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# CHRONIGAMI : FOLDING AND UNFOLDING TIME

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## CHRONIGAMI : FOLDING AND UNFOLDING TIME

**Abstract** - Time is a construct or variable that is fundamental to a variety of theories of organisational change and strategic planning, as well as numerous mid-range models such as the product life cycle. In virtually all of these models, time is assumed to be unproblematic, independent, 'out there', and unilinear; time follows its own arrow. In contrast, constructivists point out that time is socially constructed and that in any society a repertoire of chronological codes is employed. The problem is that neither of these approaches, which reflect the objective / nature - subjective / social divide, on which the epistemological discourse in the social sciences is built, is very enlightening. The naive realist understanding is a chronological cul-de-sac; clocks, calendars, and caesium atoms tell the whole story. In contrast, the constructivist approach tells us that time is a social construction and that there are multiple chronological codes, although the implications of this finding are less than obvious. This paper seeks to begin to fill this lacuna by presenting an understanding of how time is constructed and who does the construction. In doing so, it draws heavily on actor-network theory with its emphasis on overcoming the dualism between the natural and social worlds. This use of actor-network theory is illustrated with the use of a longitudinal, ethnographic study of the dynamics of organising in the context of a large construction project. The Oriental paper-folding art of Origami is introduced as a metaphor for understanding the construction and deconstruction of time.

*Keywords:* Time, Actor-Network Theory, Constructionism, Ethnography, Cyborgs.

An American tourist, travelling around Ireland, sees a farmer lifting a pig into his arms so that the pig can eat apples from an apple tree. The perplexed American inquires of the farmer: "Why don't you *pick* the apples from the tree and *give* them to the pig? Wouldn't that save a lot of time?" And the farmer replies : "Ah, but what does a pig know about time?"

## INTRODUCTION

Writers on management have recently taken a new interest in time - a fundamental construct in a variety of theories of organizational change and strategic planning, as well as in numerous mid-range models such as the product life cycle. In general, these writers have followed a longer tradition in both organization studies and in sociology by emphasising that time is socially constructed. At the same time, however, there is an ongoing debate about social constructivism itself, particularly on how the 'social' is constructed. This latter debate has now generated a number of points of departure and distinct fields such as social constructivism, constructionism, and cognitive constructivism (Knorr-Cetina, 1994). In this paper we seek to contribute to the understanding of time by drawing and building on one branch of constructionism - actor network theory - which, heretofore, has been surprisingly silent on the subject of temporality. Following the empirical tradition of actor network theory, we build our temporal model from a quasi-ethnographic study of the replacement of a control system in a pharmaceutical plant.

To abbreviate and assemble our understanding of time we have coined the term *chronigami* from the Greek word for time, *chronos*, and from the Japanese art of paper folding, *origami*. We employ this term as an inclusive metaphor to counter, what the geographer Tommy Carlstein says is, time's "somewhat discourteous practice of wearing different hats which are seldom raised to greet the unwary researcher with an unambiguous meaning" (1982, p. 2). Chronigami synthesizes our ideas on time which we understand as networked, inscribed, folded, durable, and dynamic. Not all of our readers may be aficionados of Japanese paper folding so we begin the paper with a short introduction to the art form. We then briefly

review the contemporary discussion on time in management and organization studies and also the key ideas of actor-network theory. Building on these concepts and on our empirical material, we then develop our constructionist model of time.

## ORIGAMI

Origami is the Japanese art of folding objects out of paper without cutting, pasting or decorating. A blank sheet of paper (Figure 1a) is progressively folded, each fold building in sequence on preceding folds until the final object is formed (Figure 1b). In many instances, an intermediate basic structure can be used to create a variety of final objects. For example, a Flapping Bird, a Praying Moor, a Rabbit, a Fish, a Lamp, or a Squirrel can all be constructed out of the Bird Base. Even small changes in the nature or sequence of folds, particularly the initial folds, can result in totally different objects. The objects themselves may be quite robust and easily retain their shape. Paradoxically, they are also very fragile and are often discarded once completed.

## TALKING TIME

From operations research to organizational change, management theory usually implicitly or explicitly accepts a *natural science* view of time in which time is understood as linear, chronological (i.e. clock-based), objective, universal, independent, homogeneous, quantifiable, divisible, natural, and spatial (i.e. as a Fourth Dimension)<sup>1</sup>. This paradigmatic assumption necessitates that the construct "time" is unproblematically understood as the most independent of variables, a position that is made explicit in many theories where "time" is allocated to the independent x-axis. This is most obvious in theories whose genesis is in operations research (for example, critical path theory), but it is also the norm in marketing (for example, the product life cycle model), operations management (for example, the product-process model), organisation change (for example, Miller and Friesen's

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<sup>1</sup>The label "Newtonian" is also widely used to characterise this chronological view of time although Newton himself developed a more complex understanding of time and particularly distinguished between absolute (mathematical) and relative (common) time.

model (1980)), organisation theory (for example, population ecology theory, evolutionary theory), and business strategy (for example, strategic planning and decision-making models). In other theories, such as contingency theory and transaction cost theory, time is not included as an explicit construct, but even in these theories the natural science view of time is implied.

Recently, there has been a modicum of interest in the subject of temporality in management studies. For example, Bluedorn and Denhardt (1988) reviewed the literature on time in management while Ramaprasad and Stone (1992) developed the idea of the event chain in their discussion on time and strategy. However, given that so much of the management studies literature deals with change and socio-economic processes located in time and space, it is surprising that discussion on temporality is so rare. In Burrell's mind this "demonstrates an unhealthy aversion to self-reflexivity which needs remedying" (1992, p. 328).

Clark (1990), Gherardi and Strati (1988), and Whipp (1994), in their various discussions on different forms of organizational time or "chronological codes", draw heavily on the work of Gurvitch (1964) who has made one of the most enduring contributions to the study of time in sociology. Indeed sociology, not surprisingly, has had a long and extensive discussion on time to the extent that a journal, dedicated to the subject, *Time and Society*, has now emerged<sup>2</sup>. This sociological perspective emphasises that time, rather than being a natural, objective phenomena, is a public (inter-subjective) institution that is socially constructed (Berger and Luckman, 1966). Taking this perspective we can understand the chronological, independent view of time as only one of a number of social constructions and some reflection will provide examples showing that time is also constructed on the basis of lengths of queues, distance, points scored in a squash game and a variety of other non-chronological means.

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<sup>2</sup>The interested reader is referred to Hassard's (1990) collection of some of the seminal sociological works on time, to Hall's (1959) original work and Gell's (1992) review of cultural constructions of temporal maps, to the work of Glaser and Strauss (1965) on time and dying, to Thompson's (1967) work on the inter-relationship between temporal structures and industrialization, and to the more philosophical discussions of Adam (1990), Giddens (1984, 1987) and Nowotny (1992) on time and social theory.

Berger and Luckman's social constructivist position emphasises the fundamental importance of interaction and habitualization between individuals in the construction of seemingly 'objective' social structures. However, it can be criticised as being overly anthropocentric, unreflective about its own constitution, and for providing too much purchase to habitualization and mutual negotiation instead of asymmetric trials of strength. Their discussion on space and time is also most perfunctory. The former is dismissed as "quite peripheral to our present considerations" (1966, p. 40), while they take a particularly anthropocentric view of temporality which they see as "an intrinsic property of consciousness ... founded on the physiological rhythms of the organism" (p. 40). This cursory approach to space and time is unsatisfactory since, as Giddens (1987, 1990) has repeatedly pointed out, societies do not simply exist within time-space containers: time-space relations are constitutive features of social life. Indeed the linking of space and time has been a key insight of modern social theory, following similar insights in 20th century physics. As Giddens (1987, p. 148) remarks:

" All societies, even the smallest, can be analysed as time-space zones, within which individuals trace out the recurrent paths of their day-to-day lives and which are structured through the very tracing of those paths. The introduction of quantified forms of time reckoning always has direct implications for spatial organizations."

The thrust of the above arguments points to a need to reconceptualise time and space as constitutive features of socio-economic systems. Furthermore, the construction of time must be understood as the outcome of processes involving struggles and negotiations. The argument is not simply that time is socially constructed but that the processes involved in such construction need to be elucidated and made visible.

Zerubavel (1978; 1979; 1982; 1985) has provided a rich collection of empirical material that depicts just such construction processes. His story of the introduction of Greenwich Mean Time (GMT) as the standard English time, for example, is a tale of clocks, the Royal Observatory in Greenwich, railroads, post offices and the growing links of interdependence between communities (1982). Here he provides a

vivid description of a heterogeneous network where time is an outcome of construction processes. Actor-network theory, which is also concerned with construction processes, now provides a set of concepts that can build on and contribute to Zerubavel's original work . In the next section we will review this theory. We will then use the theory and our own and Zerubavel's empirical material to build our model of time.

### **ACTOR-NETWORK THEORY**

Actor-network theory can be presented as an attempt to build on earlier insights on the sociology of science and technology, usually known as the sociology of scientific knowledge (SSK) (see e.g. Pickering, 1992). The actor-network approach is generally associated with the work of Callon (1986, 1987) and Latour (1987, 1988, 1993) in France, and Law (1986, 1994) in England.

The term actor-network was first introduced by Callon (1986, 1987) in his description of the case of a failed project by *Electricite de France* (EDF) to introduce an electrical vehicle in the early 1970s. This project involved a multitude of actors and a series of heterogeneous elements whose identity and relationship to each other were problematic. In practice, the success of the project depended on the ability of the engineers of EDF to enrol the support of and hold together an association of social movements, political and economic interests (e.g. ministries, the Renault car company) as well as a host of inanimate elements, the technical solution to building an electrical vehicle (e.g. fuel cells, accumulators). To describe this heterogeneous association of animate and inanimate elements and the mechanisms through which these associations are established, transformed or consolidated, Callon (1987, p. 93) introduced the term of actor-network. The purposeful association of 'actor' and 'network' attempts to supersede the classical sociological category of 'actor', a term reserved for humans and not generally associated with the notion of a network. The concept of actor-network depicts the notion that 'actor' is an empirically based category, an heterogeneous association of human and non-human elements that is

open to redefinition and transformation. As Callon (1987, p. 93) explains : "An actor-network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of " .

At the heart of actor-network theory is a determined attempt to conceive institutions - e.g. organizations, the economy, science, technologies - as patterned networks of heterogeneous materials (Law, 1992). This claim is relatively novel to the extent that it regards the social world, itself, as no longer constituted by pure associations between humans and the stable background against which everything can be judged to be 'socially constructed'. To conceive of social order as resting solely on interaction between human beings, and take face-to-face situations as prototypical of human interaction (Berger and Luckman, 1966), is to ignore the role that material resources often play in addition to or in substitution to face-to-face interaction. The networks of the social are also heterogeneous and composed of people, texts, machines, money and a host of other intermediaries. To investigate how something is 'socially constructed' begs the symmetrical question of how the 'social' in 'socially constructed' is, itself, the product of a construction.

If the networks of the social were simply associations of people, then social order wouldn't rest on particularly stable or durable foundations (Callon and Latour, 1981). Because the networks of the social are heterogeneous and composed of materials with different degrees of durability, society is able to recursively reproduce itself (Law, 1992).

Perhaps the most hotly contested claim of actor-network theory is that agency is not the sole privilege of humans but can also reside in non-humans, inanimate objects and artefacts (see e.g. Collins and Yearley, 1992a, b and Callon and Latour, 1992). Whereas Callon and Latour (1992) insist on the notion of symmetry between society and nature and a variable distribution of agencies between the social and natural worlds, Collins and Yearley (1992a) stick to the traditional sociological viewpoint that agency is to be understood solely as human agency. Pickering's (1993) analysis of this debate is illuminating because of his central concern to

develop a view of human and material agency as temporally emergent phenomena. Treading in the footsteps of actor-network theory, Pickering (1993) attempts to develop a post-humanist view of agency and is prepared to examine the ways in which the inanimate objects and artefacts frame human agency and can be said to possess agency in themselves.

These points are of special interest because actor-network theory hasn't, so far, put forward its own view of time and temporality. Whereas notions of temporality are implicit in a number of works, and it permeates notions such as gradients of durability of materials (Law, 1994) and irreversibility of translations (Callon, 1992), there are very few explicit references to notions of time in actor-network theory.

Pickering's solution to the material vs. human agency debate is to introduce a heightened sense of time and to revert to an examination of agency in what he calls, its temporal unfolding. Pickering's (1993, p. 567) proposal is to conceive of the trajectories of emergence of human and material agency as enmeshed in practice, by means of an emergent dialectic of resistance and accommodation described via the metaphor of a mangle. The mangle metaphor conjures up images of interpenetration and mutual constitution of human and material agency at the boundaries of their intersection. Nothing is predetermined or given in the nature of things: human and material agency are temporally emergent products of practices, and cannot be disentangled and understood independently of each other (Foucault 1989, pp. 92-102).

The challenge is thus to conceive of a notion of time that takes into account the shifting distributions of agency between the human and material realms, the dialectic of resistance and accommodation between the human and non-human worlds. By concentrating on how time is constructed, we are inevitably drawn into ontological debates on the nature of being, humanity and the relationship between the human and material worlds. As Heidegger (1978) emphasised, to the point of titling his most famous work *Being and Time*, any discussion on time and temporality necessarily includes an ontological agenda. Similarly, Lyotard (1993) and Elias (1992)

also grapple with the interpenetrated issues of time, being, technology, humanity and inhumanity. Lyotard (1993), for example, is embroiled with the nature of being in a technological world, filled with the inhuman, where the technological sciences are trying to find out ". . . how to make thought without a body possible" (p. 13).

The blurring of the distinction between the human and non-human is also a common theme in science fiction films such as *Terminator*, *Blade Runner*, *Alien*, and *Robocop* and in the television series *Star Trek: The Next Generation*. These films, intentionally or unintentionally, include the same ontological agenda about the nature of being, humanity, reality and the relationship between subjects and objects that Latour (1993) and others such as the feminist Donna Haraway (1985) are exploring in a different medium. The issue that this diverse group of philosophers, feminists, and scriptwriters are attempting to grapple with is what is the nature of being in the late twentieth century? What is the nature of beings that are neither human nor inhuman *nor mixtures of human and inhuman but a fusion of the two?*

To refer to these new category of beings, products of human-machine fusion, we use the term cyborg - itself the product of a fusion, cybernetics and organism - popularised by Haraway (1985). Following the theoretical agenda of these writers, we argue that to develop our understanding of time and temporality we must at once try to understand the nature of these cyborgs, which we can then conversely begin to understand by investigating temporality itself.

### **CYBORG ETHNOGRAPHY**

The cyborg that we have selected to study is the actor-network associated with the replacement of a process control system in a pharmaceutical plant owned by the multinational company, Merck Sharp & Dohme (MSD). The plant was built in 1975 in a place called Ballydine - a quiet valley in County Tipperary, Ireland. Pharmaceutical plants are, in effect, large kitchens that produce expensive product - the engineers sometimes refer to the vessels and tanks as "pots and pans". Each

product has its own unique "recipe" and the primary function of the control system is to ensure that the recipe is followed correctly and accurately. This control system includes the field instrumentation, wiring, software, hardware, Field Operators and Control Room Attendants (CRAs) and it acts to open and shut valves, to pump product between reaction vessels, to monitor temperature, pressure, etc. The Process Control System (PCS) in Ballydine includes a small computer (64k memory) to run the control software and it also includes a manual backup system. During the 1980s, it became more and more difficult to get parts for this old system and so in 1991 MSD decided to install a new Distributed Control System (DCS) at a cost of about \$15m. A project of this complexity had never been attempted before and MSD personnel often referred to it as a "heart transplant" although a brain transplant might be a better metaphor. This, then, is the cyborg that we are studying.

Just about the easiest way to comprehend the cyborg is as an organism but this is unsatisfactory because of the rate at which it changes and because of the difficulty in establishing coherent boundaries either between the inside and outside of the organism or between its various constituent elements. For example in MSD, a variety of actants (using Latour's term) in Ballydine, in MSD's head office in the US, in the European office in Brussels and in a number of MSD plants in Europe and the US were variously involved. Similarly, MSD's appointed supplier of the software and hardware, Asea Brown Boveri, drew on actants in Stevenage (UK), Dundalk (Ireland) and Rochester (US). Jacobs Engineering, the third major corporate entity, charged with engineering design and construction and project management, involved actants in Cork, Dublin and Ballydine (Ireland) and Cincinnati and Pasadena (US). When their subcontractors and suppliers are included the network quickly becomes incomprehensible. Structuring the cyborg as a nexus of corporate contracts is a useful exercise but it fails to shed much light on the question: "what is this cyborg?"

Imagine that you are an ethnographer studying this cyborg<sup>3</sup>. You have spent a number of months observing the software and hardware management meetings held in England and Ireland, but today you are visiting the control room in Ballydine. As you climb the checker-plate stairs an image of the control room in Woody Allen's *Everything You Wanted to Know About Sex* flashes through your mind. But this is different; it is busy, noisy, colourful and vibrant. It is a small room, about 12m by 6m, with banks of panels, covering three walls from desk to ceiling, packed with coloured lights and dials that give a kaleidoscopic representation of the equipment in the plant. The room itself has about twenty computer terminals as well as ten printers of various makes and shapes that sporadically spit into life and then stop, mute. One man - everyone in the control room is male - is speaking on the telephone at a corner desk, another takes readings from the wall panels while two more are discussing the contents of a computer printout. Four CRAs are working at the computer terminals, periodically communicating with the Field Operators who ghost into the room over the radio system. Somebody whistles pleasantly. You engage one of the CRAs in conversation while he continues to track the progress of the batch, as displayed on his computer console, against the associated batch sheet (the recipe). Occasionally he leaves his desk to check instrument readings on the wall panel which he also uses to manually control the plant. The physical actions - valves opening, pumps turning on and off - are initiated through a combination of the computer programme and direct intervention by either the CRA or the Field Operator. A cyborg - a heterogeneous network - is at work.

The key problem now is how can we make some sense of this heterogeneity; how should it be ordered? In particular what does time mean for, or in, this cyborg? In the remainder of the paper we will develop our understanding of time which we see as networked, inscribed, folded, durable and dynamic. In short, chronigami.

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<sup>3</sup>For a comprehensive review of the potential impact of cyberspace on anthropology see Escobar (1994).

## NETWORKED TIME

Since actor-network theory has little to say on temporality, we now draw on the ideas of Elias (1992, p. 73) and Bateson (1979, p. 106). Following these writers, we argue that time is a symbol for a triadic relationship between two or more continua of change and a third dimension of consciousness which connects the two continua. For example, clock-time is defined by the relationship between the clock hands and the face of the clock (which we take as a standard continuum) and the person who is perceiving the difference between both. The person in this case could just as easily be replaced by a non-human instrument with the capacity for perception, memory and synthesis. This is precisely the situation in MSD's control room where the computer program, the "intelligent" instrumentation, and the CRAs variously adopt the role of perceiver. The engineers who designing the original plant control system were, in essence, attempting to create a network of such triads pulsating to a single temporal rhythm - a local clockwork universe. In practice, this is impossible since it would demand an infinitely powerful being that could instantaneously monitor every dyadic change and also enforce changes throughout the network<sup>4</sup>. Applying our origami metaphor, we see no single or grand origami, no universal time, no single history. Rather, we see a multiplicity of times, of chronigamis, constructed in a loose, dynamic network of tangles, mangles, ensembles and assemblages (Deleuze, 1992; Pickering 1993; Miller & O'Leary, 1994). Cyborgs, therefore, are always volatile networks of time; heterogeneous temporal networks containing a multiplicity of times - a temporal syntax.

Within such a syntax, temporal zones - albeit partial and provisional - are discernible. For example, the CRA, the computer control programme, the batch sheet, the field instrumentation, and the field operators largely operate in, what we may term, *batch time*. Batch time is defined, not by a clock, but by events such as "batch temperature reached 45 degrees" or "toluene level less than 2%". The CRAs

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<sup>4</sup>Interestingly, the new DCS - Distributed Control System - seeks to overcome this and other limitations by invoking a scheme of parallel processing in distributed nodes (Varela, 1986, p. 2).

work, sometimes frantically, to maintain the progress of the batch - to maintain batch time<sup>5</sup>. And while they are interacting with their instrument panels, consoles and batch sheets they are, literally, making time. Time, therefore, is the outcome of the hard work put into this network of relationships by the multiplicity of actants.

Now when you, the ethnographer, speak with the CRA, you are immediately withdrawing him from the batch time network. He now enters into a relationship with you which produces its own time as you talk about the World Cup and hurling matches. Then a light flashes and he excuses himself to return to the console, to batch time. Time flips when he shifts from talking to you to interacting with his computer. He, the batch sheet, the software and the console (which is itself a black box full of cyborgs) is one time zone and he and you are another. Time, therefore, is not a thing but is defined by the network of relationships between actants. Hence we speak of *networked time*.

Other temporal zones are also decipherable. It might take 24 hours to produce one batch of a drug with the next batch starting as soon as equipment availability allows. This cycle continues for an extended period and this period is termed a campaign. Here then is the temporal zone that identifies another cyborg - *campaign time*, and the pertinent actants in production planning, marketing, and new product development are engaged in organising the mix of drugs that will be produced in the medium term. Similarly, we can also decipher *plant time*, which is the temporal zone that concerns the production management team who are interested in the future capacity of the plant, the mix of equipment, the plant flexibility, and the infrastructure and control systems that will be required.

These temporal zones, in turn, reflect and map out social differences, belief patterns and interpretative frames (Zerubavel, 1987). For example, the campaign time cyborg normally prevails over the batch time cyborg and this reflects a quasi-hierarchical power structure in the plant. But actor-network theory forswears the

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<sup>5</sup>Significantly, the control room has no windows - "it could be winter or summer outside and we wouldn't know it in here", complained one CRA.

implied permanence and stability embodied in the idea of hierarchy and instead favours the more dynamic notion of "trials of strength". Temporal zones, and consequently perceived structures, are always partial and provisional. A batch is not necessarily tied to a specific campaign in a specific plant; it need be the batch - and its associated temporal frame - could be moved to another MSD plant. Time moves in space. Cyborgs, which we decipher as temporal zones, are continually campaigning to stay alive and to extend themselves through a series of trials of strength. And as patterns develop through these trials we then decipher what we call a hierarchy and a structure.

These trials of strength become more obvious when we introduce another temporal frame - *project time*. In this instance the project is the replacement of the old Process Control System with a new Distributed Control System. Project time is most vividly represented in the bar charts, schedules and progress reports around which the project revolves. For Jacobs Engineering and Merck Central Engineering, the PCS project is just one project in an endless cycle of projects; for the plant the PCS project is just one of the innumerable battles in the ongoing war to maintain the plant's existence; for the CRAs it is a possible threat to their reality - their batch time. And hence we have trials of strength between actants as they strive to maintain themselves and their time. Latour's intriguing comment about time now makes more sense.

"Time is the distant consequence of actors as they seek to create a *fait accompli* on their own behalf that cannot be reversed. In this way time passes . . .

Time does not pass. Times are what are at stake between forces. Of course, one force may overtake the others, but this can only be local and temporary because permanence costs too much and requires too many allies." (Latour, 1988, p. 165)

Here it is important not to see just the humans and to divide them into different temporal zones. Rather we should see temporal cyborgs that act to conscript humans, but only temporarily. The flashing light on the computer screen acted to conscript the CRA and to break his temporary and temporal relationship with you, the ethnographer. Similarly, the manufacturing manager is conscripted,

intermittently and rapidly, into cyborg relationships that define plant, campaign, project, or batch time. This is not to present a deterministic world view, devoid of agency; rather, it celebrates agency but at once extends it to the inhuman.

### INSCRIBED TIME

The easiest way to learn origami is to buy a book on the subject and procure a few square sheets of paper. As you follow the series of instructions, diagrams and symbols, the shape of the paper - which we can understand as a continuum - changes before your eyes. You, the paper and the table now form the triadic network necessary for the construction of time. Following Akrich (1992) we term the final object, whether it be a pigeon or a pink elephant, a *script*. Inscribed invisibly within the paper pigeon is the series of instructions that the author of the book carefully wrote down and which you, the novice, carefully followed. We call this series of instructions a *program of action* (Akrich and Latour, 1992; Latour, 1992), the successful enactment of which creates a transformation - a continuum of change - and consequently time.

Our cyborg is brim-full of such programs of action and, indeed, the replacement of the control system involved a considerable investment in writing an extensive suite of new programs of action - including computer programmes, hardware, procedures and rules. An "IF ... THEN" statement in a computer programme is one of the simplest examples of part of a program of action: "IF the temperature reaches 45 degrees THEN turn on the cold water". These simple instructions, in turn, are built up into standard programmes to empty, fill, clean and heat vessels in the production plant. These standard programmes - not unlike the bird base in origami - are referred to as phases in the MSD project and they are the building blocks of recipes - also called phase grids - for the variety of drugs produced in the plant. The writing of such programs of action - which involves writing general design specifications, detail design specifications, programs, testing specifications etc.- is a process of *inscription* and what the MSD and ABB engineers are doing is

physically *inscribing* programs of action which, if successfully enacted, will create time. So the process of inscribing is an attempt to create scripts - be they paper pigeons or production plants - and also time, which is immanent - inscribed.

Time is not only inscribed within physical artifacts and computer software, but also in operating routines (Nelson and Winter, 1982), in habitualized norms and sedimented practices (Berger and Luckman, 1966), and even in organic matter such as genes which can be seen as sophisticated programs of action (Dawkins, 1989). The regular ethnographic journey from Cork to Stevenage also provided numerous examples; even the interior of the London taxi was festooned with signs and exhortations such as "No Smoking", "Do Not Speak to the Driver", "Fasten Seat Belts", "Sit Well Back!".

Furthermore, we find that that programs of action exist in dynamic complexes of human and non-human inscriptions where the boundaries are neither well defined nor stable. In their attempt to understand such complexes of inscriptions, actor-network theorists have borrowed from linguistics by showing that just as a sentence is made up of an associative chain of words, so too are cyborgs made up of an associative chain of human and non-human programs of action (Latour, 1992; Kallinikos, 1992). And just as words in a sentence exist in a linguistic structure wherein they may be substituted along a paradigmatic dimension by other related words, the opportunity also exists to substitute programs of action with other related programs. For example, a sticking valve in the pharmaceutical plant may be remedied through an associative chain that involves the transmission of a digital signal to the control room which activates a visual and audio alarm to which the CRA responds by instructing an operator to lubricate the valve. Or alternatively, the remedial action could be automated by substituting the CRA and the operator by non-human programs of action, a substitution, it should be noted, that also alters the cyborg's temporal framework.

As designers inscribe, they are also *prescribing* since they are defining their envisioned actors with specific competences, beliefs, and aspirations. For example,

while the old process control system expected that the CRAs would intervene and act in certain situations the new distributed control system has significantly limited the scope for intervention available to them. Machines - in this case a control system - have a morality in that they forbid and permit their envisioned actors to act (Akrich, 1992; Akrich and Latour, 1992; Johnson and Latour, 1988; Latour, 1992). Actor-network theory is not, however, advocating technological determinism, because actors, according to their own programs of action, may or may not *subscribe* to the inscribed prescriptions - I do not have to follow the instructions in an origami book, even though it is likely that I will once I have begun. Indeed, it is this gap between conflicting programs of action, between prescription and subscription, that allows trials of strength to be described, continua of change to be perceived, and time to be created.

### FOLDED TIME

This, then, is why we use origami - the craft of paper folding - as a metaphor. The folds represent the outcome of trials of strength - events - where there are gaps between competing programs of action, between prescription and subscription. Here, our use of origami as a metaphor complements Kermode's (1967) distinction between *kairos* and *chronos*. *Kairos* is crisis, an event or point in time charged with significance - a fold in origami. *Chronos* - represented by the flatness of the paper connecting the folds - is the 'passing time' or 'waiting time' between events. And the overlaying and interweaving of folds signifies the movement of time backwards and forwards or, as T.S. Elliot more poetically noted in *Four Quartets*:

"Time present and time past are both perhaps present in time future, and time future contained in time past".

An example will illustrate the ideas. MSD commissioned Jacobs Engineering to design the new control room and the Jacobs architect duly presented a room layout which bore an uncanny resemblance - not inappropriately - to the deck of the star ship Enterprise. The MSD manufacturing manager rejected this design because he was worried that the CRAs would be upset if they were seated at a lower

elevation than their supervisors (who were allocated Captain Kirk's position). Here, the manufacturing manager was envisioning a future scenario and, by changing the drawings, was inscribing in the present a future that is now unlikely to occur. This process of envisioning scenarios, hypothesizing trials of strength, and re-inscribing eventually produced eight radically different layouts for the control room, different scripts, different futures and non-futures. Futures continually being created and destroyed.

The notion of folding time also encompasses Latour and Akrich's ideas of conscription - "the series of actors that have to be aligned for a setting to be kept in existence or that have to be aligned to prevent others from invading the setting and interrupting its existence" (Akrich and Latour, 1992, p. 261). In this case, the manufacturing manager has been conscripted by the "future" CRAs to represent their demands for equality. Another example illustrates time folding in the opposite direction. Asea Brown Boveri were using a scheduling package to manage their work on the project but this was a different package to that used by Jacobs and both were different from the scheduling package previously used in Merck Central Engineering. We can understand this scenario as one in which the developers of the various software packages - more cyborgs - have conscripted MSD, Asea Brown Boveri, and Jacobs in their efforts to dominate their own networks. Here then, are three cyborgs, three programs of action competing through trials of strength to achieve dominance and to extend themselves into other networks. And in this process of conscription, actants from the chronological past - software development cyborgs - conscript actants in the present who duly battle earnestly on their behalf. Time folds again.

This concept of folding also encompasses the idea of returning that is of central importance in actor-network theory. Latour, for example, emphasises that "You have to go and come back *with* the "things" if your moves are not to be wasted" (1986, p. 7). We also see the importance of going and returning in the MSD project where the recipes (batch time) physically move from Ballydine to Stevenage where

they are *inscribed* in software programmes that then *return* to Ballydine embedded in computer hardware. Real time is then understood as the synchronisation of two time frames, involving a displacement and a return which are both necessary if the system (cyborg) is to "go live". Similarly in Zerubavel's story, the spread of standard time crucially depended on the mail coaches returning so that their on-board clocks could be re-adjusted to GMT.

In origami, one folds paper repeatedly, building fold on fold to create a structure and finally an object, be it a representation of a ship, a bird, or a house. Each successive fold in the structure is both a constraint and an opportunity regarding the final shape of the object. In its temporal equivalent, chronigami, folds are events which are outcomes of trials of strength that also occur in structured circumstances<sup>6</sup>. Each trial of strength is both enabled and constrained by deep layers of embedded prior trials. But these are not prior in the chronological sense; rather, in the process of envisioning, hypothesizing and enacting, they are folds from many pasts and many futures. This process is vividly demonstrated in the development of the control software where seven months was spent on modular testing, integrated testing, pre-shipment qualification, installation qualification and operation qualification. In this extensive series of "stress tests", the operation of the control system in most conceivable situations is enacted. By folding the future trials of strength into the present, the necessary series of actors are conscripted and aligned to ensure that a preferred path is followed. So, ex-post we can recognise gradients of aligned set-ups that push, prescribe and constrain actants to follow particular paths rather than others - chreods in Latour's (Johnson and Latour, 1988) language borrowed from Waddington (1963).

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<sup>6</sup>The formulation of actor-network theory presented here echoes Giddens' (1979; 1984) theory of structuration, the work of the geographer Michael Storper (1988), and Paul David's (1988) concept of path dependence in dynamic systems. In one of the few discussions of temporality and strategy, Ramaprasad and Stone (1992) describe a similar conceptualisation of time that focuses on events in "occurrence chains".

As with the paper folds in origami, the process of constructing and extending networks through trials of strength between actors, becomes embedded, hidden, invisible, or, in Latour's language, blackboxed:

"A black box contains that which no longer needs to be reconsidered, those things whose contents have become a matter of indifference. The more elements one can place in black boxes - modes of thought, habits, forces and objects - the broader the construction one can raise (Callon and Latour 1981, p. 285)."

These black boxes, containing habits and modes of thought, are neither closed nor complete; rather they too are partial and provisional, or in Latour's language, "leaky". And so it is that "macro-actors" - institutions and corporations such as MSD and ABB - come about: by enrolling, conscripting, intervening, inscribing, building, maintaining and extending networks of leaky black boxes.

### **DURABLE TIME**

The concept of durable time represents our attempt to come to grips with the way that standardised forms of time come into existence and what keeps them in place. As we pointed out before, the existence of standard time is a prerequisite for complex forms of social and economic organisation to emerge. Without standardised forms of time reckoning no coordination of social and economic activities would be possible. The existence of calendars, clock time, international time zones, etc., is an unquestioned feature of modern societies. Time, in this sense, has been blackboxed and hidden from view. If we unmask what lies behind standardised forms of time reckoning we find heterogeneous networks of conscripted material and human elements that actively construct standard time.

First, networks grow through the successive enrolment of different sorts of allies. The DCS project vividly illustrates the process through which actors, be they corporations, CRAs, centrifuges or computer consoles are inexorably conscripted into networks. The plant itself, which in the words of an MSD engineer is "nothing more than a giant chemistry set", can be seen as another conscripted actor in the heterogeneous network which has grown out of Merck's' research and development

labs much in the same way as Pasteur's laboratory "grew" throughout the farms of France (Latour, 1988). As networks grow, parts of them became stable and regularised. For example, by November 1993, almost three years after the DCS project had started, parts of this network had stabilised to the extent that the engineers began to talk about the "system". Increasingly, the logistical and scheduling issues entailed them negotiating with and accommodating this new, stabilised entity in their lives.

In Zerubavel's (1982) story of the introduction of GMT in England, the process of standardisation of time relied on successive enrolment of different sorts of allies, brought together by the desire to establish a supra-local form of time-reckoning. The first push towards this aim was given by the British Post Office: all mail coaches needed to be run by a uniform standard of time, since coordination of delivery services at a national level would otherwise be difficult to achieve: "*This was the first attempt in history to synchronise different communities with one another*" (Zerubavel 1982, p. 6, emphasis in original).

Second, at the heart of such stable networks are, in the language of actor-network theory, *centres of calculation* which allow the network to be governed and acted upon from a distance (Latour, 1987; Law, 1994). In the DCS project a variety of centres of calculation associated with temporal frames of the project, governed the network at different stages. For example, the original project schedule was constructed by the MSD manufacturing team but we could observe the centre of calculation moving during the project from MSD manufacturing to Merck Central Engineering to ABB and finally to Jacobs Engineering. Once the network has stabilised, the research and development laboratory and its chemists are the calculus at the heart of the batch time network, as discussed in our section on networked time.

In Zerubavel's story the Royal Observatory at Greenwich, with all its apparatus and procedures for measuring time, filled the role of centre of calculation. Initially the network was small and included mail coaches and post offices but the advent of the rail network and other forms of communication, the diffusion of

standard time gained momentum. As clocks diffused into factories, households, public offices, etc., the Royal Observatory found itself at the hub of an even bigger and more stable network, a metrological chain.

Third, an essential aspect of the dynamics of actor-networks is the presence of what Latour (1990) calls *immutable mobiles*. These are effective representations that translate or speak on behalf of other actors in the network, who can then act a distance through these conscripted allies. The DCS project supplies us with several examples of these allies. The 'recipe' for each drug is inscribed on a batch sheet which the CRAs use to monitor and control the progress of the batch. These batch sheets ensure that batch time is standardised and consequently those who designed the drug can act effectively at a distance. The control software programmes provide another example. Through the process of writing, hypothesizing scenarios, testing and re-testing, these programmes eventually become stable, predictable, durable and to some extent, immutable. Eventually, they are trusted and are dispatched from Stevenage to re-present their designers in Ballydine where they continue to operate for years into the future, maintaining and re-creating their inscribed times.

In Zerubavel's story, this role was performed by the timepieces carried by mail coach guards which were used by post offices along the route to check the accuracy of their clocks in relation to GMT. Post offices didn't have direct access to GMT but they had frequent access to reasonably faithful representatives that had the important properties of being transportable and immobile.

Fourth, as networks grow larger and more standardised they create a powerful systemic effect that makes it difficult for other networks with other temporal frames to persist. Callon (1992, p. 91) calls this systemic effect *irreversibilisation* :

" ...A network whose interfaces have all been standardised transforms all the actors composing it into docile agents, and all the intermediaries which circulate into stimuli which automatically evoke and sometimes determine certain types of response. The rules of coordination then become constraining norms, which create deviance as well as they control it: the past engages the future."

As networks grow and become standardised they also become durable. They ensure their own recursive reproduction and create strong exclusionary and path-dependent effects (Arthur, 1989 ; David, 1992). For example, the use of a proprietary scheduling (timekeeping) software system in the DCS project makes it more likely to be used in future projects. Similarly, the network of standardised time governed by GMT was inevitably destined to become the global standard time, based on a history of past events that can be traced back to the rather innocuous decision of having mail guards carrying timepieces. The construction of durable time has thus no special properties in relation to the construction of other irreversible networks. It generates the same strong, systemic path-dependent effects and, in this sense, makes its own future very much dependent on its past. The origami becomes thus highly progressive: after a few folds, the paper maker is speedily locked into the path leading to the final shape.

### **DYNAMIC TIME**

The notion of path-dependency and the systemic effects associated with increasing returns to scale in the adoption of GMT leads us to the issue of how history is constructed as a string of events connected through time. In particular, we need to understand how sets of concrete, small events cumulate and get locked into particular paths rather than others - as Storper (1988, p. 166) puts it, we need to be able to explain 'paths taken' and 'paths foreclosed' in concrete events. From the perspective of our chronigami metaphor, we need to be able to understand the interaction between successive folds and how each new fold constrains the range of possible final outcomes. This question is intimately linked to the broader debate in the social sciences regarding the balance between agency and structure in explaining social action and the relationship between micro and macro social phenomena.

Storper (1988, p. 170) proposes a meso-level of analysis that attempts to come to grips with these dilemmas. Small events are seen as the outcomes of structured but

not fully determined situations - choices and strategies are being pursued within structured limited situations. The accumulation of small events produces large processes but not necessarily in a logical or additive sense. Lastly, large processes may contribute to the reproduction or change of the structures in which they are embedded.

Large processes are thus chains of small events that create choices and opportunities as they move along, whilst foreclosing other possible chains of events. Successful strategies can always be pursued and reinforced, provided positive feedback mechanisms are available to keep them on relatively narrow tracks - chreods, in the language we used in our discussion on folded time. In our terms, these strategies will cumulate into large processes - 'paths taken' - once they are inscribed in relatively durable materials and programs of action that will prescribe back the range of events admissible in the future. Materials come in different forms and in gradients of durability; strategies inscribed in thought and talk come cheap but have no lasting effects unless they are continuously renewed. Strategies inscribed in texts, artefacts, machines, buildings, etc. require larger investments but last a lot longer (Law, 1992). When strategies are inscribed in and performed by a range of durable materials, they acquire a degree of continuity and stability that accounts for the large processes - 'paths taken' - that Storper (1988) alludes to.

Callon and Latour (1981, pp. 286-7) make a similar argument to argue the case that macro-actors are simply micro-actors seated on top of black-boxes, networks of stabilised associations between human and non-human elements. The concept of actor is tied to the notion of representative, an element that is capable of conscripting and enrolling other elements and translating their will in a language of its own. To use Callon and Latour's expression, an actor is able to lay down a spatial organization and time of itself, to define chronologies, what is past and future. By adding new associations, inscribing these associations into more durable elements and by continuously substituting weak by strong interactions, actors are able to grow in size and power. As these networks grow longer and stronger: "... Instead of

swarms of possibilities, we find lines of force, obligatory passing points, directions and deductions" (Callon and Latour 1981, p. 287). For example the actor, Jacobs Engineering, was able to extend itself by replicating a role it played in an earlier, but quite different, MSD capital project involving an extension to the plant in Ballydine. Within the DCS project, Jacobs's scheduling software sought to become the dominant timekeeper, but could only do so because of its ability to translate and represent the information contained in the ABB scheduling software which it sought to engulf. The plant itself further vividly illustrates the dynamic character of actor-networks. It was constructed in the early 1970s as a replica of a sister plant in Flint River in the US. Yet despite this determined effort to obtain long-term economies of scale in the two plants, they have each evolved into, what are today, two distinctly different plants - physically, operationally, and temporally.

Dynamic time, in the sense of chains of small events locked into particular paths with a momentum of their own and contributing to the transformation or reproduction of big structures, completes our multi-layered view of time and links it with notions of evolution and the construction of macro-actors, capable of laying down their own versions of space and time. As in origami, where small variations in the sequence of folds can lead to very different final outcomes, we see chains of small events as cumulating into large processes through a mesh of strategic agency, chance and post-hoc rationalisation. As Arthur (1989) and David (1992) have shown, small variations in the initial conditions can lead to radically different outcomes in strongly path-dependent processes<sup>7</sup>.

## CONCLUSION

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<sup>7</sup>These concepts bear some striking resemblances to a class of phenomena in the physical sciences described by modern thermodynamics as dissipative structures (Prigogine and Stengers, 1984; Coveney and Highfield, 1990). Dissipative structures evolve according to a deterministic and stable laws until they reach what is called a bifurcation point, in far from equilibrium conditions. Once it attains this first bifurcation point, the system is faced with a succession of other bifurcation points and its trajectory of evolution can no longer be understood by reference to deterministic criteria. Small variations in the initial conditions can lead to huge differences in the final outcome.

This paper has been concerned with different notions of time in the context of our ethnographic study of the construction and operation of the cyborg, represented by the new DCS at Merck, Sharp & Dohme's plant in Ballydine. To convey the different notions of temporality found during the MSD project we have invoked actor-network theory and the metaphor of *chronigami*, a fusion of the terms 'chronos' and 'origami' the Japanese art of paper folding. Actor-network theory has allowed us to develop a language to describe the multiple and interpenetrating alliances between human and non-human elements present in the cyborg we have studied. The 'chronigami' metaphor has supplied us with an image of the construction of durable and standardised forms of time as a slow and progressive affair, of fold after fold successively limiting the range of admissible final objects which, once built, will retain their shape but can also be easily discarded.

We divided our notions of temporality into five different categories: networked, inscribed, folded, durable and dynamic time. The notion of networked time represents our attempt to come to grips with the multiplicity of times present in the PCS cyborg. For example, CRAs shift in and out of local time zones as they attend to a variety of signals and instrument readings or exchange the language game of 'batch time' to 'talk to you, the ethnographer' time. This multiplicity of local times arises out of patterned effects of other forms of time. For example, 'batch time' is itself the product of inscriptions and chains of translations that link a variety of actants - e.g. drug designers, plant design engineers - who have left durable programmes of action, prescribing admissible courses of action. Hence we speak of inscribed time. But, at the same time, these programmes of action that govern local forms of time have themselves been the product of struggles and negotiations to gain control of these networks. They are able to impose their own inscribed times as a result of past victorious outcomes in their struggle to conscript networks of actors, allowing them to exist and battle earnestly on behalf of their creators. We speak of folded time to refer to actors' abilities to fold time backwards and forwards, as they struggle to envision scenarios, hypothesise trials of strengths and inscribing programmes of

action in durable materials that will translate their present will into the future. We speak of durable and dynamic time, to denote forms of time that successfully engulf and conscript other actors and subordinate local forms of time-reckoning to standardised, supra-local time. For example, the recipe for each drug produced in Ballydine is a direct product of simulations, experiments and trials that have taken place at Merck's laboratories. Batch sheets ensure that batch time is standardised and drug designers have effectively ensured that the plant will continuously produce identical batches of their drug. The network linking the representation of the drug in Merck's laboratories and in Ballydine has stabilised to the extent that we can safely assume there will be no difference between the 'original' drug and the millions of 'copies' coming out of Ballydine. We speak of durable time to refer to the construction of networks of supra-local time, attempting to impose their own standards and partially subvert other forms of time. Finally, we introduce the notion of dynamic time to account for the ways in which micro-actors are able to grow in size and power by imposing their own versions of temporal and spatial organisation on their networks of conscripted allies. Dynamic time can be regarded as enfolding, constraining and engulfing other forms of time reckoning as macro-actors impose their own versions of past and future, and a variety of different chronological codes - e.g. batch time, campaign time - on the networks they control.

Our view of time is thus a multi-layered view in which different temporal frames coexist and draw upon each other for their existence and sustenance. The appearance of standardised forms of time, for example, doesn't displace or eliminate local forms of time reckoning embedded in particularities of local contexts and practices. But standardised forms of time provide new contexts for re-embedding time in local contexts and practices, for new forms of local time. What this paper has attempted to demonstrate through the use of actor-network theory is how these different forms of temporality are the product of heterogeneous networks combining associations of human and non-human elements. In our view, this is where the advantage of using an actor-network based ethnography lies - through its ability to

look at different forms of temporality in the foreground and to explore the backstage, heterogeneous networks that account for their existence. In other words, to look at the products of social construction and to enquire about the processes involved in that construction.

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