled the 185 miles from Barrow-on-Humber to London to expose his ideas and further them first before Halley and Graham, and then the Royal Society and the Board of Longitude. By 1746, Harrison declared himself so committed and tirelessly dedicated to the work that he was "quite incapable of following any gainfull employment for the support of himself and family" (Board of Longitude, confirmed minutes, 4 June 1746, CUL RGO 14/5p. 14). He actually relocated to London, where he spent the rest of his life and also had access to skilled artisans and clockmakers whose help proved critical as he further developed and worked on his new designs. Also, his outsider's perspective gave him freedom to explore solutions to the longitude problem in an unconventional way. For example, although H3 failed to qualify for the great longitude reward, it incorporated two original and extremely important inventions, still relevant today: the bimetallic strip (still in use worldwide in thermostats of all kinds), which compensated the balance spring for the effects of changes in temperature; and the caged roller bearing, a device found in nearly all modern mechanical engineering – the ultimate version of his anti-friction devices. Historians suggest that Harrison's lack of formal and, therefore, standardized training explains why many of his ideas – e.g., the preference for large arcs of swing (whether for pendulums or balances), the temperature compensation mechanism, and the sophisticated use of woods in clock movements – differed from standard assumptions about how a precision timekeeper should be made. This point is also apparent in Folkes' speech to the Royal Society when he presented John Harrison with the Copley Medal: he emphasized that Harrison "*was not originally brought up to the business he now professes but his genius had taken him much further than would have been possible by the most elaborate precepts and rules of art.*" There are eighteenth-century references to Harrison that underscore his 'atypicality' by calling him as 'nature's mechanic' (Hatton 1773, p. 22) – a linguistic trope combining the incongruous and usually opposed categories of the *natural* and the *artificial*.

Scientific Advancements in Astronomy and Confrontation with the Field Insiders

By the time Harrison was working on H3 and H4, the British astronomer Nevil Maskelyne had further improved the lunar-distance method. In particular, the clarification and recognition of the concepts of function and differential equations by the eminent Swiss mathematician Leonhard Euler during the first half of the eighteenth century had laid the foundations for his mathematical theory of lunar motions. Working from this Tobias Mayer published very accurate tables of lunar motion in 1755 (Chandler 1996), and these developments gave astronomers renewed hope of solving the longitude problem through astronomical observation. Indeed, after "the lunar-distance method had been tried at sea and a special version of Hadley's quadrant – the sextant – had been developed for making the necessary observations, astronomers seemed set to bring to fruition the solution to the longitude problem that Newton had so firmly recommended" (Andrewes 1996a, p. 221). In 1763 (under the Board's patronage), Maskelyne published the *British Mariner's Guide*, which explained lunar observations at sea in simple terms. While the lunar distance method was still vulnerable to the vagaries of time, weather and date; and also required that the moon and other known astronomical objects (the sun, planets certain stars) be visible (Charney 2003), these advances were gradually making it a much stronger practical contender.[17] As noted by Taylor (1962, p. 259), the measurement and timing of "the Moon's distance from a fixed star and a comparison with tables drawn up in advance for a prime meridian, had now become quite straightforward—at least for those not afraid of figures." The advances in astronomical knowledge during the 1750s made astronomers more skeptical of the mechanical method and increasingly confident that their method was the only viable – and, from their own perspective, the only scientifically valid – solution to the longitude problem. As a result, following the Board's decision to officially test H4 on voyage to Jamaica, Harrison published a *Memorial* in which he expressed his concern about who should conduct the astronomical observations at the point of arrival (Jamaica) and the point of departure (Portsmouth).[18]

On 18 November 1761, Harrison's son William then sailed to Jamaica aboard the ship *H.M.S. Deptford*. Having been used to correct an en route sailing error of over 100 miles, the chronometer's reputation was further enhanced on anchoring at the mid-way port of Madeira on 9 December, when it was found that *H.M.S. Beaver* (which was following the same route but using the lunar distance method) had not yet arrived, despite having left Portsmouth ten days before the *Deptford* (Quill 1966, 1976; Andrewes 1996b). On 18 December Captain Digges wrote from the *Deptford* to John Harrison:

> "*Dear Sir, I have just time to acquaint you in your son's letter, in which he is so good as to enclose this, of the great perfection of your watch in making the island on the Meridian; according to our log we were 1 degree 27 minutes to the eastward, this I made by a French map which lays down the Longitude of Teneriffe, therefore I think your watch must be right. Adieu. I am Sir, your humble Servt. D. Digges*" (p. 83).[19]

Captain Digges ceremonially presented William and his father, in absentia, with an octant to commemorate the successful trial and placed his order for the first Harrison-built chronometer, which should be offered for sale. The quality of this performance had to be assessed carefully via calculations upon return to England. However, the observations that had been taken seemed to indicate that H4 had performed with exceptional accuracy (Quill 1966). On the Deptford's return to Portsmouth, after a period of 147 days, its error was 1

[17] For instance, a 1765 Board minute reports the following observation from four captains of the East India Company: "We have used the said Method many times... as illustrated [in the British Mariner's Guide] … and we always managed to have our Longitude in a matter of a mere four hours" (Board of Longitude confirmed Minutes, February 9, 1765, MS. RGO 14/5, Royal Greenwich Observatory Archives, Cambridge University Library).
[18] A Memorial to the Commissioners of Longitude delivered to Lord Anson, by Mr. Harrison, the 13th of April 1761 (http://cudl.lib.cam.ac.uk/view/PR-HO-00025/67).
[19] Anonymous, 1763. An account of the proceedings in order to the Discovery of the Longitude at Sea, II edition, London.

minute 54.5 seconds, and only 5.1 seconds on the whole return voyage: an outstanding achievement, well beyond the Longitude Act's requirements. Rumors about H4's performance soon spread throughout His Majesty's Navy – in comparison, although it had been considerably refined, the lunar distance method was still more difficult to use, required competence in using a complex instrument (the sextant), and calculations for the lunar method remained by far longer to determine.

In 1762 (shortly after the Deptford's return) all of Harrison's most influential supporters who had contributed to his legitimation early on – e.g., Graham, Halley, Folkes and Bradley – were dead and Nathaniel Bliss, an influential member of the academic party, was appointed to succeed Bradley (one of the five members who had signed Harrison's letter of endorsement in 1735) as Astronomer Royal. As Bliss continued Newton's legacy, the influence of astronomers and mathematicians in the Board gained new impetus. So, when the Board met on 17 August 1762 to consider the official results of the trial, while declaring Harrison's chronometer to be "of considerable Use to the Public," they resolved (to Harrison's dismay) that:

> "*The experiments already made of the watch have not been sufficient to determine longitude at sea…the watch must needs submit to a new trial under stricter scrutiny… [John Harrison] receives £1,500 in recognition of the fact that his watch tho' not yet found to be of such great use for discovering the Longitude is nevertheless an invention of considerable utility for the public...*"[20]

A further £1,000 was promised for payment after a second voyage to the West Indies, but no reason was ever given to explain this decision, nor were the official figures of the performance of H4 ever made public (Quill 1976; Randall 1996). Harrison, who expected an explicit acknowledgment of H4 performance and hence the award of the £20,000 reward, was surprised at the Board's silence that he decided to render the behavior of the Board a matter of public interest. To this end, in December 1762 he published three broadsheets,[21] followed by a pamphlet in February 1763. Addressed to "Members of Parliament," the three broadsheets and the pamphlet reveal Harrison's intention to inform, but also influence, the legislator and the public about the conduct of the Commissioners (Chapin 1978). In particular, a paragraph of the pamphlet, reported that:[22]

> "*Mr. Harrison's invention had twenty years ago, after a Trial to Lisbon, received the Approbation of two Presidents of the Royal Society, Dr. Halley, Dr. Bradley, Dr. Smith, and others the most eminent Mathematicians then living, given to the*

[20] Board of Longitude confirmed Minutes, August 17, 1762, MS. RGO 14/5, Royal Greenwich Observatory Archives, Cambridge University Library.

[21] a) Memorial concerning Mr. Harrison's invention for measuring the time at sea; b) Proposal for examining Mr. Harrison's timekeeper at sea; c) A calculation showing the result of an experiment made by Mr. Harrison's timekeeper. These original booklets are available from the British Library (London, UK).

[22] *An account of the proceedings in order to the discovery of Longitude at sea* (http://cudl.lib.cam.ac.uk/view/PR-HO-00025/36).

Commissioners of Longitude, in a very solemn Manner, as is before mentioned, and at large set forth in the Appendix. It is by no means designed to impeach the Conduct of the Commissioners, in giving so far the Credits to these Objections as to direct to a further Trial of Instruments; especially as Mr. Harrison had by his Memorial offered, if the Success of the voyage was not satisfactory, to make any further Experiments. The Commissioners had neither Time or Opportunity then, fully to Examine the Answers which could be made to the Objections offered… Mr. Harrison to avoid these Difficulties, and to shew his Readiness and Desire to give all imaginable Satisfaction, even to the most scrupulous Objector, has by the Advice of some Gentlemen of the Royal Society, printed Proposals, which are hereunto annexed, and inserted in the Appendix, which it is hoped will meet with the Approbation of the Commissioners, and of the Legislature, to whose Wisdom, Encouragement, and Liberality, this most useful Invention must be attributed."

The Parliament responded to Harrison's appeal with an Act – "An Act for the Encouragement of John Harrison" (Act 3 Geo. III c. 14) – which protected Harrison against any other person's winning the longitude reward by means of a timekeeper for a period of four years. It also specified that he would be entitled to an additional reward of £5000 if he had provided "a full and clear Discovery [i.e., explanation] of the Principles" of his watch, "and of the true Manner and Method in which the same is and may be constructed." In order to fulfill this requirement, Harrison would have to supply drawings and descriptions, but also dismantle the watch piece by piece before the committee and supervise workmen in making two or more copies of it, which would have to be tested. Harrison, fearful of the delay that this would entail refused.

It took almost two years before the Board arranged a second trial of H4 to Barbados. When William Harrison embarked for Barbados aboard the *H.M.S. Tartar* on 28 March 1764, Astronomer Royal Nathaniel Bliss sent Maskelyne with the task of carrying out geographical and astronomical records, and of assessing the accuracy of H4. As in the first trial, William used H4 to predict the ship's arrival at Madeira with extraordinary accuracy, the average error of the watch being only 39.3 seconds after a voyage of 47 days, a level of accuracy three times better than the level required to win the £20,000 reward. Again, the arrival was certified by the commander of the *Tartar*, Sir John Lindsay, on 19 April 1764:

"*I do hereby certify that yesterday at four o'clock in the afternoon, Mr. Harrison took two altitudes of the sun to ascertain the difference of longitude given by the time keeper from Portsmouth, according to which observations he declared to me, we were at that time 43 miles to the Eastward of Porto Santo. I then steered the direct course for it, and at one o'clock this morning we saw the inland, which exactly agreed with the distance mentioned above.*"[23]

[23] Quoted in the Proceedings relative to the Discovery of the Longitude, The Gentleman's and London Magazine, 1765, Vol. XXXV, p. 114.

The second test of H4 to Barbados had demonstrated that H4 was a very precise timekeeper: a panel of experts (mathematicians and physicists) had declared that its average error was 39.2 seconds, a result three times better than the one required for the £20,000 reward. [24]

Nathaniel Bliss's period as Astronomer Royal lasted two years, and when he died in 1764 he was replaced (on 8 February 1765) by Maskelyne, who took his place as an *ex officio* member of the Board the very next day. This new generational shift among the members of the core set of astronomers and mathematicians reinforced the Board's disposition in favor of the astronomical method. At its meeting on 9 February 1765, for the very first time the Board discussed the mechanical and lunar distance methods together. While it (unanimously) acknowledged that the second trial of H4 had more than fulfilled the conditions for establishing longitude as set by the 1714 Act, it also resolved that Harrison's method would need to be fully explained and copies of his watches successfully made before "the said Invention might be adjudged *practicable* and *useful* in terms of the said Act & agreeable to the true Intent and meaning thereof."[25] The argument was that the Barbados trial had done no more than prove that H4 was practicable and useful on that particular voyage, but the Board still questioned whether the chronometer provided a method that could be brought into *general* use at sea. Maskelyne also gave a negative report about H4, observing that the drift rate of the clock (the amount of time it gained or lost per day) was actually an inaccuracy, and refused to allow it to be factored out when measuring longitude. He informed the Board that he had successfully tested the accuracy of Tobias Mayer's lunar tables *en route* to St. Helena and Barbados, and reiterated that the publication of a Nautical Almanac would make calculations for the lunar method more practicable for seamen (Barrett 2011). Maskelyne published the first Nautical Almanac the next year (in 1766, for 1767), which significantly reduced the computational effort involved in the necessary calculations – though it still took a few hours.

The astronomers' renewed confidence in their favored method was illustrated in their using their influence to persuade the Board to adopt a more stringent interpretation of section IV of the Longitude Act. The new criteria implied that the longitude problem would not be solved until it could be demonstrated that a chronometer could be reproduced and put it into general use, and would have the effect of obliging Harrison

[24] The average error of 39.2 seconds corresponds to 9.8 geographical miles, at the Latitude of the Barbados (16° North).
[25] Board of Longitude confirmed Minutes, 9 February, 1765, MS. RGO 14/5, p. 77, Royal Greenwich Observatory Archives, Cambridge University Library.

to fulfill additional requirements (e.g., disassembling H4) to qualify for the final reward. Harrison, on the other hand, assumed that his timekeeper had already satisfied the requirements that the Longitude Act had set to qualify for the first of the Longitude rewards. Indeed, on January 19, 1765, shortly before the Board meeting, Harrison prepared and distributed a new pamphlet,[26] in which he tried to persuade the Board members that he deserved to receive the final reward. On February 25, for the second time Harrison submitted a petition to Parliament in which he claimed to be "'legally entitled' to the greatest longitude reward and praying 'that this Honourable House, will take his Case into Consideration, and give your Petitioner such Relief, as to this House shall seem meet" (Barrett 2011, p. 149). The Board reacted to Harrison's moves by pressuring Parliament to clarify the conditions under which the reward could be awarded. In May 1765, Parliament responded by passing a new Longitude Act (Act 5 George III, cap. 20) – to explain and render more effectual its previous Longitude Act – which stated that the first £10,000 of the £20,000 reward was promised to Harrison as soon as he explained the principles of his chronometer (Quill 1966). But the Board then went on to lay down a new set of criteria, which were far more stringent than those of the original Act, for the second £10,000. The new Act specified that Harrison (now aged 73) would only receive the other half of the first reward when two additional replicas of the chronometer were made, which, after trials, were found capable of determining the longitude within half a degree – but provided "no particular method by which this 'trial' was to take place" (Siegel 2009, p. 23). At a meeting held on 13 June 1765, the Board explained to Harrison that, in order to qualify for even the first £10,000, he would have to disassemble his watch in front of a committee appointed by the Board.

Harrison initially resisted the request of disclosing how his chronometers were made – "[…] nor will I ever come under the direction of Men of Theory" (reported in Bennett 1993, p. 285) – suspecting that some of the Board members were trying to sabotage his chances of winning the final reward. Eventually he dismantled H4 before the Board's appointed representatives (including Maskelyne in his capacity as a Commissioner) over six days from 14 August 1765. On 22 August the Board members finally certified that Harrison had satisfactorily explained its mechanism, and – after he agreed to hand over all four chronometers – awarded Harrison the first £10,000 when it next met in October 1765. In 1767, the Board published a

[26] *The Memorial of John Harrison, of Red Lyon Square* (http://cudl.lib.cam.ac.uk/view/PR-HO-00025/121).

booklet entitled *The Principles of Mr. Harrison's Timekeeper* based on these disclosures, which described H4's technology and with many careful drawings illustrated the main inventions concealed in H4's case. In line with the Board's further requirements that he made two duplicates of H4 (Quill 1976; Siegel 2009), Harrison and his son began to build the first copy (H5) in 1767, while at the same time the Board commissioned the watchmaker Larcum Kendall to make a further copy of H4 (known as K1, and recognized by Harrison himself as an exceptional copy) which was completed in 1769 and inspected in 1770 by the same panel that had inspected H4.

"From the Inside Out": Field Core's Resistance

By the time Harrison was ready to run the first official test of his invention, the field was no longer as well disposed towards his mechanical approach as it was just a decade earlier. The mid-1750s witnessed a series of scientific advances that tipped the momentum in favor of the lunar method and brought Harrison's legitimacy journey to a standstill. Besides, all of Harrison's most influential supporters who had contributed to his legitimation early on – e.g., Graham, Halley, Folkes and Bradley – were dead by the early 1760s, raising concerns about whether his reputation could survive them. This became apparent in 1762 upon returning from the first official transoceanic trip to Jamaica. Despite the positive, almost enthusiastic, feedback of subsequent generations of navigators, the renewed confidence in the lunar-distance method – spurred by Euler's discoveries – paved the way for a shift in the orientation of the astronomers who eventually nullified the outcomes of the first trial and requested a second trial imposing new conditions on Harrison. This change in the Board's orientation was at least in part the result of the waxing influence of a new generation of Newtonian scientists who became core members of the astronomy community and ex-officio Board members over the latter part of Harrison's legitimation journey. To be sure, by the time the astronomical method regained new impetus four different individuals had served as Astronomer Royal in the Board. This leadership discontinuity contributed significantly to the shift in orientation, especially after Bliss and then Maskelyne came to the fore during the critical period in which the chronometer was officially tested for the first time. Interestingly, except for Halley's tenure that lasted only 2 meetings, during the time Maskelyne was Astronomer Royal, only one astronomer turned over in the course of 21 meetings, while 5 politicians and 4 seamen turned over during the same period. This stability in the astronomer group composition during the period 1765-1773 – the most critical years for the adjudication of the longitude contest – is likely to have facilitated the formation of a 'cohesive' group within the Board under the direct influence of Maskelyne, in his role of Astronomer Royal (Table 2). It is during this period that the conflict of interest between the Board and Harrison became apparent.

<Insert Table 2 about here>

Under the pressure of the astronomers, the politicians – who up to that moment had maintained a more neutral position – acceded to a petition for the revision of the original Longitude Act through Parliamentary intervention. In particular, while Section III of the original Act stipulated that the reward should be paid to the inventor of a method capable of measuring the Longitude with the required level of accuracy on a passage to the West Indies, the Board chose to interpret section IV as imposing an additional requirement (over and above success in a single trial), redefining the words "*practicable* and *useful* at Sea" [(Longitude Act, 1714, 12 Anne, cap. 15, § 3 & 4 (Eng.), emphasis added] as meaning that the method be capable of being put into *general use*. This prime example of the aforementioned 'moving the goal posts' tactic occurred after the second H4 trial (to Barbados), when the Board decided to reinterpret the two requirements as being distinct. While the Board could not but accept Harrison's claims that the trial had demonstrated his method as being practicable (as it had been successfully put into practice and had kept the longitude accurately throughout the duration of the Barbados trial), this separation of the two criteria allowed it to reject his claim that his method was useful (Siegel 2009, p. 43). At the same meeting, the Board awarded Harrison half the first reward (for H4's practicability) but withheld the remainder on the grounds that he had to demonstrate that his method could be put into 'general use' (though this was not part of the original Act's criteria). So, the Board further raised the bar by requiring Harrison to make a full disclosure of H4's mechanisms in front of a special subcommittee appointed by the Board; it also stipulated that two additional copies of the watch should be made and tested (Act 5 George III, cap 20).

This change in the field's disposition towards Harrison in the 1750s and the 1760s caused a setback in Harrison's legitimacy journey. This is represented in Figure 2 (sub c) by showing Harrison's gravitating back towards an outer legitimacy layer. Harrison's lack of insider status likely exacerbated his escalating conflict with the Board, as Harrison himself pointed out in one of his polemic pamphlets: "*My being neither*

University-man, Knight nor Earl, insomuch, that even an Act of Parliament could not possibly, or at least, not so well, as on my Behalf stand good" (reported in Bennett 1993, p. 285). Yet, the Board's additional requirements must be gauged against its intention to bestow the final reward on a method of common and general utility that others could replicate at a reasonable cost and that naval officers could use at sea.[27] The introduction of new and more stringent criteria, therefore, revealed the conflict between different evaluation routines (Garud and Rappa 1994). The Board realized that mechanical success could not depend on the skills of one or just a few individuals. A well-understood and shared rule in science is that no scientific advancement can be legitimately accepted if certain results cannot be replicated, especially if those results are claimed to solve the anomalies of an existing paradigm. Regardless of possible conflicts of interest between Harrison and some of the Board members, it was necessary to make the principles behind his chronometers public and so allow others to reproduce them. William Wildman, Viscount Barrington, British politician and *ex officio* member of the Board, made this point very clear when he explained that the Board Commissioners did not doubt the successful trial of Harrison's H4, but wanted to know the watch's principles and assess its replicability before they deemed Harrison to have won the reward. In particular:

> *"If the Commissioners had been certain that other timekeepers could be made which would enable other Ships to find their Longitude with equal exactness they would have given a Certificate for the great reward. But no other Watch has been made and they know not the principles of this. They think therefore they are not justified according to the Act to give the Certificate till farther discovery be made in these points. However they think there is great presumption in Harrison's favour and if his principles were discovered and other watches made deem him entitled to the whole reward. I think they might do this without application to Parliament. But Parliament should be consulted in a point where the honour of the nation as well as Navigation is so much concerned"* (The Barrington Papers (BGN), 1740-1765, *Notes for a speech to the House of Commons*, p. 8:1).

Conflict is the means by which dialectical tensions play out. A necessary condition for conflict to emerge is that opposing parties have sufficient weight to engage in the struggle. Yet conflict tends to remain hidden until challengers can mobilize sufficient support for their claims. It had taken Harrison twenty years of tests, trials and experiments to establish his credibility as a legitimate and serious contender for the reward.

By the early 1750s Harrison's claims were no longer a hidden possibility and the dialectical tension between him and the Board had escalated. It is at this stage that Harrison started to shift the focus of his

[27] The Commissioners concluded that Harrison "*had not yet made a discovery of the principles upon which his said time-keeper is constructed; nor of the method of carrying those principles into execution, by means whereof other such time-keepers might be framed of sufficient correctness to find the longitude at sea …*" (The Gentleman's and London Magazine, January, 1765, p. 114)

efforts by appealing directly to Parliament and adopting strategies to discredit the Board and to champion the marine timekeeper through the dissemination of texts combining interest and normative appeals (Phillips, Lawrence, and Hardy 2004). These texts included a booklet in which he questioned the fairness and objectivity of the tests conducted on the marine timekeepers run by Maskelyne under the authority of the Board of Longitude, as well as a series of pamphlets in which he accused the Board of having orchestrated the 1765 Act to cheat him out of the reward (*Sandwich Papers*, National Maritime Museum, Greenwich, London, SAN/F/2). Additionally, in 1771 Harrison wrote a letter to the Earl of Sandwich, First Lord of the Admiralty and Chairman of the Board of Longitude from 1770 to 1776, reinforcing his main complaints: that he was now old, that he had been unjustly treated, that it was unnecessary to make more watches to prove H4's accuracy, and that in any case he was being deprived access to the watch – which made making copies particularly hard. Harrison used "the propaganda technique of printed broadsheets and ghost-written pamphlets to embarrass the Board and further his cause" (Bennett 1993, pp. 281-282). None of these texts, however, were written by Harrison. Unable to express himself coherently and even write in proper English, but also foreign to the standards of technical notation, he counted on the support of James Short, a Scottish physicist and optical instruments maker, and a Fellow of the Royal Society. Short first defended Harrison's priority over the gridiron pendulum in a paper published in the *Philosophical Transactions* and then helped him compose the pamphlets presenting Harrison's case to the public or Parliament, including a manuscript known as *The Harrison Journal* (Bennett 2014). The manuscript is an account from John Harrison's perspective of his interactions with the Board of Longitude in the 1760s, starting from the Board meeting on 12 March 1761, when the first trial of H4 to Jamaica was agreed, till 23 May 1766, when Maskelyne collected H1, H2 and H3 from Harrison's house in Red Lion Square (London) and moved them to the Royal Observatory. The account is in the third person, but is Harrison's tale, and dwells at length over his grievances with the Commissioners.

During this period, after Harrison received the Copley Medal, there is no evidence of any other explicit act or initiative by the Royal Society in support of Harrison's cause. This lack of direct, visible involvement, is illustrated by the removal of the Royal Society from Figure 2. This is consistent with a conceptualization of 'field' as an arena of social action where players come to organize themselves around an outcome of interest (Hoffman 1999). This does not mean that no other players outside that arena can affect what is going on within the field; it only means that the game is being played mainly by those who strive to gain control over what is at stake. Thus, at any given point in time, it makes sense to focus primarily on the players who are interested in that outcome.

Epilogue

In contrast to the growing opposition from the Board, which was under the influence of core members of the astronomy community, Harrison continued to receive symbolic support from members of other audiences, particularly seamen who eventually were supposed to use Harrison's sea chronometers. The endorsement of seamen – first confirmed when H1 was put on trial during the voyage to Lisbon (1736), and subsequently when H4 was tested on two transoceanic voyages to Jamaica (1761) and Barbados (1764) – was further reinforced when K1 was put on trial – along with *nautical almanac* – on Captain Cook's second South Seas voyage in 1772 under auspices of the Board. Being trained in the use of the lunar distance method, Cook and William Wales (the astronomer aboard the *Resolution*) began to measure the longitude using the chronometer (Quill 1966) as they found it a much easier method and, more importantly, so accurate that they could work out their position to within about 2 miles – a remarkable achievement at the time. Evidence from the ship's log records that Cook referred to the chronometer as

> "*[…] our faithful guide through all the vicissitudes of climate" and "our never failing friend." He further praised the timekeeper's accuracy by saying: "I would not be doing justice to Mr. Harrison and Mr. Kendall if I did not own that we have received very great assistance from this useful and valuable time piece…*"[28]

After 3 years at sea, Cook trusted K1 so much that he would write (on leaving Cape Town for St. Helen):[29]

> "*Depending on goodness of K1 I resolved to try to make the island by a direct course, it did not deceive us and we made it accordingly on the 15th of May at Day-break…*" (Reported in Gurney 1997, p. 32).

Harrison and his son had completed H5 in 1772. But it was clear that, at the age of 79 and with poor health and eyesight, Harrison could not go on and produce a second copy; besides, the Board had still not specified

[28] Beaglehole, J. C. 1961. The Journals of Captain James Cook on his Voyages of Discovery, vol.2: The Voyage of the Resolution and Adventure, 1772-1775. Hakluyt Society Publications, n.35. Cambridge: Cambridge University Press, p. 654, note 1. This page is followed by Cook's signature and is included in the entry for Tuesday, 21 March 1775, the last entry in MS. Adm.55/108, Public Record Office.

[29] When Cook returned to England in 1775, his reports included several glowing references to the chronometer's accuracy and reliability: "Back in England he sang the praises of the chronometer in all his reports and logs, stating Harrison had with no doubt cracked the longitude problem" (Rutherford-Moore 2007, p. 95).

its requirements for testing the H4 duplicates. As a last resort, Harrison appealed to the highest authority, King George III. When Harrison approached him on 31 January, 1772 and gave him a detailed history of his chronometers and their trials, the King agreed to put H5 on trial in Richmond Park, and was impressed by its accuracy. Despite royal support, the Board rejected Harrison's petition of 28 November 1772 reporting the Richmond tests: it refused to consider trials conducted outside its jurisdiction as under the Longitude Act only the Board was authorized to conduct tests. The King responded by advising Harrison to appeal formally to the Prime Minister, Lord North, who (under the King's influence) asked the House of Commons to instruct the Board to reassess the case in Harrison's presence, witnessed by two MPs who were Harrison's supporters. This petition was successful, and in July 1773, recognizing Harrison's 'unremitting Industry,' his discovery of the principles of the longitude chronometer, and the 'great Benefit' that would arise from it to the trade and navigation of the Kingdom, Parliament awarded Harrison the sum of £8,750 [(1773, 13 George III cap. 77 § 29 (Eng.)]. While not the full £10,000 to make up the original first reward, this award meant that Harrison had received over £23,065 from the Board – more than the original first reward (Table 1). So, in the end, it took the King's intervention, and another Act of Parliament to confirm that Harrison had done what was required to qualify for the reward and oblige the Board to pay him the sum through its own account.

"Back to the Core": Acceptance and Legitimation

The later part of the legitimation journey of John Harrison and his invention, which roughly corresponds to the late-1760s and late-1770s period, was shaped by new events and actions. In 1769 two duplicates of the clock were produced, one by the Harrisons and the other by Larcum Kendall (and inspected the following year). Yet the Board continued "to resist, insisting that all the copies be made by the Harrisons" (Oakes 2002, p. 128). Once again the skepticism of the astronomers – the dominant and most vocal block within the Board – contrasted with the Navy's support, as exemplified by Captain Cook's endorsements. It was at this stage that the Monarchy made its entry into the Longitude dispute, changing the odds in favor of Harrison. A passionate horologist and instrument collector himself (Quill 1966; Betts 2007), the King George III could understand and appreciate Harrison's contribution to the solution of the Longitude problem and was well pleased with the accuracy it maintained during the private trials in Richmond. Albeit external to the Board's jurisdictional space (Abbott 1988), during the first half of his reign George III still had considerable influence over Parliament, which was under the patronage and influence of the English nobility. The King exerted this influence in 1773 by appealing directly to the Prime Minister, Lord North on Harrison's behalf. As illustrated in Figure 2 (sub d), the result of the monarchy's intervention was that in the early 1770s Harrison faced a significantly different landscape from that of a few years earlier. Not only did he enjoy the powerful support of the monarchy, a new external audience, but under the monarchy's influence the politicians too changed their orientation assenting to act 13 George III c. 77 – which awarded Harrison the remaining sum (£8750), de facto sanctioning his success and bringing the Longitude's dispute to a closure. Overall, forty-seven years had elapsed between the time Harrison first learned about the reward and the time he secured his full award.

When Harrison died on 24 March 1776, his legacy was the watchmakers' community adoption of the H4 concept, which became a model for affordable and accurate marine chronometers (Landes 1983). It was especially with John Arnold and Thomas Earnshaw that chronometers began to be mass-produced and their cost dropped sharply towards the end of the 18th and early 19th centuries. Arnold also opened a factory south of London to mass-produce chronometers in 1785. Initially adopted in conjunction with the astronomical method, chronometers were then made standard for all naval vessels (Gascoigne 2016).

DISCUSSION

When outsiders advance novel offers that challenge the dominant orthodoxy, the legitimacy of the groups associated with it is also challenged. This process usually favors powerful insiders who enjoy visibility and status within their field. As a result, most efforts to introduce novelty fail or are simply ignored. While, of course, status does not guarantee acceptance, it does increase the probability that a new offer will be noticed and taken seriously from the outset (Merton 1973; Merton and Zuckerman 1973). Prominent actors are in a better position to negotiate the credibility of their offers with their peers because their offers are bolstered by the force of their reputation and the superior resource base they can access. As Haveman and colleagues (2012, p. 595) noted: "At any point in time people […] in high status occupations, with prestigious educational credentials, and in central locations will have easier resource access than people […] in low status occupations, with less prestigious credentials, and in peripheral locations." But, if resources and credentials are crucial to make their new offers worthy of attention, how can (non-certified) outsiders advance their innovations and make an impact "on the inside"? The longitude controversy is instructive. It sheds light on the interplay of micro-, meso- and macro conditions shaping outsiders' efforts to push forward their offers in a specific field. The preceding analysis has attempted to expose such conditions by generating a series of stylized insights into the successive phases of Harrison's journey from the margins to the core of the longitude field. We focused our historical narrative specifically on how John Harrison moved from being an outsider to a legitimate contender to the Longitude reward, and how the trajectory of this journey unfolded as a result of forces operating across levels of analysis. We now leverage these insights to delineate a process model of the outsider puzzle and its potential resolution.

A process model

Figure 3 shows key process elements involved in the outsider puzzle. Central to the model is the recognition of the interdependence between micro-level efforts, and meso- and macro-level processes, which are largely independent of those efforts and yet shape their outcome. In particular, observations from the case highlight the interplay between environmental jolts, social audiences, and individual agency in shaping the process of finding a proper solution to the longitude measurement problem. Our findings also show how this multilevel process, far from being linear, can become unusually complicated in the presence of multiple audiences whose members change over time, carrying different interests and using different criteria for adjudicating credibility struggles between competing offers. For the sake of clarity, we address each of the cross-level relationships summarized in Figure 3 separately.

<Insert Figure 3 about here>

From Macro to Micro: The Agency Enabling Effect

Harrison's 'outsiderness' equipped him with a distinctive outlook and idiosyncratic approach to the longitude problem. His lack of connection to the intellectual and scientific establishment forced him to rely on his own ideas, observations, and experience; truly, he was an outsider looking in. This, however, also meant that traditional levers of legitimation were not available to Harrison, nor did he possess the cultural competence required to engage in elaborate framing efforts. In fact, so alien was Harrison to the rhetoric of scientific communication that he had to rely on James Short's support to make his arguments accessible (Bennett 2002). Both historians (e.g., Quill 1966) and horologists (e.g., Burgess 1996) have emphasized how, as a self-taught man without formal academic education, Harrison struggled to express himself clearly in writing and, therefore, to communicate his ideas cogently and comprehensibly to the astronomers' community. A review of Harrison's book *A Description Concerning Such Mechanism* (published in 1775) is quite telling in this regard: "*Any one who reads but a single page of this pamphlet will be convinced that Mr. H. is utterly unqualified to explain, by writing, his own notions, or to give a tolerable idea of his own inventions*" (The Monthly Review; or Literary Journal*:* vol. 53, Art. VIII, October 1775, p. 320). The reviewer reproduced passages from Harrison's text and offered tentative 'translations.' In short, while his unique understanding of horology allowed him to offer a fundamental contribution to solving the longitude controversy, Harrison was unable to speak the 'language' of the astronomy community of his time properly. Unlike previous accounts of entrepreneurs as skilled theorizers (e.g., Greenwood et al. 2002, David et al. 2013); Harrison did not succeed by manipulating the existing cultural structures. In fact, one cannot understand his ascendance into the arena of the longitude contestants without accounting for the mounting state of dissatisfaction caused by the failure of existing approaches to adequately measure longitude. As Kuhn (1970) noted in the context of scientific revolutions, crises serve as a necessary precondition for the emergence of new theories. In our case, this precondition was the state of indeterminacy caused by the protracted inability of extant approaches to provide safe and reliable estimates. This situation escalated dramatically with the Scilly's incident, which triggered broad search processes that resulted in easier access for peripheral players and proliferation of "unorthodox experiments" (Hoffmanm 1999, p. 353).

To clarify how this macro-to-micro *agency enabling effect* favors the exercise of agency by outsiders, whose potential for action otherwise is severely constrained, we build on the concept of *entrepreneurial action space* from the entrepreneurship literature (McMullen 2015). In this context, entrepreneurial action is defined as any activity entrepreneurs might undertake to create and exploit new opportunities (Alvarez and Barney 2007). Entrepreneurial action space refers to the range of "opportunities to engage in action" (Ramoglou and Tsang 2016, p. 422), i.e., opportunities available to innovators to further their novel claims. Our findings suggest that the jolt carried with it impetus for action that propelled innovative efforts forward. This effect opened up the field to new and unusual players with alternative views on the longitude problem. As the case analysis shows, the Scilly's disaster spurred efforts both within and outside the core set of scientists traditionally invested in the longitude quest. A variety of claimants – from religious pamphleteers, carpenters and shoe manufacturers to East Indian employees and German professors – took up the challenge to advance their solutions, generating a remarkable and richly documented stream of proposals (Burton and Nicholas 2017). By broadening the entrepreneurial action space, therefore, the jolt enabled Harrison to transcend the constraints of his outsider position and get an entry port to the longitude arena.

From Macro to Meso: The Attention Enabling Effect

While the macro-to-micro effect of the jolt was critical to enable agency, the jolt also played an important role in raising field-level awareness about the urgent need to find a solution to the longitude problem. We refer to this process as a macro-to-meso *attention enabling effect* to highlight the key role played by the jolt in sensitizing the attention of relevant audiences controlling symbolic and material resources vital for sustaining innovation. To elaborate this effect, we draw on the concept of *attention space*, first introduced by Collins (1975, 1998) and further elaborated within the sociology of ideas (Camic and Gross 2001). In his analysis of the history of science and philosophy, Collins suggests that cultural producers are driven, above all, by the desire to win the attention of their colleagues. As he succinctly puts it: "A realistic image of science ... would be an open plain with men scattered throughout it, shouting 'Listen to me! Listen to me!'" (Collins 1975, p. 480). Actors struggle to position themselves within this attention space because, Collins theorizes, status and resources flow to those who impress the members of the field with their ability to successfully mobilize the intellectual capital at their disposal, and so advance their ideas. The problem, however, is that most of the attempts at advancing novelty do not capture the attention of the audiences because over time gradual changes provide insufficient stimulation to reach people's attention thresholds for action. As noted by Van de Ven (1995, p. 279): "People adapt to gradually changing conditions and often fail to notice that conditions have signaled the appropriateness of a new idea." In addition to the blinders that humans wear because of habit, there are also blinders stemming from defense mechanisms such as denial and risk avoidance. As a consequence, "unless the stimulus is of sufficient magnitude to exceed their attention threshold – that is a shock – opportunities for innovation are either not recognized or not accepted as important enough" (Van de Ven 1995, p. 246).

In our case, the Scilly's shipwreck was the shock that produced this attention enabling effect: it catapulted the longitude problem into the public sphere, raising an unparalleled level of attention across multiple constituencies. British Parliament passed the 1714 Act and appointed a committee – later known as the Board of Longitude – whose constituents included members of the three main audiences interested in solving the longitude problem and whose task was to evaluate the proposals submitted to its attention. The Act galvanized interest in the problem also from additional audiences (external to the Board) such as The Royal Society and the Monarchy. The effect was to expand the consideration set of all relevant audiences and enable peripheral players' proposals – which otherwise would have remained outside the attention space of those audiences – to be considered. This can be partly explained by the fact that the urgency of the problem made disciplinary minds less 'territorial,' resulting in an unusual openness to new ideas. This observation is particularly salient, as the vast majority of organizational scholarship treats audiences as monolithic entities whose members are resistant to deviant offers – especially so when categorical systems are agreed upon – thus paying only limited (or no) attention to change dynamics within the audience structure that may alter the field's permeability to such offers (for exceptions see Cattani et al. 2014; Pontikes 2012; Jensen and Kim 2014; Goldberg, Hannan, and Kovács 2016). Even when audiences are receptive to deviant offers, this research attributes this disposition to the reputational resources deployed by the challenger. Yet these resources usually are unavailable to outsiders. Questions then remain about alternative sources of change in audiences' structure of attention. Our findings on the macro-to-micro and macro-to-meso relationships offer guidance in addressing such questions by uncovering forces that operate independently of the individuals who compete to win audiences' attention.[30]

Although we treat the agency and the attention-enabling effects as independent, one might wonder which their relative importance is or whether they are mutually reinforcing. However, it is not possible to assign relative weights to these effects nor to establish the precedence of one over the other in explaining the emergence and the legitimation of novelty. Our evidence does not allow us to make any such statement or

[30] Another illustration of a jolt's potential to trigger this twofold (action and attention space) enabling effect is Sine and David's (2003) analysis of the wave of entrepreneurial agency that hit the US electric power industry in the aftermath of the oil crisis "increasing access for peripheral actors to central policy makers" (p. 203). The oil crisis had two distinctive consequences for the ascent of novelty. On the one hand, it opened up the field to innovators with alternative solutions to power generating problems, so catalyzing diverse experimentation processes; on the other hand, and perhaps more crucially, it altered the attention space of the relevant social audiences (regulators and policy makers), in charge of vital intellectual and financial resources, that became more sensitive to and interested in alternative practices. Fringe voices, previously excluded from the national spotlight, were sought out "and granted access to the political élite and suddenly found themselves explaining their ideas in Congressional committees" (Sine and David 2003, p. 199).

any other beyond observing that each of the identified enabling effects seems relevant to understanding the journey of Harrison's solution.

The Micro-Meso Interplay: A Dialectical Interaction

The twofold enabling effect of the exogenous shock on the action and attention space offer valuable analytic purchase for identifying those situations in which the supply side of agentic offers and the demand side of legitimating audiences may combine to create propitious conditions for the emergence of novelty at the field's margins and its subsequent recognition. Structural forces, however, cannot explain the journey of novelty from the margins to the core without accounting for individuals' efforts and the responses of the audiences to which those efforts are directed. As Constant (1973, p. 557) fittingly put it: "it is men not 'forces' that cause technological revolution […] It is those men's faith in themselves and in their works, a faith that can only described as fanaticism, that is the critical motive force for technological revolution." Indeed, we can see in Harrison's relentless pursuit of the longitude quest a tenacity bordering on fanaticism. After he had the chance of entering the field and submitting his idea to the attention of the Board, Harrison exercised his agency in multiple manners. He relentlessly experimented with the marine clock for almost 40 years, making various versions of it and testing it in multiple transoceanic trials; circulated contentious and accusatory texts (printed broadsheets, memoirs and ghost-written pamphlets) to decry the Board as unjust, further his cause and counter the growing resistance of the Board, especially from the early 1760s onwards; actively sought to enroll higher authorities and mobilize political support through parliamentary petitions and subsequent appeals to the King. In short, he engaged in a variety of activities reminiscent of those documented within actor centric narratives of institutional entrepreneurship (see Figure 4 for a graphical representation).

<Insert Figure 4 about here>

Our study, however, also illustrates some of the limits to agency that arise when diverse audiences and their reactions figure prominently in the analysis of the change process. While there is no doubt that Harrison was uniquely gifted – so gifted, in fact, that the Royals Society awarded him the Copley Medal, the highest scientific honor of the time – his effort did not single-handedly lead to the affirmation of the mechanical approach. We have indeed shown that Harrison's legitimation journey was punctuated by crucial encounters with different social audiences displaying variable dispositions towards his solution. These encounters help expose not only the *dialectic interaction* underlying the entrepreneurship process – as agentic efforts are met with resistance or support – but also the potential for outcomes that are not necessarily those intended by the actors originally involved. We take particular note of the role of the audience structure because it has received little, if any, attention among institutional theorists, despite its implications for understanding field-level circumstances that may foster or stifle efforts at novelty. Our case analysis shows how the contemporary presence of multiple interested audiences allowed for the coexistence of different perspectives on the longitude issue, providing Harrison with more friendly niches in which to couch his claims, despite lack of general consensus. As recently pointed out by Aldrich and Martinez (2015, p. 449): "Discrepancies in expectations across multiple audiences […] can create opportunities for entrepreneurs to select niches in which they can satisfy one set of expectations while being shielded, at least temporarily, from alternative expectations." However, the diversity of audiences and the lack of clearly dominant players also means that an offer characterized by a "narrow set of attributes that resonates only with one group of actors will not mobilize the wider cooperation that is needed to bring about change" (Maguire, Hardy, and Lawrence 2004, p. 668). The astronomers' community endorsed the astronomical lunar distance method because, despite its complexity, it was regarded as a more scientific solution and thus more open to the world at large; on the contrary, the naval and political audiences preferred a proprietary, more 'seaman-friendly' technology, which had to be protected from diffusion to such enemy states as France and Spain.

Although these logics co-existed throughout the forty-seven-year period from Harrison's first visit to Halley to Parliament's acknowledgement of his claims, it was not until Captain Cook's three-year voyage around the world that the reliability of the chronometer in measuring longitude at sea was confirmed beyond any question – and even then, the academic community maintained a significant opposition to Harrison's solution. So, the presence of multiple audiences may facilitate local legitimation with one (or more) audiences shielding pressures from competing audiences, but does not ensure a widespread consensus among the interested parties. Even after the King's intervention contributed to 'settling' the controversy in Harrison's favor, the astronomers' lobby on the Board remained strong enough to deny him full symbolic recognition for solving the longitude problem for many years. Another key insight of the case analysis is that an audience's membership may not be stable, especially when focusing on historical processes that unfold on the scale of decades (Cattani, Ferriani, Negro, and Perretti 2008). A challenger's access to critical resources will remain unaffected if generational shifts leave focal audience's evaluation criteria unvaried, and new members simply continue to provide (or deny) their support as before. However, challengers may see hitherto supportive audiences withdraw their endorsement if newcomers to that audience introduce new sets of values and beliefs, so that existing evaluation criteria are reconsidered. In fact, one might even argue that the presence of multiple audiences, combined with changes in their membership, expands the number of possible destination states of the legitimation journey of novelty. This is tantamount to what sociologists of science describe as a "non-determined, multidirectional flux" (Bijker, Hughes, and Pinch 1987) that entails dialectical tensions—which are clearly in contrast with linear, impact-oriented accounts common to many innovation studies. Of course, with historical hindsight, it is possible to collapse this multidirectional understanding of the innovation journey onto a simpler linear account; but this misses the gist of our argument that the 'successful' destination states are not the only possible ones. In Harrison's case, the change in evaluation criteria was largely the result of the waxing influence of a new generation of scientists who gained new confidence in their favored (and now improved) lunar-distance method, causing a shift in the orientation of the astronomy community and significant setback in Harrison's legitimation journey.

Overall, these findings have interesting implications regarding what conditions and audience structure stifle or foster innovation. In particular, they suggest that variance in audience composition and orientation over time may help explain why one observes so much variability across settings in terms of their propensity to experiment and innovate (Cattani et al. 2014; Goldberg et al. 2016). Our model even allows for the case in which a superior innovation is eventually rejected. This may occur, for instance, when there is one dominant hostile audience; when no exogenous shock occurs that renders disciplinary mindsets less "territorial"; or when the innovator (the outsider in our case) fails to exhibit the required agency and, therefore, is unable to enlist the support of (at least) one supportive audience. Also, whereas the "majority of the literature has developed around actor-centric accounts that focus on particular institutional entrepreneurs, and how and why they are able to transform fields" (Hardy and Maguire 2008, p. 3), these findings point us towards a different narrative that is more process-centric and emphasizes the dialectic interaction that accompanies outsiders' driven efforts at novelty. While this narrative incorporates the role of agency, it also avoids the risk of swinging too far in the opposite direction and ignoring the dialectic tensions that play out when audience level dynamics are accorded a more central role in the analysis. Although the historical specificity of the audiences, their social positions, and the personal aspirations of the key players involved in solving the longitude problem may be somewhat foreign to us, the conceptual pillars of our multilevel model correspond to processes that are basic to the legitimation of novelty today as they were in the 18th century. To illustrate the plasticity of our framework across different types of innovation and fields, we offer two more contemporary examples of innovation, one successful and one unsuccessful in Appendix 2.

Concluding Remarks

In our attempt to understand the emergence and legitimation of novelty, we believe there is much to gain from embedding individual efforts at innovation into the meso and macro level processes that often remain hidden from analytical inquiry due to a narrow slicing of time and space (Padgett and Powell 2012; Johnson and Powell 2015). As the case evidence suggests, by locating outsiders' efforts in social time as well as social space it is possible to understand why a novel offer that is now perceived as a threat to the field's existing norms might later on become accepted and vice versa: why, in other words, "the nonconformist, heretic and renegade of an earlier time is often the cultural hero of today" (Merton 1968, p. 237). More broadly, we believe that a model that is sensitive to the features of the historical context and weds individual efforts directly to exogenous macro-conditions and the meso-level properties of the field in which agency unfolds can solve puzzles about entrepreneurial dynamics by exposing how interactions among multiple forces foster or hamper paths to innovation (Haveman et al. 2012). Such an approach is not oblivious to the role of agency, and yet it is less prone to celebrating certain actors as "exceptional" based on their rhetorical skills and social position in the field. Attention is not paid only to protagonists during episodes of change – the innovators – but also to their opponents, and the diffuse legitimacy struggles in which they engage, where gains for one group may imply losses for another, so providing greater scope for examining conflict and resistance (Hardy and Maguire 2008). As a result, attributions of causality to one or just a few actors are more likely to be problematized, reliance on teleological categories such as technical superiority or superior skills to explain certain outcomes is mitigated (Granovetter and McGuire 1998), and more attention is paid to how accessible and responsive the various social audiences populating a given field are to those actors' offers –

which further implies focusing on the diverse evaluation criteria used by different audiences (Cattani et al. 2014) and the evolution of these criteria in the wake of shifts in audience membership over time.

Our study suffers from obvious limitations, which also represent opportunities for future research. First, in this paper we focused on the case of a non-certified outsider, i.e., someone with no formal credentials within the field he was challenging. But outsiders can differ in their degree of 'outsiderness.' For instance, Harman and Dietrich (2013) have examined the innovations developed by scholars trained in a non-biological discipline who moved into some branch of biology. In particular, they show how the reception of crossing disciplines depends on the particular 'outside' one is coming – which determines to what extent outsiders can speak the language spoken by the relevant social audiences in charge of channeling vital resources (Hargadon and Douglas 2001). Some may even choose to become outsiders, like in the case of insiders deliberately moving towards the periphery of their institutional field – e.g., Eric Fromm (McLaughlin 1998) – to break away from pressures to conform to the field's prevailing norms and standards. Understanding whether the saliency of the pillars of our multilevel framework in explaining the emergence and the legitimation of novelty varies with the degree of outsiderness is an interesting question that deserves further exploration. Second, future research could pay closer attention to the various mechanisms through which exogenous shocks may foster or stifle an outsider's efforts at novelty. While we have primarily focused on changes in the permeability of social audiences' attention space following an exogenous shock, other studies point to other interesting possibilities such us the effect of jolts on the level of field connectivity (Cattani et al. 2008) or their role in altering actors' logics of interaction across the core-periphery continuum of an interorganizational field (Corbo et al. 2016). A fine-grained analysis of these and other mechanisms would be of great value to better understand the circumstances under which novelty may or may not succeed at altering an existing field's social structure. Third, while the sudden Scilly's incident led to an unprecedented period of experimentation and search, by the time Harrison started his quest the field of longitude measurement had been established for over two hundred years. This status of mature field in crisis suggests important similarities with emerging fields since motivation and scope for actions tend to be high in both types of contexts. However, there are also crucial differences in that emerging fields have yet to develop many core institutional features (logics, subject positions, clearly defined structures of authority and cooperation, etc.), while in established fields that are in turmoil, "those features exist but are under threat" (Maguire et al. 2004, p. 675). As a result, the kinds of struggle that may ensue in established fields in crisis are more likely to exhibit the Bourdeuian tension between insiders and outsiders. Future research that systematically examines the extent to which the dynamics exposed in this study differ at different stages of field development would be valuable since, as Fligstein pointed out, the use of skills and entrepreneurial strategies "depends very much on whether or not an organizational field is forming, stable or in crisis" (1997, p. 398). Further efforts to develop a more contingent understanding of the outsider puzzle would also benefit from a closer focus on the degree of measurability of outputs. The Longitude act established precise technical performance parameters for adjudicating competing proposals providing contestants with means of proof that may not exist in other contexts. We speculate that in other kinds of settings, where outputs are more intangible and causal processes more complex, rhetorical skills play a greater role in the legitimation process due to the need to imbue solutions with deeper symbolic values that resonate with established categories (David et al. 2013). Under such circumstances, a non-certified outsider's attack to the validity of an established technology or paradigm (Constant 1973) may prove more problematic. Fourth, all the key audiences interested in finding a solution to the longitude problem were clearly and distinctly represented on the Board, which can be seen as an ideal 'laboratory' to isolate and magnify the institutional dynamics involved. In other contexts, such confrontations might take place across the broader institutional field, without key audiences meeting in any specific formal arena – making such dynamics less well defined and thus more difficult to gauge. Finally, research on social movements provides a complementary explanation for how novel offers can become accepted in an established field. Previous studies in this tradition – from AIDS activism (Epstein 1996) to US electric power industry (e.g., Sine and David 2003) – have shown how social movements that break with past practices can result in the successful mobilization of attention, resources and support for new ideas. In Harrison's case we found evidence only for episodic and sparse rather than distributed and collective mobilization: although various prominent actors proved supportive at different times, the Harrisons had to build credibility and trust in their offers largely by themselves. In other cases, of course, distributed and collective mobilization might play a more critical role. Further exploring these areas of inquiry would help validate and enrich the concepts presented in this paper.

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Figure 1 – Harrison's H4

Table 1 – Summary of Payments to John Harrison by the Board of Longitude (adapted from William J. H. Andrewes, *The Quest for Longitude*, 1996a, p. 234)

Amount	Date	Reason
£250	30 June, 1737	Construction of H2 (£500 was granted, but £250 was contingent upon the successful trial of H2 – which was never carried out
£500	16 January, 1741	Construction of H3
£500	4 June, 1746	Construction of H3
£500	17 July, 1753	Construction of H3
£500	19 June, 1755	Completion of H3 and two watches, one of which was to become H4
£500	28 November, 1757	Fine-tuning of H3 and completion of the previous two watches
£500	18 July, 1760	Fine-tuning of H4
£250	12 March, 1761	Costs related to the first sea trial of H4
£200	13 October, 1761	Construction of H4 (£500 was authorized but only £200 was paid due to lack of funds)
£300	3 June, 1762	Construction of H4 (balance of previous due payment)
£1,500	17 August, 1762	Award following H4 first sea trial, with stipulation of another £1,000 to be paid after a second sea trial
£300	9 August, 1763	Expenses incurred during second sea trial of H4
£1,000	18 September, 1764	Award following H4 second sea trial (as stipulated on 12 August, 1762)
£15	9 February, 1765	Expenses incurred for computations after H4 sea trial to Barbados
£7,500	28 October, 1765	First half of Longitude reward (£10,000), minus £2,500 paid in 1762 and 1764 (as stipulated on 17 August, 1762)
£8,750	19 June, 1773	Second half of the Longitude reward (£10,000), minus £1,250 (the sum of what the Board had already paid in 1737, 1741/42, and 1746)
£23, 065		

Table 2 – Variation in the composition of the Board of Longitude (1737-1773)

Astronomer Royal	Period	% New Members	% Old Members	Number of Meetings	Number of New Astronomers	Number of New Politicians	Number of New Seamen
Edmund Halley	1737-1741	14	86	2	0	0	1
James Bradley	1746-1761	25.4	74.6	8	7	5	9
Nathaniel Bliss	1762-1764	8.5	91.5	7	3	3	3
Nevil Maskelyne	1765-1773	3.9	96.1	21	1	5	4

Figure 2 – Harrison's Transition across 'Layers of Legitimacy' Over Time

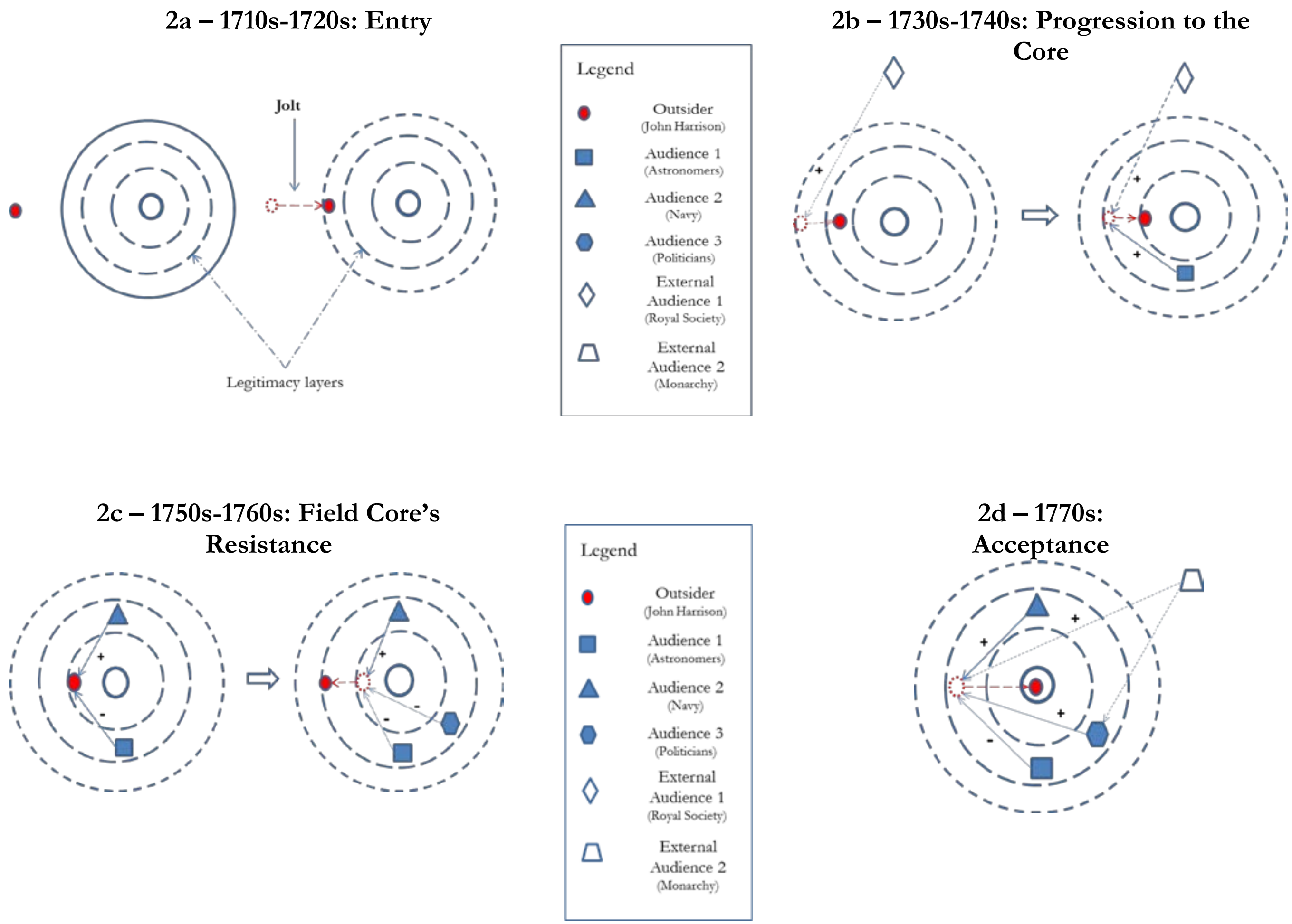
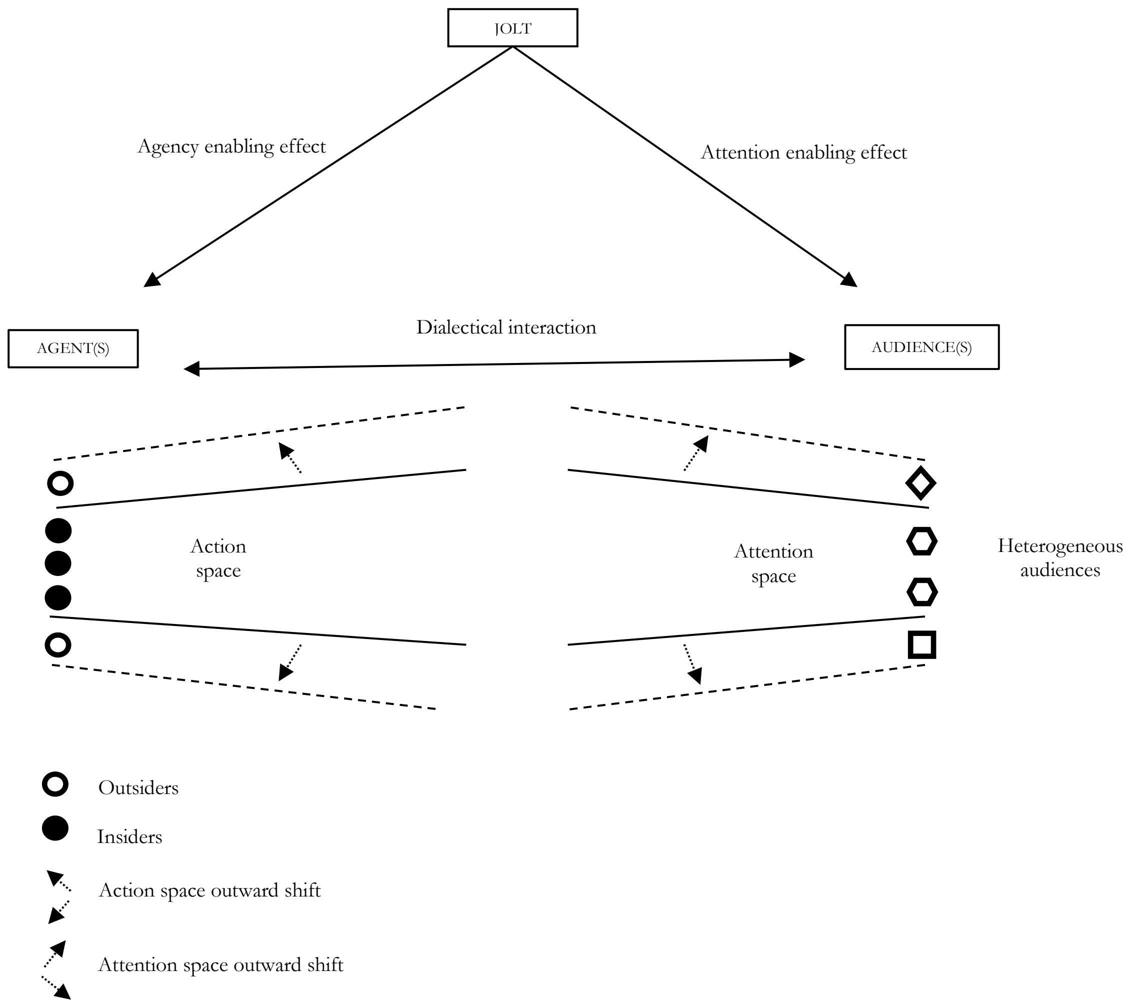
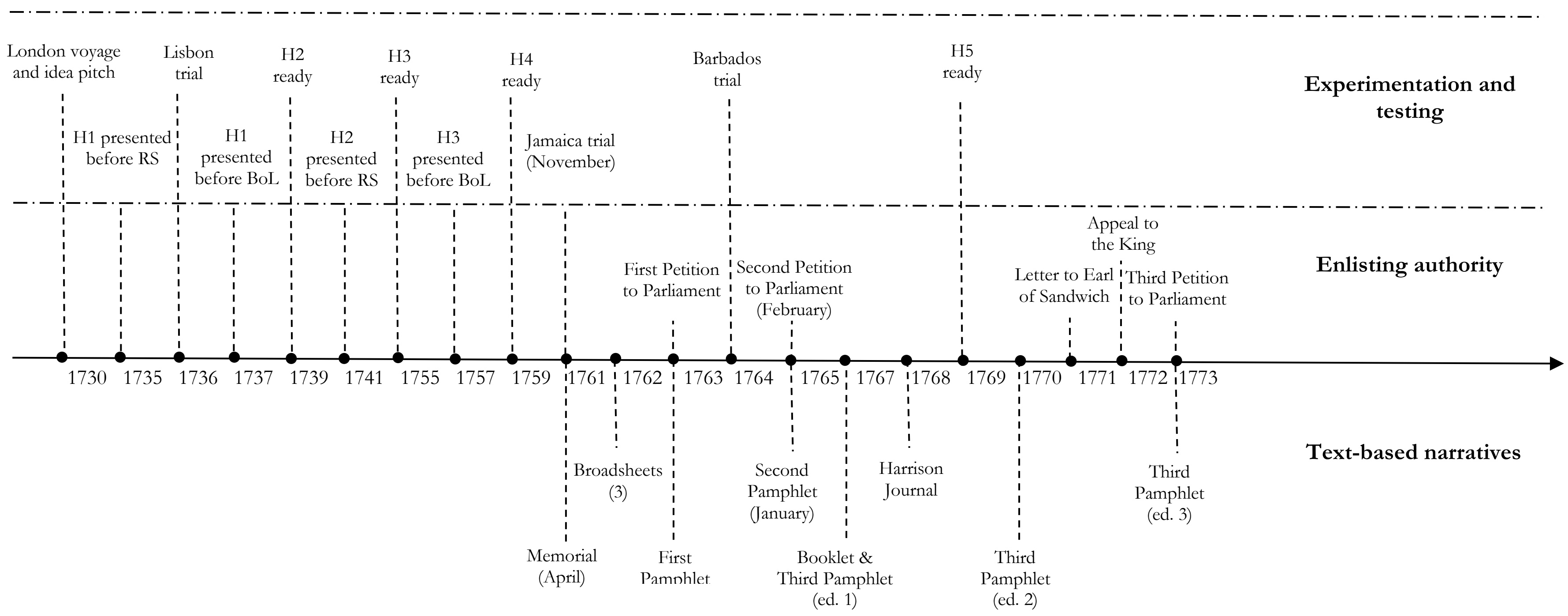


Figure 3 – Interplay of jolts, agents and audiences in shaping innovation efforts



Note: Solid lines indicate the boundaries of the action and attention spaces before the jolt, while dotted lines indicate the expansion of these boundaries *after* the jolt.

Figure 4 - Timeline of John Harrison's Agentic Efforts ('RS' - Royal Society, 'BoL' - Board of Longitude)



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 bust 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 busting star shell, which was set to explode at 6,440 feet"* (Force 1985, pp. 22-23).[31] 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).[32]

[31] 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).

[32] 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

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

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).

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 legitimation 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 interested in the traditional (gas-based) drive technology forced GM to terminate the production of EV1.