The Technicity of Time

From 1.00 oscillations/sec to 9,192,631,770 Hz

Adrian Mackenzie

ABSTRACT. In modern social and critical theory, clocks have figured as the embodiment of social order or, more ominously, as an exemplar of the threat posed to living thought by technology. As an alternative to such a bipolar evaluation, this paper examines the technicity of clocktime. The concept of technicity was suggested by the French philosopher, Gilbert Simondon. It is way of understanding the mode of existence of technical objects ontogenetically, that is, in terms of how they come to be rather than what they are. This paper introduces an ontogenetic account of clocktime as a new capacity to articulate diverse geographical, economic, technical and political realities together. It explains the convoluted precision of contemporary clocktime ensembles as just such an articulation. It discusses an ineliminable residue of metastability in the increasing precision of clocktime. KEY WORDS • GPS • pendulum clock • Simondon • time

> [T]he simple pendulum does not naturally provide an accurate and equal measure of time since its wider motions are observed to be slower than its narrower motions. But by a geometrical method we have found a different and previously unknown way to suspend the pendulum; and we have discovered a line whose curvature is marvelously and quite rationally suited to give the required equality to the pendulum. After applying this line to clocks, we have found that their motion is so accurate and constant that, after many experiments on both land and sea, it is now obvious that they are very useful for investigations in astronomy and for the art of navigation . . . Of interest to us is what we have called the power of this line to measure time, which we found not by expecting this but only by following in the footsteps of geometry. (Huygens, 1673/1986: 11)

The second is the duration of 9 192 631 770 periods of the radiation correspond-

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> ing to the transition between the two hyperfine levels of the ground state of the caesium-133 atom. (Blair, 1974: 11)

Three hundred years separate these two technical definitions of the second. The definitions both rely on oscillations of some kind – that of a pendulum, that of the radiation emitted by caesium atoms. Two different technological objects – a pendulum clock built for Christiaan Huygens in 1658 and an atomic clock dating from the 1950s, and forming the basis of current global timing standards – directly implement the definitions.[1] An infrastructure that now includes satellites stands behind the definitions. By virtue of the sheer multiplication of clocks in many different forms, clocktime may well be the most ubiquitous of modern technical infrastructures. Clocks are deeply embedded in diverse scientific, cultural, institutional, economic, and military realities, and embodied in various 'body clocks' and 'clock chips'. Clock faces are intimately woven into nearly every possible context. Through technological ensembles such as Global Positioning System, clock signals impalpably criss-cross every point on the earth's surface.

The contrast between the two clocktime definitions of the second is provocative. It incites contrasts and comparisons about more general issues. For many people today, the contrast between these two different definitions of a second is one symptom of a much broader problem concerning time: through technology, too much happens too fast. Technological speed can give the impression that the future is closed, and that time is being lost. Responding to this problem, there is even a well-publicized project in California, currently running under the name of 'The Clock of the Long Now', to brake the speed of cultural change by building a clock that will run for 10,000 years and provide at least symbolic stability and longevity amidst the increasing ephemerality of globally resonant communication systems (Brand, 1999).

Since it can very easily be interpreted as a symptom of how human time is being lost to an inhuman technological time, there is a need for different ways of understanding the contrast between 1.0 oscillations/second and 9,192,631,770 Hz. Technical performances are almost always expressed in time-based terms. The experience of technological speed relies on clocktime. The question is: how can that experience become the object of a more differentiated and reflexive response? This paper explores one possible response by re-reading clocktime in terms of a concept of *technicity* drawn from the work of the French philosopher, Gilbert Simondon (Simondon, 1958/1989a, 1989b, 1964/1995).

The pendulum clock and the atomic clock are technical objects. More specifically, they embody technical mediations concerning the temporal and spatial sequencing of events. They stand between other entities, living and non-living, which together constitute a *collective*. Technical mediations topologically knot social relations within human groups to non-living processes. In preliminary terms, 'technicity' refers to a specific virtuality or eventfulness associated with technical mediations. At the risk of misunderstanding, it could be said that technicity is a term for the historical mode of existence of technical mediations. My argument regards the technicity of clocktime as an event or inherently unstable genesis occurring at the limits of human–nonhuman collectives. As an evolutive or unfolding power, technicity structures particular technical objects, ensembles (such as the pendulum or atomic clock) and living bodies as provisional solutions to the problem of how an ensemble of living and non-living processes articulates its own temporal and topological limits. Technicity precedes and surpasses particular technological objects or social functions. Particular technological objects or technological ensembles are, in Simondon's terms, 'objectivations of technicity' (Simondon, 1958/1989a: 163). To speak of the *technicity* of clocktime implies an evolutive, genetic process subject to objectivation (for instance in different clocks) and 'subjectification' (for instance, in various embodiments of clocktime), yet remaining irreducible to particular technical treatments. Conversely, to focus on the technicity of *clocktime* is to suggest that the social ordering of time, the scientific manipulation of time as a fundamental dimension of physical systems, and the individual experience of time as imbricated in memory and anticipation, all concretize through *metastable* processes associated with clocktime as an event.[2] Such an event may well escape historical dating practices or a technological history of clocks. Those practices and knowledges must, in order to begin their work, rely on a certain ensemble of other technical mediations which are neither neutral or transparent in relation to time.

As foreshadowed above, the overarching question is whether the experience of collapse of space–time, acceleration and speed associated with contemporary technological innovation might be productively reconfigured. My response to 'the question concerning technology' (as posed by Martin Heidegger, 1977) will be staged around the *clocktime technicity* that runs through the two exemplary objectivations of time under discussion: Huygen's pendulum clock and the atomic clocks currently used, for instance, in the Global Positioning System (GPS). The first main section highlights two more-or-less conventional accounts of clocktime which regard it as a symptom of the capture of time by modern social and technoscientific processes of ordering events. The second section sketches a more nuanced approach to clocktime, able to take into account both the technical specificities of timing regimes and the divergent realities which unfold out of clocktime. The final section develops this approach into an explicit account of the technicity of clocktime as an ongoing differentiation or genesis occurring at the limits of sociotechnical collectives.

Connections between the Clocks

(a) Modern technology and the loss of time

A symbolic connection runs between the two clocks. On the one hand, the pendulum clock offers an elementary symbol of incipient technological globalization, while on the other, the atomic clock symbolizes globalization completed, since its exactitude now reveals unpredictable variations in the revolutions of the earth itself. Already in Huygens's book of 1673, where he sets out a geometrical deduction of the isochronism of the pendulum's oscillations, the importance of clocks to sovereignty, to navigation and astronomy is at the forefront. In dedicating *The Pendulum Clock, or, Geometrical Demonstrations Concerning the Motion of Pendula as Applied to Clocks* to Louis XIV, Huygens writes

> [f]or since my clocks were judged worthy to be placed in the private chambers of your palace, you are aware from daily experience how much better they are in displaying equal hours than other such instruments. Further you are not unaware of the more specialised uses which I intended for them from the beginning. For example, they are especially well suited for celestial observations and for measuring the longitudes of various locations by navigators. (Huygens, 1673/1986: 8)

The pendulum clock links the private chambers of the king to the peripheries of empire and colonies.[3] It secures the possibility of moving between the centre and periphery, by capturing invariant oscillations to mark the time and providing a technical realization of a universal, coordinated time and length. The pendulum clock modulates the incipient movement of globalization by establishing the possibility of a globally valid measurement system.[4]

The atomic clock by contrast affords an image of the completion of globalization, at least in relation to navigation, in the guise of the GPS, which relies on many atomic clocks located in orbiting satellites and in a network of ground stations. As Paul Virilio writes in the early 1990s:

> A new type of watch has been on the market for a while now in the United States. The watch does not tell you the *time*; it tells you *where* you are. Called the GPS – an abbreviation for *Global Positioning System* – this little everyday object probably constitutes the event of the decade as far as globalization of location goes. (Virilio, 1995: 155)

It is not clear whether GPS did constitute the event of the decade.[5] Nonetheless, GPS, with all the clocks it puts into orbit, aptly symbolizes the 'globalization of location' that Virilio refers to. Many different narratives of progress, technological evolution, alienation or epochal shifts could form the backdrop to this perception of the globalization of clocktime, and its suppression of different perceptions or experiences of time. In broad terms, Heidegger's view expresses a typical objection that the last century of critical theory and philosophy had to clocktime:

> But time cannot be found anywhere in the watch that indicates time, neither on the dial nor in the mechanism, nor can it be found in modern technological chronometers. The assertion forces itself upon us: the more technological – the more exact and informative – the chronometer, the less occasion to give thought first of all to time's peculiar character. (Heidegger, 1972: 12)

Throughout his work, he insists that clocks provide no insight into time.[6] The reasons for this are quite complex and would require extended discussion. In summary terms, Heidegger provides an extremely powerful account of the ways in which time marks a limit for thought. While the links he makes between temporality, thought and history shift somewhat in the course of his work, it is always the exteriorization or objectification of temporality that he questions. In his terms, there is no time itself on the one hand and the modalities of consciousness apprehending the flux of time on the other. Only a single process of temporalization occurs. It is composed of complex movements of anticipation and repetition through which provisional forms of stability, practice, institution, subjectivity, memory and historical existence unfold. Against this sophisticated framework, the core objection to clocks then is quite simple. Through clocks and clocktime, attention shifts away from the coalescent character of temporality. Not just clocks, but modern technical mediations more generally deflect attention from the deep and intricate intermeshing of time, bodies and thought. Through modern technologies of timing, profound differences in history, tradition and hence cultural existence are lost.

(b) Clocktime as social invention

As an alternative to this critical repudiation of the technical mediations of time, we could, for instance, understand clocktime as a social event or invention. This is the thesis of Norbert Elias who writes that:

> By the use of a clock, a group of people, in a sense, transmits a message to each of its individual members. The physical device is so arranged that it can function as a transmitter of messages and thereby as a means of regulating behaviour within a group. (Elias, 1993: 15)

Clocks from this perspective are 'simply mechanical movements of a specific type, employed by people for their own ends' (p. 118).[7] The notion of time as a 'relatively more unitary human-centred concept' (p. 115) effectively presents clocktime as a socio-symbolic invention concerned with more precisely regulating and coordinating the repetition of social phenomena.[8]

In Elias's rich account, the problem of how technology accelerates the experience of time can only be understood in terms of the 'specific capacity of people for envisaging together and, thus, for connecting to each other what happens "earlier" and what happens "later", what "before" and what "now" in a sequence of events' (p. 74). The 'sociocentric' nature of time consists in the use of repetitive, usually inorganic sequences (ranging from the movement of a shadow during the course of the day to the hands or digits of a clock) for the symbolic representation of non-repeatable social sequences. The very existence of time, on this account, is a social artefact of the numbering or ordering of sequences in synchronized relation to each other, and this in turn relies on phenomena that display numerable repetition. Timing technologies supply sequences of marks through which social groups code sequences of events. So, according to Elias, looking at a watch:

> [W]e read and experience the changing configuration of these moving units on the face of a watch in terms such as 'five minutes past seven' or 'ten minutes and thirty-five seconds'. In that way, moving configurations of marks used for timing events are transformed by social customs of the beholders into symbols of instances in the flux of incorporeal 'time' which, according to a common use of the term, appears to run its course independently of both any physical movement and any human beholder. (Elias, 1993: 120)

The 'social customs of the beholders' as well as the 'specific capacity' of people to envisage sequences of events are responsible for the emergence of autonomous physical time. Time *appears* to have an existence independent of social customs, but in reality it is grounded on the social acts of timing or dating by which phenomena are semiotically related. The only problem with what Elias suggests here is the nature of the transformation between different social timing regimes. While he says that 'the significance of this emergence [of autonomous clocktime] can hardly be overrated' (p. 115), the specificity of the artefact which connects events in a sequence, the clock, does not figure either in the social customs or in the specific capacity to envisage (i.e. remember) temporal orderings.

Clocktime as Technical Mediation

In such a summary account of two quite different perspectives on clocktime, stereotypes are hard to avoid. Despite the stereotypes, the broader limitations of Heidegger's and Elias's approaches are similar. Neither has a way of affirming the interval between 1.0 oscillations/second and 9 billion oscillations/second. Either it must be regarded as destructively superficial and inessential in relation to the real problem of how to think (Heidegger), or it must be accepted as deriving from social arrangements which, so to speak, are 'more real' (Elias). To speak of the technicity of clocktime is to try to offer some way of comprehending the multiplication that has occurred between 1.0 oscillations/second and roughly 9 billion oscillations/second without repudiating the role of technical mediations.

In one important respect, a lead on the technicity of clocktime comes from recent work in the field of science and technology studies on the role of technical mediations in the formation of collectives. The general lesson I draw from accounts of technical mediation such as Bruno Latour's *We Have Never Been Modern* (1993) is this: the broadly modern habit of thinking in terms of a radical break between the social and the natural (or between subject and object, sign and thing, and so on) tacitly permits technical mediations to multiply. In consequence, we have so much 'technology' comparatively speaking. From Latour's perspective, 'if . . . our [modern] Constitution authorizes anything, it is surely the accelerated socialization of [technical] nonhumans, because it never allows them to appear as elements of "real society"' (Latour, 1993: 42). Certainly the representative positions I have sketched around Heidegger's and Elias's work conform to this judgment. Counter to this modern reductionist habit, Latour (along with others such as Pickering, 1995) discerns a more differentiated topology of sociotechnical neighbourhoods between the abstract and hypostatized poles of nature and society.[9]

If we follow Latour, bringing this general approach down to a specific case such as clocktime entails apprehending clocktime as a technical mediation which does not measure or administer a pre-given time or space, but which constitutes a regime of timings and spacings (Latour, 1997: 179). To be sure, clocks are not alone in defining time. Every technical mediation, insofar as it folds, deforms and shifts relations between living and non-living elements of a sociotechnical ensemble, 'eventalizes' times and spaces. The 'time' of a medieval castle and the 'time' of a high speed train are not the same because of the different topological and temporal folds they weave into collectives. The specificity of clocks and clocktime consists only in their special status as a guarantee of a certain regime of isochrony and isotopy. Subsequent bifurcations into objective and subjective times only gain traction through the incremental synchronization of more and more clocks. To quote Latour:

> This does not mean that we are in an isotopic space and an isochronic time, but that locally, *inside* metrological chains, there are *effects* of isochrony and isotopy produced by the carefully monitored and heavily institutionalised circulation of objects that remain relatively untransformed through transportation . . . rods, hands of clocks, gears and structural isomorphies. (Latour, 1997: 185)

In other words, there is no space and time apart from the technical mediations through which selected events – oscillations and inscriptions in the case of clocktime – are linked. (The very axes of synchrony and diachrony which have organized wide domains of recent critical thought could appear quite different if we took this perspective seriously enough.) The specificity of clocks as 'metrological chains' undergoes reconfiguration here since they now function as what Simondon calls 'key-points' [*point-clefs*] from which times and spaces unfold. An example of this analysis in action can be found in Bowker (1995). Through his discussion of 19th-century technological infrastructures such as railroads and factories (technical mediations that lie within the interval under discussion here), Bowker accounts for the *convergence* of a neutral isotropic space–time with large-scale patterns of social organization. The crucial point for our purposes would be that the interval between 1.0 oscillation/second and 9 billion oscillations/second stems from the way that infrastructural technologies such as railways are constantly 'conjuring nature' into a particular representational framework in which time and space are universal and neutral (Bowker, 1995: 63).

Nonetheless, there is at least one point at which it may be necessary to diverge from this line of thought. As yet, it has been difficult for this fruitful and consequential body of work to affirm ongoing dynamism or instability in sociotechnical collectives other than as a consequence of our own inability or unwillingness to explicitly think and represent technical mediations (i.e. in the 'Parliament of Things' (Latour, 1993: 142–5). Latour for instance says that once we recognize the constitutive role that technical mediations play, we will then be able to 'sort times' (p. 76). This suggests that, despite the mutability of almost every other relation or entity, times could be taken as remaining stable.[10] If times (in the sense of the ordering of series) remain stable, proper representation could put the sociotechnical ensembles in which we live back on a stable footing. Ultimately, instability is either stabilized, or ephemeral.

We saw that the globalizing and sociocentric accounts of clocktime view the interval between the pendulum clock and the atomic as stemming from either (a) a general loss of time attributable to modern technology; or (b) a particular social habit of overlooking how social relations symbolically order events. While Latour's approach departs radically from these two accounts, it tends to say that the effects of technological speed result from a failure to properly represent the role of non-human technical mediations in stabilizing ephemeral events as essences (i.e. 'the time') within sociotechnical collectives. Despite crucial differences from Heidegger and Elias, the interval between 1.0 oscillations/second and 9,192,631,770 Hz still derives from a failure to think, and instability is always transient not ongoing. While Latour may be generally right in his judgement of the constitution of the Modern, it would be somewhat more 'enabling' if the under-representation of the technical mediation of time was not solely attributed to a failure, and if instability was not always secondary to stability. Sometimes it seems that behind this assessment, there is an implicit promise that stability is the norm and instability the deviation. Perhaps an account that emphasizes structural instability or metastability would also be of interest.

Technicity and Isochronism: Mechanism and Geography

Clocktime hardly seems a promising place to envisage ongoing instability or metastability, since it epitomizes regularity and stability. The growth of this regularity, stability and autonomy, I will argue, offers a key instance of the oscillatory or modulating aspect of technical mediations. Following and extending Latour's account of a technical mediation as event might bring us closer to the multiplicatory rhythms of clocktime as evolutive power of divergence, whose mode of existence as technicity is neither purely social nor purely technical. In an article entitled 'Time and Representation', Isabelle Stengers and Didier Gille explain how time can appear to be or become autonomous through clocks (Stengers and Gille, 1997). They too speak of the division between social and natural/scientific times. But they discuss how the split between social and scientific times occurs through the specificity of a particular technical artefact, the pendulum clock. I want to select just a few points from their complex account of the relation between time and the technical specificity of clocks. These points introduce considerations that will be useful in thinking of the evolutive or divergent character of the technicity of clocktime.

(a) Mechanical isochronism

Stengers and Gille describe an historical process out of which the social, scientific, natural and technical phenomena of timing unfold. They write: 'the concrete object whose introduction marks the establishment of an autonomous law of time can be more precisely identified with the pendulum clock that Christiaan Huygens constructed in 1658' (Stengers and Gille, 1997: 183). Natural time and social time are only the abstract poles of a zone of interaction which can be optimally read in terms of the technical specificity of the pendulum clock. Huygens's pendulum provides a point of inflection or 'intrinsic singularity' (Deleuze, 1993: 15) for the technicity of clocktime. Stengers and Gille write:

> It is usually claimed that Galileo's discovery of the law of pendular motion [the correlation between the length of a pendulum and the period of its oscillation] at last gave a scientific solution to the technical problem of the measurement of time . . . However Galileo did not produce such a mechanism: the free pendulum is a pure phenomenon; the oscillations need to be counted and the movement periodically restarted. (Stengers and Gille, 1997: 185)

The passage cited at the outset from Huygens's *Pendulum Clock* verifies the last point.

Huygens writes: 'the simple pendulum does not provide an accurate and equal measure of time . . . [W]e have found a different and previously unknown way to suspend the pendulum' (Huygens, 1673/1986: 11). While his way of suspending the pendulum is not absolutely singular, the pendulum clock possesses a technical specificity which distinguishes it from previous time-measuring techniques such as the foliot clock found in medieval clock towers. Huygens points to this when he declares that he has unexpectedly found a different way to *suspend* the pendulum. Mechanically, 'the foliot clock . . . appeared as a complex in which everything participated in the definition of the speed of the clock hands, without it being possible to specifically identify one element as regulator' (Stengers and Gille, 1997: 184). With the pendulum clock, 'the work of the clockmakers will largely consist of disconnecting, as much as possible, the pendulum-regulator from the rest of the mechanism' (p. 186). The de-coupling of the pendulum from the rest of the clockwork takes various forms – recoil escapement, deadbeat escapement, free escapement, constant force escapement – yet all these forms head in the direction of presenting the isochronic oscillations of the pendulum as an embodiment of 'the time'. The remainder of the mechanism becomes a means of either displaying information about the time or correcting for the fact that the pendulum itself is never ideal, that it always suffers from friction, and that, more importantly, as Huygens points out, the period of a simple pendulum varies according to the driving force of the clockwork. If the pendulum can be isolated from these variations, then time itself can appear to be separate from its technical realization. Through isochronic oscillation, the pendulum can exist as the autonomous embodiment of natural or physical time.[11]

(b) Geographical isotopism

The series of escapements tends to isolate the pendulum from all variations, so that the pendulum becomes a pure source of information for the work carried out by the clock in moving its hands. But this isolation only makes sense if the motions of the pendulum have more than local value. While, as Galileo recognized, the motions of the pendulum are more or less isochronic so that they can 'be used to establish the proportions between the speed of phenomena', they remain localized if their period is not standardized. Thus, write Stengers and Gille, 'the [earlier] pendulum clock developed by Huygens in 1657 had a period of oscillation of 0.743 seconds. This number had no raison d'être other than it corresponds to a particular set of cogwheels' (Stengers and Gille, 1997: 190). The metrological chain of clocktime can only be extended if the oscillations of the pendulum can be tied to something else. Huygens, developing the relation between pendulum length and the period of the pendulum, in 1658 constructed a clock that beats once per second. The geometrical (and hence heavily *spatial*) proof of the isochronic oscillation of the pendulum of this clock was published as *The Pendulum Clock* in 1673. Furthermore, it includes instructions on how to standardize the hours measured by the clock to the revolution of the earth on its axis.[12] The oscillations of the pendulum become geometrically and geographically isochronic. Thereafter movement of the cogwheels is subordinate to the length of the pendulum, itself calibrated by the regularity of the earth's revolutions. No longer expressing the relative speeds of phenomena, the time of the pendulum clock becomes autonomous, or at least, it will be represented as autonomous. The constitution of the second as a unit of time coupled to the earth's revolutions allows it to claim independence from all terrestrial locality. It is now identified with the earth's diurnal revolution rather than the alternation of day and night, or the apparent movement of the stars, which vary seasonally and from place to place. Whereas the foliot clock of the medieval clock tower proclaimed variable hours adjusted to fit the varying length of the solar day at particular places, the pendulum clock measuring the standard second displays constant hours, regardless of the time of year or the location of the clock. As Stengers and Gille observe, 'objective, regular, normalized time, existing by and for itself, is born, uncoupled from what is now no more than the straight-jacket of phenomena' (1997: 191). The cost of normalized time is a strengthened relation between the pendulum's and the earth's movements.

At the end of *The Pendulum Clock,* Huygens goes on to propose that a global standard of measurement should be derived from the pendulum clock. Again the connection between timing and spacing is unavoidable, and the pendulum clock ends up looking like a precursor of the global clock system that GPS implements:

> A certain and permanent measure of magnitudes, which is not subject to chance modifications and which cannot be abolished, corrupted, or damaged by the passage of time, is a most useful thing which many have sought for a long time . . . [T]his measure is easily established by means of our clock, without which this either could not be done or else could be done only with great difficulty. (Huygens, 1673/1986: 167)

The method that Huygens offers as the basis of a universal, atemporal standard of length involves tuning a simple unregulated pendulum's oscillations to the regulated oscillations of the pendulum clock by adjusting its length. The length of the synchronized simple pendulum will be the universal 'hour-foot', a length that will be the same at all places which share the time of the pendulum clock. Such a measure would have been valid everywhere and 'for ages to come' as Huygens hoped, if there were not variations in gravity at different points on the earth's surface.

This proposal for a universal measure opens a continuous path from the oscillations of the pendulum clock to the oscillations of the atomic clocks used in GPS, even if it is convoluted and full of fluctuations. In 'the ages to come' mentioned by Huygens, for instance, in the measurement of distances carried out through GPS, a local unregulated oscillator in a receiver (a quartz clock) is tuned to the regulated oscillators of the atomic clocks in at least three GPS satellites. Synchronization is now no longer carried out by hand and eyes, but via a set of circuits in the receiver which modulate the local oscillator of the GPS receiver until it coincides with the oscillations being transmitted by the GPS satellites (Kaplan, 1996: 121).[13] The location of the receiver is determined by finding the intersection of the distances from those three satellites. The oscillations stretch between the pendulum clock and GPS: the speeding up between 1.0 and 9,192,631,770 oscillations/second requires that one oscillator be tuned to another oscillator of known period in order to synchronize the oscillations, to allow them to resonate with each other. Perhaps one important aspect of what we experience as globalization today is the cumulative effect of the synchronization of dispersed oscillations.[14]

In broad terms, the technical specificity of the pendulum clock begins to reveal some singularities that the other accounts of modern technology and time had to varying degrees denied it. The approach drawn from Stengers and Gilles does not present the pendulum clock as determining what time in the form of clocktime will be. Rather it seeks to show how the emergence of autonomous clocktime, or the 'physical time' which Elias described as 'branching off' from social time, requires a specific and localized de-coupling of pendulum and clockwork together with a specific yet generalized coupling of the pendulum with an associated milieu, the revolutions of the earth. Through its suspension, and the resulting mechanical isochronism of its oscillations, clocktime can appear as the embodiment of autonomous time. Through synchronization of oscillating pendulums, the pendulum's oscillations geographically distribute clocktime, and indeed serve as a way of establishing spatial relations between distant places.

The emphasis that Huygens himself places on the *suspension* of the pendulum (and in particular, on the precise geometrical description of the two curved plates which limit the motion of the pendulum) will be examined more closely in the next section.

Metastability: from Isochronism to Event

Is this tuning or resonance between dispersed oscillators the homogeneous extension of the essence of modern technology, is it the transmission of a message regulating behaviour within a social grouping, or is it the institution of an ‘immutable mobile’ (Latour, 1997: 180)? It might be something of all these. They all emphasize stability and homogeneity within an expanding collective. Later technical developments of the pendulum clock, especially during the 18th and 19th centuries, concentrate on refining the isochronism of the pendulum over a wider range of milieus, taking into account variations in air pressure and temperature.[15] When the oscillator becomes piezo-electric, as in the case of the quartz crystal oscillator, or atomic as in the GPS, this is partly an attempt to maintain isochronism over an ever wider range of milieus. The technical problem remains constant throughout: how can the isochronic constraint necessary for autonomous time be maintained over a wider range of milieus? From the perspective of the technical history of clocks, it can only be maintained if the clock can stabilize new sources of variation. From the perspective of technicity, and for an understanding of the divergence symbolized by the interval between 1.0 and 9,192,631,770 oscillations per second, *metastability* rather than *stability* is crucial. So far, this account of the technicity of clocktime has mainly concerned the *stabilization* of an autonomous time through isochronic oscillation. I now want to focus on an ongoing *metastability* associated with clocktime.

Metastability refers to the provisional equilibrium established when a system rich in potential differences resolves inherent incompatibilities by restructuring itself topologically and temporally (Simondon, 1958/1989a: 154–5). In Simondon’s preferred example of a physical metastability, a super-saturated chemical solution begins to crystallize. As it does, it ‘individuates’: some singular point – an impurity, a seed-crystal – in the solution permits the solution to restructure itself as a growing crystal. The crystal structures the energetic potentials of the solution (Simondon, 1964/1995: 24). At the point of crystallization, the solution is metastable. The growth of the crystal represents a provisional resolution of the potential differences which precede it. It would be faintly ridiculous to say that clocktime is a physical individuation. There are significant differences between a super-saturated solution and a sociotechnical collective. Yet taking into consideration the fact that the collectives we are talking about extensively couple living and non-living processes, there are points of contact here. Clocktime as it moves between 1 oscillation and 9 billion oscillations per second can be seen as a temporal and topological ordering that continues to unfold from a metastability. The way in which clocktime incorporates new sources of variation, and restructures itself in the process, can be compared to the provisional resolution that a crystal represents for the metastable super-saturated solution. The question is: what metastability are we talking about here? What *virtuality* (to use Latour’s term [1997: 190]), who draws it from the work of Gilles Deleuze [1993], who in turn perhaps borrowed it from Simondon?) inhabits the accelerating trajectory of clocktime?

In broad terms, metastability arises from the character of our own collective involvement with things. By framing metastability this way, it might be possible to preserve certain elements of all three approaches represented by Heidegger, Elias and Latour. From Heidegger comes an insistence on temporality as the concomitant of any attempt to think what is. Temporality allows Heidegger to think radical finitude; that is, as historical existence in the absence of absolute foundations. Elias emphasizes the social or group character of timing. His work alludes to the historically variable constitution of timing regimes, and their diverse social functions within social groups. Latour provides something different again: the 'dark matter' of the societies we inhabit consists in the manifold technical mediations which stabilize the collective so that something like history and time becomes possible. We might now be in a position to add something at the intersection of these very different approaches: the metastability of our collective involvement with clocktime.

(a) Localization of indeterminacy in critical phases

Let us locate this metastability a little more specifically. No matter how ideal the motion of the pendulum becomes over a range of conditions, it still involves contact in which energy of some kind is converted into information displayed on the face of the clock. There are always moments of contact between the pendulum and the clockwork that it regulates. As Stengers and Gille suggest, the technical development of the pendulum and escapement tends to minimize the energy converted in this process, and to constrain it as a one-way process in which information flows from the pendulum-regulator to the clock face, but not in reverse. From the technical perspective, contact between the pendulum and the clockwork represents a deviation away from the ideal of the autonomous pendulum. Perfect suspension as an ideal seeks to disguise the technical constitution of clocktime. If an irreversible expenditure of energy appears in the constitution of clocktime as pure information, then the autonomous character of time would be under threat.[16]

From the standpoint of the technicity of clocktime, however, this transfer of energy is critical: the intermittent moments of contact constitute the metastability of the system. In effect, these moments constitute clocktime. Simondon describes the technicity of machines in general as a capacity to be repeatedly informed through a carefully staged ensemble of critical phases:

> [T]he existence of a margin of indeterminacy in machines should be understood as the existence of a certain number of critical phases in its functioning; a machine which can receive information temporally localises its indetermination in sensible instants, rich in possibilities . . . Machines which can receive information are those which localize their indetermination. (Simondon, 1958/1989a: 141)

What was earlier termed the 'de-coupling' of pendulum and clockwork can now be described somewhat differently. In Huygens's clock-machine of 1658, the pendulum repeatedly comes into contact with a rod attached to the clockwork escapement:

> [T]he small rod . . . which is moved very slightly by the force of the [clockwork] wheels, not only follows the pendulum which moves it, but also helps its motion for a short time during each swing of the pendulum. (Huygens, 1673/1986: 16)

This contact between the rod and the pendulum localizes indetermination in a very specific way. The pendulum, whose associated energetic milieu is the earth's gravitational field, informs the cogwheel gear-train of the clockwork by touching the rod. Despite worn or sticking cogs, the pendulum 'informs' the rod of the period of its oscillations. As Huygens says, 'it will always measure the correct time, or else it will measure nothing at all' (p. 16). During 'the short time', the pendulum enters into a complicated and highly mediated exchange with the potential energy stored in the weights that drive the clock. The gravity-driven clockwork transfers some of its stored energy to the pendulum, and reciprocally, the pendulum's oscillations inflect the rhythm of the clockwork's movement. The 'sensible instants, rich in possibilities' that Simondon refers to occur during the wavering, inconstant contact between rod and pendulum. Out of the super-saturated, undifferentiated potentials of those instants, two divergent realities unfold, one facing towards a geographical-terrestrial milieu (the earth's gravitational field), the other facing towards a social milieu of symbols, numbers and counting conveyed as 'the time'.

The atomic clocks orbiting in the GPS constellation could be subjected to a similar analysis, although there we would have to accept the necessity of following a more complicated itinerary in tracking down the localization of indeterminacy. The principal point however remains: clocks topologically localize metastability at certain points of repeated contact. The resolution of metastability is much more provisional in the case of the clock than in the case of the crystal. The clock *suspends* any final resolution of its metastability by localizing indetermination at key points. In suspending resolution, it repeats it. The very stability of time as a recurring sequence rests on that localized metastability. Clocks are not alone in this. Machines and technical ensembles in general effect localized suspension of indetermination.

(b) Modulation as temporal molding

Perhaps regarding the clock as a machine that stages a suspension of the resolution of metastability does not go far enough. The clock on this account is only a step away from the physical individuation of a crystal. It figures as a suspended or prolonged individuation which sustains a relation to both an energetic milieu (gravitation) and a social milieu ordered by repeatable sequences of marks. How is a collective involved here? We can view what takes place during those moments of localized indetermination a little differently by regarding clocktime as a way of staging *modulation* of oscillations. 'A modulator,' writes Simondon, 'is a continuous temporal mold . . . [T]o modulate is to mold in a continuous and perpetually variable manner' (Simondon, 1964/1995: 45). Modulation occurs at two levels.

First, Galileo's simple pendulum, whose naturally resonant oscillations gradually die away after it has been set in motion, undergoes quasi-continuous modulation in Huygens's clock. The temporal form of the clockwork is molded by the oscillations of the pendulum. The temporal 'matter' of the pendulum requires the energy stored in the weight-driven clockwork. The clock in a sense has no fixed form or matter, since both the oscillations of the pendulum and the cyclical motions of clockwork are reciprocally interacting and adjusting each other. The pendulum modulates the clockwork, and the clockwork modulates the pendulum.

Secondly, the 'form' and 'matter' of clocktime undergoes *continuous* development and variation through modulation. (These terms are taken up by Deleuze when he describes 'a very modern conception of the technological object' [1993: 19]: such an object involves continuous development of form and continuous variation of matter.) The modulation is legible as we move from Huygens's clock to the GPS. The increasing rapidity of oscillation between Huygens's pendulum and the atomic clocks of GPS requires that what is modulated, the oscillating matter, changes. As Simondon says, 'the viscosity of the support is diminished as much as possible' (Simondon, 1964/1995: 45) when modulation occurs more rapidly. The almost sensible instants in which pendulum and escapement reciprocally modulate each other are replaced by imperceptibly rapid contacts between the oscillating fields of microwave radiation and electric potential fields of certain electrons belonging to caesium atoms. Although the reciprocity of modulations essential to clocktime remains operative, the localization of indetermination in the atomic clock-machine has now been displaced from oscillations coupled to the earth's gravitational field and redeployed in the less palpable yet still localized interactions of oscillating electromagnetic fields.

(c) Multiplication and incorporation of divergence

As a temporal molding, clocktime is 'continuous and perpetually variable'. Clocktime could be seen as a kind of event whose 'harmonics' or 'submultiples' fold different layers or conjunctions of oscillation together. Gilles Deleuze, as if describing the modulation that develops between the oscillations of a pendulum and the oscillating fields of the resonating caesium atom, speaks of an event as 'a vibration with an infinity of harmonics or submultiples, such as an audible wave, a luminous wave, or even an increasingly smaller part of space over the course of an increasingly shorter duration' (Deleuze, 1993: 77). The question as to what triggers this multiplication remains.

The missing term here is the involvement of a collective. Again, if we wish to diverge from the stereotypes surrounding the acceleration of clocktime, the technical specificity of a particular timing regime, the GPS system, opens a way to this involvement. As a positioning system based on clock signals, GPS confirms the inseparability of timing and spacing. More important, it shows that what counts as time and place depends heavily on the kinds of technicity through which a given collective structures itself temporally and topologically. The 'trigger' for the multiplication of clocktime oscillations is neither extrinsic or intrinsic to society. Rather it resides in the recurrent play occasioned by non-coincidence between a collective's topological and temporal limits.

Because of the complexity of GPS as a technological system, I will focus on just one illustration of this point: the production of the GPS signal structure through modulation of the basic oscillation produced by atomic clocks. In one form or another, this signal, broadcast from each satellite in the GPS constellation, contains all the information needed for a local receiver to determine its map location. A block diagram showing the modulations which comprise the satellite signal structure conveys the multiplication and filtering of the oscillations derived from the atomic clock, now termed 'the frequency standard'.[17] In technical terms, the modulating fields of the encoding oscillators superimpose various streams of information on the basic clock signal by shifting the phase of the primary oscillator. Several different layers of modulation are superimposed in the coded and encrypted locational and timing signals transmitted by the GPS satellites. There is not just one zone of contact between the primary oscillator and what parallels the clockwork, the rest of the GPS system. Here the oscillations of the clock are modulated along divergent paths within the device. Signals coming from different sources continuously mold the primary oscillations (Kaplan, 1996: 241–3).[18] A diagram of signal structure indicates some of the 'harmonics' of the oscillations.

This layering of modulation corresponds to an incorporation of diverse realities not yet fully represented or accommodated within the time of Huygens's pendulum clock (although Huygens did promise them to the king). His plan for a universal standard of length based on the oscillations of a pendulum relied on constant gravity everywhere on the earth's surface. The GPS constellation, orbiting the planet roughly every 11 hr 58 min on slightly elliptical orbits cannot make that assumption. Its orbits and the propagation of its timing signals are perturbed by non-ideal and difficult to calculate factors such as the sun and moon's gravitational fields inducing tidal changes in the earth's gravitation field, solar winds impinging on the satellite, orbital deviations caused by the slow release of atmospheric gases from satellites made on earth, variations in ionospheric and tropospheric conditions, multipath distortion of signals, and above all, *Selective Availability* (the deliberate manipulation of the satellite clocks and navigational data by the US Department of Defense to ensure that the highest levels of signal accuracy are only available to authorised users). The modulations present in the clock signal testify to this complicated intersection. The signal broadcast by a GPS satellite is not just a clock signal. It also describes the status of the clock itself, and includes current and predictive data about the satellite's location and the atmospheric conditions relevant to the propagation of the clock signal, as well as the encrypted signals required by the USA for its national security purposes.

The simplest account of the complex structure of the GPS signal would be to say that GPS takes the variations of its milieu into account.[19] It would be possible to trace how the multi-layered modulation of the primary oscillations links geographical, meteorological, cosmological, military, economic and legal domains. The intersection of these domains with each other through various forms of feedback and reciprocal modulation in GPS constitutes another provisional structuring of the metastable technicity of clocktime. When compared to the pendulum clock, the increase in the rate of primary oscillations does not derive from a de-localizing or homogenizing dynamism intrinsic to modern technology. Rather, it stems from the articulation of different points of contact between human and nonhuman collectives and their associated milieus. 'Technicity,' Simondon writes, 'super-saturates itself by incorporating anew the reality of the world to which it applies' (Simondon, 1958/1989a: 158). Out of this super-saturated state, particular structures precipitate. The rate of oscillation of contemporary clocktime indicates the absorption of a field of contingencies that were previously outside the limits of the collective, or that were previously subject to different kinds of treatment (for instance, social, political or cultural representation).

Super-saturated by that incorporation, the technicity of clocktime restructures the limits of the collectives it belongs to. It initiates points of contact between collectives and what lies outside them, and in doing so, establishes new limits, new pathways of action and affect within the collectives to which it belongs. The multiplying modulation of clocktime which underlies something like GPS (or the computer clocks whose oscillations are a fundamental component of contemporary digital technologies) moves the critical phases which in the pendulum clock mediated between the pendulum's movements and the clock's hands into a more complicated ensemble of mediations. The quantitative multiplication accompanies a topological complication in the structures of the collectives.

The Impropriety of Clocktime

My focus on the technicity of clocktime has not addressed the integration of clocks within past or contemporary cultures in specifically sociological, economic or semiotic terms. Clocks carry meaning. For instance, Otto Mayr has shown how the clock as a metaphor of order, regularity, authority and the work of creation was particularly significant to natural and political thought for several centuries in modern Europe (Mayr, 1986). Rather, I have argued that the ongoing genesis of clocktime can be read as the provisional resolutions of metastability in a collective whose limits are not given in advance. Clocktime technicity, in the terms used here, refers to the way in which collectives absorb contingency within certain sequences of order and synchronization. The absorption remains incomplete because timing and spacing include undifferentiated potentials whose ongoing individuation accounts for the interval between 1.0 and 9,192,631,770 oscillations/second. The major point of divergence from the evaluations of clocktime offered by Heidegger, Virilio, Elias and Latour rests on the notion that a collective cannot completely define its own limits because it is not completely in phase with itself. A kind of structural incompleteness or virtuality remains.

At the outset, I said that technicity refers to the historical mode existence of technical mediations. This claim can now be refined a little. Technical mediations are not simply semiotic, and they only figure obliquely in the processes whereby cultures or societies represent their own ongoing collective life to themselves. ('Technology', by contrast, figures hugely as an object of contemporary discourse.) Clearly, clocks as a technical mediation have a history. But it is through history, not technicity, that a society represents itself to itself. Clocktime technicity refers to something different. While still integral to the life of a collective, it is concerned with the ways in which certain collectives structure their belonging-together as an ensemble of living and non-living processes within temporal and topological limits that cannot in advance be fully lived or represented. Different timing regimes – the pendulum clock, the atomic clock – represent different configurations of those limits, and different ways of articulating divergent realities, living and non-living, with each other.

Something like clocktime is necessary to the ongoing existence of our globalized collectives. But why say anything more about clocktime technicity? Why not treat the work of clocks as a strictly social coding or ordering of relations with a group? Only because mutability of clocktime then remains inexplicable. Conversely, why not regard clocktime as the symptom of a generalized and pervasive technologization? Because that attributes an essential dynamism to an abstract entity ('technology') to which societies would be passively subject. Clocktime neither stands apart from collectives nor is it completely coded within their social functions or purposes. Its mutability stems from the structural incompleteness of collectives themselves.

Attention to the technicity of clocktime offers, in contrast to both the globalizing and sociocentric views of modern technologies, a more nuanced and historically deeper treatment of why our collectives are at once durable and unstable. Clocktime permeates temporality. It inflects the anticipation of a future and the appropriation of a past. Through the localization of specific kinds of indeterminacy, the ongoing modulation of matter and form, and the incorporation of divergent realities in timing ensembles, the technicity of clocktime figures as one way in which collectives provisionally stabilize their points of contact with what exceeds them and also open themselves to ongoing differentiation.

Notes

1. See Appendices III and IV of Howse (1980) for a brief technical description of the two clocks.
2. See Janicaud (1997: 189) for a discussion of the processes of concretization of an event.
3. Otto Mayr writes: 'individuals also welcomed clocks into their private lives. Princes and their courts led the way. Courts, with their complex ceremonials and their many-layered staff hierarchies demanded punctuality . . . The clock became an attribute of nobility' (Mayr, 1986: 16–17).
4. This development becomes crucial during the course of the 18th century, when voyages of discovery such as those of James Cook first began to rely on pendulum clocks to establish longitude.
5. A recent article on GPS remarks that 'the history of GPS is a classic case of a technology in search of a market' (Tristram, 1999: 70). On the other hand, the Presidential Directive on GPS signed into law by President Clinton in 1996 guarantees some ongoing life for GPS.
6. The reasons for this are complicated, and cannot be discussed here. The clock as an exemplary modern technological object cannot tell us anything essential about time mainly because it is *technical*. It forms a component of the more general framework of technologies which materialize in response to the essence of modern technology, but which themselves are not essential. See Heidegger (1977). For a clear and accessible account of Heidegger on temporality, see Dastur (1998).
7. Historically, Elias writes: '[before Galileo] timing had been human-centred. Galileo's innovatory imagination led him to change the function of the ancient timing device [the clepsydra] by using it systematically as gauge not for the flux of social but of natural events. In that way a new concept of "time", that of "physical time", began to branch off from the older, relatively more unitary human-centred concept . . . The significance of this emergence of the concept of "physical time" from the matrix of "social time" can hardly be overrated' (Elias, 1993: 115).
8. Time was, prior to Galileo, tightly woven together with law and especially with the state. The Roman calendar, the medieval *tempora* or hours, or the *computus* (the

system of calculation used in the Middle Ages in the Church to decide on what day important religious feasts would occur) had all been manifestations of the 'human-centred concept' of time. With Galileo, 'natural events' are brought within the domain of this time.

9. A theoretical account of the irreducibility of technical mediations to either social or natural poles can be found in Latour (1988: 153–236).
10. This brief assessment of Latour's understanding of the temporality of sociotechnical collectives risks missing its main objective: to present sociotechnical temporality as a multiplicity of times derived from relations between different elements, rather than a linear, irreversible flow dominated by accelerating technological progress. It would require a much more detailed engagement with the role that time plays in technical mediations to establish Latour's argument fully. Here I merely want to indicate that the status of instability or metastability still remains somewhat obscure and perhaps undervalued.
11. Today, as the Long Now Foundation considers designs for a clock that could keep time for 10,000 years, or roughly until the next Ice Age, with only Bronze Age maintenance technology, a mechanical oscillator such as a pendulum or spring, coupled to solar events, still figures as the regulating mechanism of choice. The Long Now clock designer, Daniel Hillis, suggests: '[s]ince no single [timing] source does the job, use an unreliable timer to adjust an inaccurate timer, creating a phase locked loop. My current favorite combination is to use solar alignment to adjust a slow mechanical oscillator' (Hillis, 1999). This is the same technical project that Stengers and Gille describe as constitutive of autonomous time: the pendulum clock materialized as a way to count and periodically re-start mechanical oscillations. Furthermore, synchronizing solar and mechanical time is the explicit object of much of Huygens's own discourse on the globalization of clock times in *The Pendulum Clock*.
12. For the method of synchronizing the clock with the earth's revolution see Huygens (1658/1986: 23–5). For an account of how Huygens came to present a geometrical proof of the accuracy of the clock, see the introduction by H.J.M. Bos to *The Pendulum Clock* (Huygens, 1673/1986: 1–2).
13. Heightening the suspension even further, the atomic clocks orbiting in the GPS satellites are themselves synchronized ultimately to another global timing standard: UTC, Universal Co-ordinated Time. The interesting thing about UTC is that it exists nowhere as such. There is no single master clock. UTC is a 'paper standard' with no concrete embodiment apart from the statistical procedures used to correlate and synchronize several dozen atomic clocks scattered around the globe (Kaplan, 1996: 55).
14. Obviously, it also requires the wave theory of electromagnetic radiation, which again understands the phenomena of light as an oscillation. Huygens again, in 1678, proposed the wave theory of light which allowed the propagation of light to be understood and rendered predictable.
15. There are many histories of clocks which describe this process. See Appendix III Howse (1980).
16. In an unexpected and highly original move, Stengers and Gille analyse these moments of contact between the pendulum and the clockwork in strictly thermodynamic terms, as a dissipative system. They understand the motions of the pendulum and the moments of its contact with the escapement as a cycle which converts potential energy to kinetic energy, and energy to information. I will not reproduce

their analysis here, but merely indicate that the outcome is a conception of the pendulum clock as a dissipative system. That is, they show that there is only autonomous clocktime on the condition that energy constantly flows into and out of the system. The implication is that the ideal law of time as linear succession of measurable durations rests on a complicated series of losses or dissipative flows of energy. These losses are not deviations from the ideal, but the indispensable condition of the functioning of the ideal as a norm (Stengers and Gille, 1997: 198).

17. This shift in terminology shows that reading the face of a contemporary clock is less important than the clock's role in directly regulating and synchronizing events.
18. The different data sources include the system that generates a unique code identifying the satellite that is broadcasting the signal, 'almanac' and 'ephemeris' data describing the current status of the satellite's orbit (uploaded from the ground control stations operated by the US Department of Defense), and 'errors' deliberately introduced into the signal by the Department of Defense to deny precise locational data to unauthorized users. The basic oscillations derived from the atomic clocks are divided, modulated, superimposed on each other at a number of different rates to produce the final signal structure broadcast by each satellite.
19. The structure of the signal, for instance, bears within it the history of late 19th-century contests between imperial nation-states over time-standards. See Chapters 5 and 6 of Howse (1980) for the debates on the establishment of GMT, on which UTC is based.

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ADRIAN MACKENZIE is a research associate in the Department of Computing, University of Lancaster. His research interests include technology, time and embodiment, as well as the limits of representation in the information sciences. A book on the problem of speed and thought, entitled *Transductions: Bodies and Machines at Speed* (Athlone Press, 2001), will appear later this year. ADDRESS: Department of Computing, University of Lancaster, Lancaster LA1 4YR, UK.
[email: a.mackenzie@lancaster.ac.uk]