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# Emergent Temporal Behaviour and Collaborative Work

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**Abstract.** Although collaboration manifestly takes place in time, the role of time in shaping the behaviour of collaborations, and collaborative systems, is not well understood. Time is more than clock-time or the subjective experience of time; its effects on systems include differential rates of change of system elements, temporally non-linear behaviour and phenomena such as entrainment and synchronization. As a system driver, it generates emergent effects shaping systems and their behaviour. In the paper we present a systems view of time, and consider the implications of such a view through the case of collaborative development of a new university timetabling system. Teasing out the key temporal phenomena using the notion of temporal trajectories helps us understand the emergent temporal behaviour and suggests a means for improving outcomes.

## Introduction

Socio-technical systems are complex and change with time. Brittle systems handle such changes poorly, while plastic systems are more able to adapt to changing circumstances and requirements. While most readers would consider this assertion to be self-evident, we nonetheless have at best a poor understanding of the drivers underpinning the dynamic of socio-technical systems, and in particular the temporal factors at work in this dynamic. We believe that understanding these drivers will help us to better comprehend system-level behaviours, thus informing good (i.e., more plastic) system design.

Time contributes to the wicked behavior of design problems (Seebeck and Kaplan, 2004), and constitutes a fundamental driver of social systems. Irreversible, time forces change on systems; systems in turn must find some means to handle its effects, or risk a loss of integrity, even dissolution (Luhmann, 1995:41-52). We contend that temporal behavior within socio-technical systems is not the simple enumeration of processual steps, but an *emergent characteristic of the systems and their compositional elements*. While time and its effects are not contributors to all the characteristics of system wickedness, a deeper understanding of temporal effects should improve our ability to cope with that wickedness.

We begin by briefly introducing a case study of the development of a university timetabling system. We will then investigate time and its characteristics and construct a means of analyzing time in systems using the case to illustrate our ideas and argument. Lastly, we draw some conclusions regarding accounting for temporal effects in the design of collaborative systems.

# The Case

One of the authors conducted a 12-month longitudinal case study concerning the introduction of a novel academic scheduling system at an Australian university referred to as ASU. He conducted interviews with key players and had access to project and steering committee meetings and teleconferences with the vendor, all of which were taped and transcribed, and had access to project documentation including tenders, notes and policy documents. Kim and Kaplan (2005) describe the co-evolutionary aspects of this case from an actor-network perspective without considering the temporal aspects that we shall consider here.

ASU's Central Timetabling section coordinated class timetabling using a software application called OLDSIS. Schools would enter their scheduling requirements into OLDSIS specifying day, time, class size and room requirements. Once all the requests from the schools had been collated, Central Timetabling would initiate the space optimization function in OLDSIS to automatically allocate centrally controlled rooms against the Schools' predefined timetable. Over recent years however OLDSIS became increasingly unstable and was unsupported by its vendor. Fearing that they would 'break it' if they attempted to re-optimize room allocations, Central Timetabling decided to commence the process by rolling the prior year's timetable forward each year and then adjust the allocations manually.

There was a perception amongst senior management that the university timetable contained significant inefficiencies due to the inability of OLDSIS to produce a 'fully optimized timetable' (i.e., a timetable which optimizes day and time allocations for a class as well as finding an available room), for which it was never designed, to say nothing of its inability to reliably optimize room allocation against a fixed timetable, for which it *was* supposedly designed. Therefore, in August 2002 the university tendered for a replacement for its class and examination timetabling systems. The final decision came to a choice between two systems: COMMONSIS, developed by an English company; and an offering from Stellar, a US company.

Within the national context, two-thirds of Australian universities and six of the seven institutions that ASU regards as its peers use COMMONSIS. Stellar on the other hand offered the mature STRIPES, which like OLDSIS optimized room allocation against a fixed day/time/staff timetable, and its planned flagship product STARS, based on STRIPES and nearing the end of development, which claimed to fully optimize day/time/room/staff assignments. Although Stellar had no sales outside of North America, they tendered and demonstrated STARS saying that it would meet all of the tender requirements without customization. In August 2003 ASU awarded the contract to Stellar. The reasons for that decision will not be examined here except to say that ASU felt that "COMMONSIS [had] had its hour in the sun" and considered it advantageous to be involved in the design and development of a new scheduling system, not least because ASU thought it could influence the design of STARS to best suit itself.

At the time of writing, STARS has yet to be implemented at ASU, 21 months after its first due date, and after four subsequent missed delivery dates. To help us understand why this outcome eventuated, we consider how temporal behaviour influences socio-technical systems and system development and how the lack of understanding of temporal issues and drivers on the part of both Stellar and ASU significantly contributed to these outcomes.

## Why Time is Important

When we design complex socio-technical systems, such as computer supported collaborative work (CSCW) systems, we are designing both for, and within the context of, wider socio-technical systems. Such systems are *complex adaptive systems* (Kaplan and Seebeck, 2001): irreducible, heterogeneous, many-bodied systems which exhibit non-linear, emergent behaviour, and all the characteristics of 'wickedness'. The temptation — and often the expectation — in the face of wickedness is to design for the known, defined by the user, the developer or the client organization, and for the static. But without a better understanding of the drivers of wickedness, which can render even careful design brittle or irrelevant, system design remains hostage to complexity and contingency. A similar attention to deep system drivers may be found in Murphy's (2001) consideration of nature's temporalities; in Dourish's (1995) effort to identify a generic set of behaviours underpinning socio-technical systems; and in

Alexander's efforts to understand patterns inherent to good design (1979; 2002). We are concerned with that which makes systems change, shift, evolve and so elude easy diagnosis: time.

In system analysis and design, time and its socio-technical effects are infrequently considered explicitly (Bluedorn and Denhardt, 1988; Butler, 1995; Lee and Liebenau, 2000). There are, of course, a number of worthy exceptions. Time has a not inconsiderable literature within sociology, including Sorokin and Merton (1937), Zerubavel (1981), Adam (1990), and Gell (1992). Within the CSCW field, Reddy and Dourish (2002) investigate the temporal rhythms apparent in an intensive care unit. Huy and Mitzberg (2003) similarly suggest that there's a time and place — a rhythm of change — particular to different organizations, and change should not be forced outside of those rhythms. Orlikowski and Yates (2002) differentiate between objective and subjective time, arguing that in practice people and organizations 'temporally structure' their environments and work. Temporal pacing, like entrainment in organizations (Ancona and Chong, 1996), has been identified as a means of shaping group work (Gersick, 1988; 1994) as well as of dominating industries (Brown and Eisenhardt, 1997). But generally these authors focus on temporal phenomena without addressing their underlying causes.

Time's exclusion leads to problems such as that identified by Dix et al (1998) — the neglect of long pauses, delay and gaps in favor of the interaction in the here and now. Time typically is assumed to be linear; proceeding in unitary step-wise intervals; and homogenous, its effects experienced uniformly across the system — if not simply a constant (Seebeck and Kaplan, 2004). Change in at least part of the system, and often the wider environment, is often held constant. Even within the CSCW discipline, the focus has been more on what people actually do in terms of their work and workplace (eg Bannon, 1995; McCarthy, 2000; Suchman, 1995), and less on how that work might change over time, as a result of economic, technological, social or demographic change.

In part, the exclusion of explicit consideration of temporal effects can be explained through humanity's habit of discounting over time; lower, short-term gains are preferred over higher, but longer-term gains (Fehr, 2002). But when human endeavor *does* plan for longer-term systems and outcomes, then time must be factored in. Time is a major consideration in systems, system development and projects. Artifacts such as calendars, synchronisation, and planning and budgeting cycles enable the coordination of highly complex systems; such is the purpose of the university timetabling system described in our case.

There also are less obvious uses of and challenges presented by time. Teams and management use 'pacing' to achieve outcomes and to resist centrifugal tendencies in organizations (Ancona and Chong, 1996; Gersick, 1988; 1994). Beer (1974) observed that bureaucracies use time as a coping mechanism: delay can be used to eliminate problems, or to aggregate data to a level more easily handled. In our planning efforts we seek to see *through* time, a uniquely human characteristic (Luhmann, 1995). In doing so, we make our best estimate of the system state at some future point and then behave accordingly; the longer the leap through time, the greater the risk of divergence between expectation and reality; too timid a projection, the more likely events will overtake us.

## Unpacking Time in Systems

Unpacking our understanding of time, and how time affects systems, is key to accounting for time and improving system design and management. Time is neither uniformly distributed nor homogenous nor linear. This is beyond merely people's perceptions, and the notion of constructed time (Butler, 1995; Nowotny, 1994), but resides deep within the system and its dynamics — it extends beyond the social (Gell, 1992:89). Time in systems has three key behavioural characteristics: different elements have differing rates of change; time affects the system non-linearly; and interacting elements with similar temporal characteristics will tend to synchronize.

**Differing rates of change**: All socio-technical systems, such as CSCW systems, workplaces, even information systems, are comprised of many interacting parts, whether modularised and interdependent, as within an IT system, or free-flowing and non-hierarchical, as in society more generally. Each part or agent within the system has its own integral temporal behaviour. For example, our bodies respond to circadian rhythms, entrained by the natural environment (Strogatz, 2003). Artifacts decay unless attended to and maintained on a regular basis. Rest and replenishment and a resumption of normal temporal patterns must balance periods of abnormal, usually increased, tempo. But change does not occur in lockstep across the system: eg, we do not alter the database structure or hardware each time we enter new data.

This insight allows us to conceptually partition a system temporally. While there are various means of partitioning systems, Brand's model (1994) offers a user-friendly means of differentiating 'layers' via their relative rates of change. In our university example, the academic year evolves slowly, set by tradition and constrained by adjacent systems such as the high school year. The set of degrees offered by the university evolve more quickly, and the individual subjects within degrees more quickly still. The content of individual lectures evolves yet faster. Each of these represents a layer; to the extent that these layers can evolve relatively independently the system comprising the university's academic offerings achieves a degree of plasticity. Similarly, the information and communications technologies used for pedagogical purposes within ASU are evolving more rapidly than those used to support the university's 'back-office' business processes.

In our case, there is a natural rhythm to university timetabling generated by the flow of semesters, commencement and graduation. The ASU timetable achieved a degree of stability over time, as subjects and staff changed relatively slowly, allowing a consensus to be reached based on mutual expectations. But several years ago, ASU adopted a new academic information system that in turn forced changes to degree structures and subject offerings throughout the university. ASU management seemed to recognize the deep nature of those changes and worked hard to identify and plan for their consequences. However, with the timetable, ASU imagined Stellar could deliver solutions within the temporal cycles of its own planning processes; Stellar, however, would discover that its deeply-embedded assumptions about how timetabling should work would make this impossible.

**Non-linearity**: The modern conception of time assumes a mechanical, stepwise progression — 'clock-time' (Bluedorn and Denhardt, 1988; Levine, 1997). But multi-agent systems experience time in a dissimilar and non-uniform — and so non-linear — way. Temporal non-linearity encompasses concepts, or temporal experiences, such as 'novelty', 'regularity' and 'movability' (as listed by Butler, 1995: 390) — though such non-linearities extend beyond the personal experience of individuals. If we consider systems as networks of interactions and inter-relationships in multi-agent systems, we can understand phenomena such as self-organized criticality; co-evolution; and concurrence as examples of temporally non-linear phenomena.

In the case of self-organized criticality (Bak, 1997; Jensen, 1998), a critical point is reached at which change crashes, cascades or ripples inexorably across the system until the pent-up energy for change has been dispersed. Examples include avalanches, the spread of fads, cascading power failures, and revolutions. These system effects represent discontinuities in temporal behaviour, potentially shifting the system into a new set of behaviours or circumstances.

Co-evolution (Kauffman, 1995) also drives temporal change. Change in one system alters the environment of interacting or proximate systems; those must adjust their own configurations, behaviours or strategies, or their temporal behaviour, resulting in constant restlessness across the system-of-systems.

Lastly, the concurrence of change also can affect system. Temporal cycles may coincide, resulting in system disruption or demanding extra effort to maintain stability. Generally, change in deeper, slower layers, will affect upper, faster layers: a sudden shift in a deep layer may result in system shear (Brand, 1994).

In our case, the increasing instability of OLDSIS, culminating in withdrawal of support by its vendor, created a criticality and the impetus for cascading change. The introduction of STARS and STRIPES triggered co-evolution by forcing change on interfaces and dataflows within ASU's web-based course sign-on system and student information systems. In preparation for system change, ASU shifted timetable production from an annual to semi-annual basis. But doing so shifted timetable production workload to coincide with peak workloads in schools, placing extra stress on staff to balance competing demands. This is an example of concurrence — a non-linearity in one place in a system forcing consequential behavioural change elsewhere.

**Synchronization**: The third temporal characteristic is synchronization, which extends well beyond simple social interaction. In systems that work well, temporal cycles are both independent and interdependent. The closer their respective temporal behaviour, the more likely interacting system elements are to synchronize their behaviour, whether the systems are natural or artificial (Strogatz, 2003). Some natural cycles, such as the circadian rhythm, may diverge wildly in the prolonged absence of reinforcing cues. Synchronization can be forced, but at a cost, especially where the natural temporal behaviours are substantially different — as is evident in forced logistical systems (eg Khouja, 2003).

Organizational and biological systems use entrainment mechanisms, supra-processes or events that reset subordinate or associate processes, holding them in synchrony for a period to ensure goals are achieved or stability ensured (Ancona and Chong, 1996). A university timetable is one such entrainment mechanism. It orders and reinforces organizational processes, and provides a basis for interaction and synchronization of the activities of students and staff. As such the timetable operates as a commons — the realization of compromises mutually co-evolved over many years between academics and administrators. A shift in such a socially critical structure may presage massive disruptions within the organization.

## Emergent Temporalities

The heterogeneous agents comprising socio-technical systems exhibit temporal behaviour. Aspects of that behaviour will be regulated by an inherent, self-centered dynamic, but may alter in response to environmental or self-generated change. In particular, agents will tend to synchronize their temporal behaviour with others with whom they interact and share some temporal similarities. At a system level, we expect these behaviours to generate emergent temporalities as individuals collaborate.

For example, workloads may be dictated by influences external to the workplace yet intrinsic to it. Implementing STARS may seem a comparatively simple task, but if coinciding with other system demands, such as the start of semester, it may generate changes cascading across the system, altering internal workload patterns, and disrupting associated patterns, such as the working day of staff, system maintenance schedules, and lecture schedules. An emergent temporality may be a continuing, even a growing, lag between the work at hand and available resources, tipped by a new software implementation, while the system shifts into a new pattern of behaviour.

Such characteristics suggest that understanding temporal structures as linear sequences is insufficient; such sequences fail to capture the underlying dynamics and the deeper temporal behaviour inherent in systems. Similarly, the focus on 'interaction in the small' (Dix, et al., 1998) traditional within CSCW can lead to a failure to appreciate the richness and persistence of system behaviour resulting from temporal dynamics. And it may lead analysts and managers to assume eternity — that the system of tomorrow, next week, next year, will be that of today — at the risk of misunderstanding large system shifts due to criticality or shear.

Having identified the manifestations of time in systems, we introduce a conceptual tool that helps contextualize those behaviours within the circumstances of particular systems. For example, we identified an example of concurrence within our case, but what effect does that have on the delivery of a suitable version of STARS? Understanding how different temporal behaviours interact and fit together within the system can help resolve such issues.

**Temporal trajectories**: Temporal behaviour may build on and repeat itself, with that repetition contributing to wider temporal patterns with the system. For example, a lecture delivers information to students — that means of delivery may become embedded through its contribution to deeper social and organizational processes reinforced through practice and social artifacts. Or, lacking sufficient support and reinforcing behaviours — perhaps due to the level and pace of work, teacher knowledge, or the organizational culture — attempts to deliver information in that form may dissipate.

Temporal behaviour thus may be constrained by deeper institutional processes and work habits that support and reinforce existing programmes. For example, in our case, Central Timetabling considered standardizing university teaching weeks for courses. However this was abandoned due to factors external to the university, such as the timing of the Education School's teacher placement courses which are negotiated each year with other universities offering similar courses — not all universities can have their students placed in the same schools at the same time. Alternatively, an unpredicted, 'deep' event, such as the September 11 attacks, or an IT crash with critical data loss, may result in a massive system shift, cascading in unanticipated ways. September 11, for example, resulted in changes to American policy, the invasion of Afghanistan and Iraq, and ongoing changes to behaviour of organizations and individuals concerning communication, security, and risk.

Thinking about time as a system phenomenon allows us to consider the *temporal trajectory* of particular occurrences. Using notions of *instance*, *pattern*, *meso-layer* and *temporal layer*, we can talk about a system's temporal behaviour. Triangulating temporal trajectories helps understanding of the emergent temporal behaviour within the system. The use of arenas, the interaction of various 'social worlds' around issues of interest (borrowing generously from Strauss, 1993:226), allows us to encompass a wide range of temporalities, from the slow and taken-for-granted to the fast, eye-catching change of the moment.

An event, termed an *instance*, possesses simple characteristics of timing and duration. For example, a lecture is held at a particular time of day for a certain period. The instantiation of the activity possesses both timing, as compared to the clock and relative to other activities and agents in the system, and duration.

Repeated instances may generate a temporal *pattern*, which comprises rhythm, frequency and duration, and a higher level of complexity; e. g. a lecture is held each Monday for the duration of the semester, at 10am, for 50 minutes, in a particular space. We notice that staff and students attend and at the peripheries of the lecture students socialize or move directly on to another, common lecture.

Combinations of patterns across the whole or part of a system comprise a *meso-layer,* comprising increased complexity again. Here we find interacting patterns: lecture time is determined by other patterns (lecturer, student availability) and the physical environment (suitable teaching space), accounting for the complexity of the timetabling process. Socialization depends on student group composition, environmental conditions, student schedules and the university's own rhythm — assignments and exams can alter social activity. We may find that asynchrony or differing temporal patterns form semi-permeable barriers to interaction (Axelrod and Cohen, 1999) .

The interlinking of inter-related temporal processes form *temporal layers*. At this point we can begin to conceive of the temporal behaviour of the system as an emergent outcome of temporal processes and structures of compositional agents and substructures. What here we refer to as layers possess system-wide attributes and are based on the periodicity of change; their contents need not be linked through interaction, but are of a temporal nature. Our understanding of layering improves as we merge our understanding of a number of temporal trajectories, and we can arrange the system conceptually in terms of the relative pace of change. To illustrate: fast layers, such as the interchange of information during a lecture, depend on slower layers, such as the families of subjects and degrees offered by the university; those in turn depend on yet slower layers, such as the teaching pedagogy of the university. A middle layer may be the university timetable, which mediates teaching practice and social interaction.

Temporal layers may be described through separate temporal trajectories, but only make sense in a system context: for example, for a course of study to 'fit' we need a relevant body of knowledge and organized interaction between students and lecturers. Understanding the whole as an emergent outcome of inter-related temporal meso-layers, patterns and instances helps us to understand why, for example, bureaucracies inherently are slow despite efforts at reform: their behaviour is an emergent outcome of the temporalities of their interacting components.

Working from instances, through patterns, meso-structures and layers, we can build narratives that offer insights into the system's temporal nature — in particular, to help identify emergent temporal behaviours. For example, understanding repetition as a temporal pattern helps us to look for synchronizing patterns that may support the repetition. Or if non-linearities or significant stresses are evident, we can look for a dominant entraining activity.

Triangulated temporal trajectories provide a structured means of understanding how the manifestation of time in systems — differential rates of change, non-linearities including concurrence and co-evolution, and synchronization — is apparent within the system of interest. Furthermore it provides a means of binding together fast-moving 'interaction in the small' with deep, slow behaviours that shape and constrain those faster elements. Thus by drawing our eye beyond events encountered linearly as an observer passing through the system — for example, Barley's (1990) experience and Dourish and Button's (1998) 'moment-by-moment' sequential organization — to patterns, the interaction of patterns, and finally to a temporal representation of the system, we can overcome our natural inclination to ignore those effects that lie beyond our cognitive range. Such effects range from the slow cultural and economic shapers of work to the transitory passage of data through technological systems (Zaheer, et al., 1999).

## Revisiting the Case

We now revisit the case to expose, and structure, emergent temporalities. We investigate three distinct arenas, or areas of interaction, in the case to draw out the outcomes more clearly. The first arena focuses on the organizational context of the timetabling system: how the timetable is used by and shapes organizational work. The second, the scheduling arena, concerns the assumptions and system dynamics built into the software itself. This, as we'll see, proves to be a point of tension between client and developer: the client expects the software to reflect the organizational context while the developer is more interested in attainment of a workable, and saleable, product. Those tensions are played out in the project environment, which comprises the third and final arena we consider.

**The organizational arena**: Within the Australian university environment the academic year commences in February and primarily consists of two semesters running from February to June (semester one) and July to November (semester two). Some courses are also offered in a Summer Semester (December/January). Normally the Central Timetabling section is required to produce by each November a full-year timetable for the following academic year. However, ASU management approved a request to allow the Project Team to focus on producing only the first semester 2004 timetable; semi-annual timetabling has now been in place for two years.

Central Timetabling undertake the following tasks to produce a class timetable: collect data from departments and schools; perform data entry; validate the data; run the optimization; perform an initial adjustment of the automated timetable; publish a draft timetable for academic comment; incorporate feedback and adjust the timetable; and publish the official timetable prior to the start of semester.

To accomplish these tasks, Central Timetabling starts the process between five and six months prior to the start of semester. So as departments and schools enroll students for semester one in February, they also provide details of their projected timetabling needs for July. Running parallel but offset by four months is the process of producing the examination timetable, a second task assigned to STARS. The rhythm of the university year means there are two immovable deadlines by which a new class timetabling system must be tested and in place: September, for semester one of the following year; and March, for semester two.

The delivery dates for critical modules of STARS were missed on four occasions: either revisions were needed to overcome the interoperability, consistency or functionality issues which emerged in testing, or else the rising cadence of work as deadlines approached defeated the developers. On each occasion the decision was made to reduce the project scope and downgrade to STRIPES to produce the following semester's timetable simply on the basis of space optimization, whilst retaining preset days and times from prior years. (Kim and Kaplan (2005) cover the reasons why ASU could implement STRIPES but not STARS, including the limited optimization of STRIPES, which matched current practice at ASU; the temporal assumptions that remain embedded in STARS; and the changeable nature of STARS versus the mature stability of STRIPES.)

After the initial attempt to implement STARS in September 2003, a Stellar consultant, Myers, arrived in January 2004 with a revised version of STARS to retrain the Project Team. They encountered a number of critical bugs during training, so Stellar's lead programmer, "working more hours than human beings should", produced and shipped nightly builds of the software. But after Myers left, ASU found more critical bugs, including the inability to optimize; problems representing course delivery patterns; and date problems, thought to have been fixed in STRIPES. Time pressures, the lack of a working version of STARS, and Stellar's inability to provide a definitive delivery date, led ASU in late March to downgrade again from STARS to STRIPES for the semester two 2004 timetable, and again in September 2004 and January 2005. STARS, if delivered by March 2005, could not be used until the semester one 2006 timetable was due.

While ASU was able to tinker with timetable production, shifting from the annual to a semi-annual production of timetables, it could not alter the deeply embedded cycle of semesters. High school student matriculation and State tertiary admission board processing reinforce that cycle. As such, it is an inherent organizational rhythm — it can only be altered on the margins, as with the Education School mentioned earlier. The university timetable itself does not simply order staff, students and space; its production entrains the entire university. Despite that, STARS's delivery has proven slippery and immune from such coercion.

**The scheduling arena**: ASU is the first institution outside North America to implement Stellar's products and numerous temporal constraints were encountered, reflecting organizational and temporal assumptions inappropriate to the Australian environment. For example, Australia uses a day/month/year system, and not the American month/day/year representation embedded in earlier versions of STRIPES and re-encountered in STARS. Such assumptions are in principle easily solvable if the code was internationalized appropriately during development. That was not the case in STRIPES, and that lack of internationalization was carried through into STARS. For a system that deals ostensibly with when things occur that's a substantial problem: the system has to recognize that within a given year the 4$^{th}$ of June (04/06) is not before the 9$^{th}$ of February (09/02) and so not an error condition. Both the developers and ASU's project team would stumble over such misunderstandings constantly and unexpectedly. Although data packages exist that can handle these issues invisibly, Stellar did not use them; later attempts to 'hack around' these problems simply exacerbated them.

But the time-related problems encountered were not limited to dates. The project team experienced considerable difficulties translating Stellar's delivery models and traits to the Australian scheduling environment. For example, a course at ASU might consist of a two-hour lecture and two one-hour laboratories. These three classes are largely independent, and each can be scheduled independently of the other two — provided they occur at a time that the lecturer, students and space are free. In contrast, the delivery models inscribed within STRIPES and STARS would regard the same course as comprising two sections: a two-hour lecture section; and a one-hour laboratory section having two in-week repeats. Where a section has a repeated meeting within the week, for example Tuesday and Thursday, it is scheduled for the same time in the same room, with the same staff member; students are expected to attend all repeats. The difference is most pronounced for large courses at ASU that offer many classes — 'section clusters' — to meet the enrolment demand. Myers noted these differences, referring to the way that ASU timetables as being a "data issue that needs resolution":

> "Section records are not properly clustered. Currently there is not one section record that has more than one days met. Very few sections have a repeating meeting pattern."
>
> Myers' Notes

Scheduling issues thus rest on differences between Stellar's assumptions and the realities at ASU, in terms of date representation as well as temporal patterning. Given the diversity of scheduling arrangements in North America, Stellar could expect to find similar issues with temporal patterning in its home market.

**The project arena**: The timetabling project had processes that required working around temporal constraints. Notably, Stellar's interaction with ASU was affected by the time difference between North America and Australia. Not only was Stellar operating some 17 hours behind eastern Australia, but the time shift meant that of every week there was only four days overlap. The folklore of software development holds that these temporal offsets can be exploited to speed up development (eg Wright, 2005), but that was not the case here:

> "You lose almost a day every time we talk to each other, you know, that makes it hard. So time goes by very, very slowly."
>
> Director of Sales & Marketing, Stellar, interview, 8 September 2004

It also led to other 'temporalogically' correct statements such as the following

> "On Monday we're going to have to make a decision…because we're at a pretty desperate point…Monday is Sunday and even then we're going to need to retest."
>
> Project Manager, ASU, project meeting, 26 March 2004

Project development improved during Myers' January 2004 visit and the visit by the lead developer in September 2004. Physical and temporal proximity improved communication and helped synchronize behaviour, not least because Myers became aware of the timing constraints on the ASU project team.

> "The trip that I made out there was just absolutely how can I say it, essential and productive towards being able to create a product that is going to totally suit your needs. Does that make sense? In other words I feel that it was a very productive and effective, we were able to collect a lot of information that has caused us to go in and make a tremendous amount of additions and changes to the program."
>
> Myers, teleconference with Project Manager, 7 May 2004

Where possible, the synchronizing of behaviour helped to build social bonds as well. Stellar's lead developer shared office space and work purpose — ASU's implementation of STARS — with ASU's Project Manager during his visit. As both were smokers, they also began to synchronize their social behaviour.

It's clear that time differences have not helped the project's delivery. Bursts of progress are most apparent when Stellar sends a trainer or developer to work with the ASU team, deepening understanding, readjusting the product, and synchronizing activity — but lacking repetition, such effects are transitory.

# Emergent Temporal Behaviour in the Case

Timetables entrain not merely that which they are scheduling, but in a university, they entrain the organization through their very production. The dominant temporal feature is the timetable itself; it acts as a commons, and can be highly sensitive to change. Failure to realize — both in terms of understanding and actuality — the place of the timetable within the client's organizational environment would be a contributing factor to the difficulties encountered within the project.

But first let us consider the project through temporal trajectories. While the case allows several points of entry, we start from the instance of a lecture and the resulting trajectory in each of the arenas. Table 1 sets out the temporal trajectories for the respective arenas (read down the columns); Table 2 explores the consequences of the emergent temporalities identified via Table 1.

| | (a) Scheduling Arena | (b) Organizational Arena | (c) Project Arena |
|---|---|---|---|
| Instance | The delivery of a lecture to a class in a particular space. | Provide a resource (space, staff member, technology). | Allow a resource to be entered (one occurrence, Aust. format). |
| Pattern | Lectures delivered once a week, at the same time, but occurrence and place may vary (eg lab in week 4, early semester start) | Allocation of space; allocation of staff to teach courses in faculties; student lists per course; preparation of course materials. | STARS needs reconfiguring from the set US template to allow progressive flexibility through the semester. Exceptions difficult. |
| Meso-layer | Semester-based delivery of 14 weeks, mid-semester break, study week and exams. Some programs start earlier. | Timetabling and space schedules coordinate with course offerings, degree programs, tutor requirements. Shift from annual to semi-annual planning. | Efforts to realign STARS constrained time difference between teams, other clients. Delivery times must align with semester dates. |
| Layering | Timetable development; individual subject; degree; timetable structure; academic year; policy; institutional environment | Individual lectures; individual subject; timetabling; degree; timetable structure; policy; organizational & academic culture | Code; project team developer interaction; ASU/Stellar management interaction; delivery dates; contract; scheduling assumptions; business models |

Table 1. Temporal trajectories within (a) scheduling, (b) organisational and (c) project arenas

Reviewing Table 1, we see that each arena has a different interpretation of a lecture. The first problem arises at the pattern level: Stellar has major problems translating ASU's scheduling pattern; its scheduling assumptions are embedded deep within the software, and hard to change. Another issue emerges at the meso-layer: Stellar is unable to match ASU's organizational rhythm. That rhythm reflects the timetabling cycle itself and entrains staff and student behaviour and the deployment of resources. It also reflects the deeper pattern of the academic year. Shifting to semi-annual production of the timetable was meant to enable the anticipated imminent delivery of STARS and make ASU more responsive to the market, but strained organizational resources elsewhere.

At the layering level, we find that the project arena changes more quickly than either the organizational arena or the slower scheduling arena. Layering allows us to identify the 'limiting resource' (Simon, 1996), the key constraint of the system. In Brand's schema (1994), the slow layers constrain the fast; here, scope for change is set by two factors: the scheduling layer, dictated by the timetabling cycle; and the scheduling assumptions embedded deeply within STARS.

Stellar's inability to grasp the Australian scheduling system, as evidenced by their failure to match the university's organizational cadence which is reflected in the delivery dates, is due to a set of assumptions concerning the organization of time that is deeply embedded in the software.

> "Some of the others might not have understood how embedded that was into the system and how many different places that had to be changed and modified and the kind of routines that we really needed to create to make sure that it was working right in the database and in display."
>
> Lead Developer, Stellar, interview, 1 September 2004

Myers, for example, considered the difference between Stellar's working assumptions and ASU's scheduling system as a 'data issue' — a matter of getting the data right, rather than of user practice or temporal behaviour.

Attempts to come to grips with the problem are not helped by time differences, and different temporal perspectives, between client and developer. ASU, working to a steady beat, see the project as slow and plagued by delay; Stellar, working between several customers and trying to meet deadlines, cannot match ASU's pace:

> We have five simultaneous STARS implementations going on right now and all have demanded attention at different times and I can see when I step back our attention going wooo [arcing back-and-forward hand motion] zooming from one client to another like that and ASU is one of those who have probably seen us give a lot of attention and then swing somewhere else."
>
> Director of Sales & Marketing, Stellar, interview, 8 September 2004

ASU believed that Stellar could adapt to their practices and that little or no customization would be needed, only to find out that some assumptions were deeply embedded into the Stellar products. Each organization came into the project with a constraint deeply embedded on a 'slow layer', and the assumption that the other's reciprocal constraints would be on a 'fast layer' (see Table 2). But because the family of constraints at issue exists on 'slow layers', it has become difficult for Stellar and ASU to work together and the project has ended up in a kind of limbo; a further example of an emergent temporality.

The temporal behaviour of the overall system emerges from the interactions of the temporal characteristics of the system and its constituents — the developers, their clients, the technology and the environment. Because of problems in deep layers, attempts to entrain development through artifacts such as milestones, contracts and deliverables, run into difficulties. The critical entrainment mechanism is the timetable production schedule itself. The time differences between client and developer contribute to the problem, but are insufficient cause of the continued delay to STARS. Instead, the limiting resource is Stellar's inability to account for the nature of lecture schedules over the semester at ASU within its system, and to do so in time to match the timetable production schedule.

| Emergent Temporalities | Consequences | | |
|---|---|---|---|
| | ASU | Stellar | User Domain |
| Time assumptions in STRIPES (unanticipated, a barrier to adoption) deeply embedded | Unable to meet public commitments to new system. Ongoing, and increasing, political and resource burden. | Increases resource commitments. Continuously underestimates or misdiagnoses problem; unable to meet contractual or subsequent verbal commitments | Continued use of old timetabling process, using STRIPES, but collecting data as for STARS. Users acclimated to what were to be transitory arrangements |
| Time differences across the Pacific | Acts as an interaction barrier, affecting communication and responsiveness between ASU and Stellar | | |
| ASU needs to entrain Stellar to meet delivery dates | ASU wanted a rapid delivery, had assumed changes were quick, cosmetic and few. Use of legal threats. | Stellar commits to unachievable timetable; massive expectation mismatch. | Schools carry burden of semi-annual collection of data for Stars. Academics assume the status quo is optimized & meets their needs. |
| ASU's own time constraints are deeply embedded in wider socio-economic system. | ASU unable to shift its own schedule. When changes prove to be big and many, ASU can't evolve its own constraints,. | Stellar assumed no issues, a quick evolution, and a good fit between its product and ASU's system | ASU instituted semi-annual timetabling to match Stellar's promised delivery and improve optimization |

Table 2: Emergent Temporalities in ASU, Stellar and in the User Domain

# Implications

We believe that any deep consideration of the behavioral characteristics and drivers of collaborative systems must necessarily include a broad view of time. That means appreciating how time affects systems, and that system-level temporal behaviour emerges from the distinctive temporal behaviors of constituent elements.

Our case allows us to consider the effect of time and collaboration within a socio-technical system that is itself used to shape time and collaboration. Not only does the notion and impact of time differ in each of the arenas, its interaction through the collaboration of the system's participants yields unanticipated outcomes and shapes the overall system. Two temporal patterns dominate the system: the timetable as an entrainment mechanism both in its ordering and in its production; and the nature of ASU's scheduling paradigms, in particular how it differs from the system embedded in Stellar's software. A third temporal characteristic exacerbated efforts to resolve difficulties generated by these two patterns: the time difference between ASU and Stellar, which militated against synchronization of effort and deepening understanding. The resulting interplay of these deep temporal characteristics has left the project in limbo, while retaining a perception of progress through frenetic activity and tight deadlines. This emergent characteristic of time has not been addressed as far as we are aware.

A more 'traditional' approach to our case might have focused on the interaction of the client and developer teams, noting the effect of geographical time differences (eg Massey, et al., 2003) and possibly attributing the lack of delivery on fragmentary, opaque interaction, independent of deep temporal drivers. Such simplification of time has its uses: understanding the sequence of actions contributes to an understanding of 'interaction in the small' and allows tasks to be automated and routines formalized. But it risks underestimating the depth of complexity — the wickedness — of the work environment, and the possibility of temporal behaviour emerging from the inherent presence of time in systems.

From our analysis, we can draw some tentative guidance so as to help shape temporally sensitive design of collaborative systems. First, analysts and designers need to be aware of *patterns of temporal interaction*, and the contribution those patterns make to the overall temporal profile of the system. The timetable production cycle, for example, entrains other organizational processes.

Second, temporal behavior, like other behaviors, is often negotiated at the *interface of social spheres and policy arenas*. Temporal behaviors do not necessarily translate directly between arenas. Scheduling, for example, comprises deeply entrenched expectations, perceptions and behaviors; it changes slowly and so acts as a brake, or if understood, as a base for fast changing behaviors. Despite the strong entrainment mechanism of the timetable production cycle, it was not able to drive STARS to delivery, as deep scheduling problems had not been resolved.

Last, *encapsulation* is a common technique in software engineering; socio-technical systems and sub-systems are often 'black-boxed'. Both forms of encapsulation contain assumptions concerning the temporal behavior of their contents. Those assumptions may shape system behaviour, especially when system elements are tightly coupled, yet remain opaque to analysts, designers, developers and users; critical errors based on flawed assumptions may be perceived as a 'data problem'. Thus Stellar's assumptions concerning the scheduling profile of a university, deeply embedded within its software and based upon its past US-based experience, contributes to its current inability to deliver STARS.

Social and socio-technical systems always will be 'intransparent' in good part to external observers (Luhmann, 1995;1997). However, harnessing time as a framework may help mitigate that intransparency. For example, watching for patterns of activities and their interactions may reveal insights concerning system drivers, and contributors to system behaviour. Treating time simply as homogenous, uniform and step-wise contributes to intransparency. If failing to account properly for temporal phenomena can reduce the utility and functionality of a system, then better understanding of temporal behaviour holds the promise of providing systems developers with a variety of new conceptual tools, including: (1) levers for control through mechanisms for entrainment, or simply identifying points of tension and coincidence; (2) removal of controls, for example through the inverse of the previous point; and (3) by recognizing when parts of systems functionality are on the 'wrong' temporal layers (the system will allow them to evolve too quickly, or not quickly enough), the system can be rearchitected.

# Conclusion

Time is a deep driver of system behaviour, contributing to the wickedness of the socio-technical design problem. Time manifests in many ways — differential rates of change, non-linearities though co-evolution, criticality, and concurrence, and entrainment and synchronization — and generates emergent behaviours at the system level. In our case, failure to understand these factors contributed to the repeated failure to deliver the STARS timetabling system. Rather than seeking to build quick fixes within ASU's temporal cycle, Stellar would have been better served by stepping outside of those immovable deadlines and working on resolving those issues deeply embedded within its own product. Deep, slow temporal layers must be resolved on their own terms — slowly. Rushing simply meant that the deep, systemic assumptions built into STARS could not be identified, challenged and properly re-engineered.

The use of time as a lens has helped us to understand such drivers, and the consequential temporal behaviour within the system. Without regard for time, analysts risk missing some of the rich behaviour that it generates within the system. Accordingly, we suggest that tools such as temporal trajectories offer useful scaffolding for extricating temporal behaviours. In particular, the trajectories allow a more holistic view of time, encompassing slow behaviours often disregarded in our focus on the workplace and on the present. We also suggest that designers watch for patterns of temporal interaction, particularly at the interface of social spheres and policy arenas, and that care be taken to consider the temporal assumption often embedded within socio-technical systems.

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