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Routines and representations at work - Observing the architecture of conceptual design

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Routines and representations at work - Observing the architecture of conceptual design

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Abstract

We present an analysis of observational data from work settings in the conceptual design phase of manufacturing product development. We pay particular attention to the architecture within which individual routines appear, describe the resources that are involved in the observed innovation activities, and discuss the way in which resources are furnished in work settings by formal routines. The field study and the analysis place a distinctive emphasis on the contributions made by representational artifacts, and we connect this with the literature on ostensive and performative aspects of routines. Adopting a strong 'performing' perspective from work-practice research, the paper develops interpretations of evolution, context and pattern which are contrasted with those typically employed in routines research.

Keywords

Routines, representations, artifacts, product development, workplace observation, evolutionary economics, chip manufacturing.

In recent years empirical studies of routines have become increasingly important in research in innovation economics (Pentland & Rueter, 1994; Edmonson et al., 2001; Jones & Craven, 2001; Becker et al., 2005; Lazaric & Denis, 2005). One rationale for this, which we share, is offered by Pentland and Feldman: "Our need to understand internal dynamics of routines is particularly strong if we want to influence, design or manage them. To craft good theory, we cannot rely on surface regularities and correlations..." (Pentland & Feldman, 2005). The present paper reports findings of a six-month observational study of the dynamics of a pivotal phase of innovation within a manufacturing organisation: conceptual design. We examined in detail the conduct of activities in which multiple participants worked with multiple knowledges, within a process of committing assets and resources to a beta design and beta launch of an upgraded product model, and thus - in principle - to an entire cycle of committed investments, sales returns and operating margins. In the present paper

we develop a discussion of the contributions that were made in this evolutionary and highly strategic work setting, by routines.

1 Theoretical orientation*

In the field of evolutionary innovation economics much theoretical development stems from Nelson and Winter's (1982) central use of the concept of routines, seen as regular and predictable behavioural patterns of the firm. In a competence-based perspective on the dynamism and strategic capability of firms (e.g. Teece & Pisano, 1994; Teece et al., 1997; Eisenhardt & Martin, 2000), the firm has itself been presented as a complex of routines, including meta-level routines for co-ordinating among routines and for changing or creating routines. In the present paper we develop a distinctive approach to issues of evolution and behaviour, and in order to do this we pay close attention to the notion of *'context'*, which in our view has received too little attention. Our concern with context leads us also to focus on the composition of *architectures* of work practice. Thus, we examine particular routines within a context of multiple actors, activities, routines and other elements of work organisation. Again, this is in contrast to the tacit stance of most discussions of routines, which address them as if they were discrete behavioural entities, operated singly as 'pieces' of organisation.

Our approach lies close to recent research on the work done by and within routines, in evolving orders of practice. Like Feldman & Pentland (Feldman & Pentland, 2003; 2005; Pentland & Feldman, 2005) we wish to highlight ways in which both stability and change, the reproduction and production of order, are played out in practice, in contexts where *ostensive aspects of* routines are prominent features of the work environment. Like them and like Howard-Grenville (2005) we are concerned to give prominence to the active agency of participants in organisational settings where routines are performed, and to carefully observe and critically examine relationships that exist in practice between the 'ostensives' of routines and actual performances of work.

The work that we present here builds most closely on the existing body of routines research with regard to concepts of architecture, context and artifacts. It departs most obviously with regard to concepts of pattern and performance. The remainder of this section looks in turn at each of these two conceptual clusters.

1.1 *Architecture, context, artifacts*

The consensus in the literature on routines is that they are collective phenomena, and thus distinct from skills of human individuals. For example, Becker (2005b: 645), makes the distinction between recurrent patterns of action (including individual skills) and *inter*action. Nevertheless, much of the discussion treats routines as if they themselves are discrete behavioural entities. The most advanced position acknowledges a dual reality, of ostensive aspects (the abstract idea of the routine) and performative aspects (the concrete performances of a routine) (Feldman & Pentland,

2003; Becker et al., 2005; Pentland & Feldman, 2005). Even this position nevertheless tacitly maintains the idea of single routines, performed singly, as a significant empirical, analytical focus; and perhaps even as a practical focus in the real world?

In contrast, we are attracted by the realism and practical insight of a more complex conceptualisation offered by Warglien, involving multiple routines, concurrently enacted and constituting 'an architecture'.

> "[I]f one wants to characterize a kanban system as a recurring action pattern, one has to look not only at these diverse ingredients [explicitly stated rules and instructions; carefully designed artifactual environment] but also (and maybe chiefly) at the architecture of relations between these ingredients - how they fit reciprocally, and with other processes such as set-up time reduction and working capital reduction..." (Cohen et al., 1996: 659)

In this paper we develop an analysis of this kind. As our unit of observation we adopt not the singular routine, or its performing, or its 'ostensives'; but *the interactional episode* within *a course of action*. It is then contingent, whether an interactional episode is in practice enacted as a performance of a routine, or contains performances of routines.

Context is not well developed as a construct in the evolutionary economics literature. This is a substantial weakness, since context is frequently invoked as a foundational concept. To offer a typical example: Winter notes that:

> "[T]he cognitive approach neglects, and hence risks obfuscating, the contextual aspects of routines. Context dependence is fundamental; the effectiveness of a routine is not measured by what is achieved in principle but by what is achieved in practice...". (Cohen et al., 1996: 662)

He identifies an artifactual environment:

> "One important aspect of total context is the physical, which includes both the local/artifactual complements of the routine (eg the requisite plant and equipment) and the broader physical environment that was not produced for the benefit of the routine..." (loc. cit.).

The notion of an artifactual environment is developed by some researchers to include physical, linguistic and cultural items (including 'cognitive artifacts': Warglien in Cohen et al., 1996: 674), such as the following summary list of 'representations of action' derived from Cohen et al (1996: 661):

* Memories of individual humans, for their respective roles.
* Locally shared language.
* Global language forms: formal oral codes, pledges, 'war stories'.
* Physical artifacts: tools, spatial arrangements, written codes (eg documented operating procedures), coded in software.
* Organizational practices: archives, personnel rotations, maintenance of working examples, building key assumptions into organizational structure.

In our own field research we adopted a particular observational focus on representational artifacts (more of this in 2.2 below) and this enables us to contribute to the development and refinement of this line of thinking, with regard to artifacts,

representations and the evolution of knowledges, products, strategies and market positions.

Helpfully, the ostensive/performative model of routines has been extended (Pentland & Feldman, 2005) to include a third 'pole' of internal structure - artifacts. Feldman and Pentland note that 'organizations are a sea of interdependent actions, interpretations and artifacts' (Feldman & Pentland, 2003: 798). We use representational artifacts as a central component of our observational approach in deriving data about these 'seas' and we welcome this oceanic metaphor's emphasis on fluidity, constant dynamism, risk, scale and all-embracing horizons. At the same time we also wish to promote a sense that when people plunge into in these cultural seas - certainly, in the highly self-conscious domain of strategic activity that we were observing - they equip themselves well with navigation tools, and with devices for staying culturally afloat and purposefully moving from cultural place to cultural place. Needless to say, in practice these 'seas' are also highly organised systems of resources, well travelled and with many durable, well-known (and often deliberately furnished and maintained) local features. Indeed, unlike literal seas, they have man-made components and they have manageable architecture, which we mean to elucidate in this paper.

1.2 Pattern, performance, agency

The distinction between ostensive and performative aspects of routines now seems well accepted (Becker et al., 2005), and opens ways of framing empirical research which are more precisely formulated (Pentland & Feldman, 2005). This 'performance turn' in routines research opens the possibility of an increased concern with how tasks are accomplished in practice. For example Becker (2005a: 819) cites Barley & Kunda's injunction (Barley & Kunda, 2001), to 'bring work back in'. This is very much in the spirit of our own study, which derives partly from traditions of ethnographic 'work practice' research (Barley, 1986, 1988; Kunda, 1993; Suchman & Trigg, 1996; Henderson, 1998, 1999; Suchman, 2000a, 2000b; Suchman et al., 2002) and interactionist research on organisational coordination: e.g. boundary objects (Star & Griesemer, 1989; Star, 1989a, 1993) and organisational reach (Gerson, in press; Star, 1989b, 1995). Work-practice approaches - eg in the fields of computer supported cooperative work (Randall et al, 2007), human-computer interaction research or the sociology of technology - differ in some significant and interesting ways from the usual approaches in routines research.

Recurrence or repetition are central phenomena in the world of routines. Under the rubric 'routines and other recurring action patterns', the published outcome of a review of routines research at the Santa Fe Institute (Cohen et al., 1996) discussed 'heuristics and strategies' and 'paradigms and cognitive frameworks' as well as 'routines in the narrow sense' and 'rules of thumb'. The notion - we might refer to it as a 'cognitivist' principle - shared by all these constructs is that something (some map, model, ostensive description, rule, representation, etc) is repeatedly performed (implemented, followed, interpreted, enacted, etc), and that this produces a repetition

of a previously *recognised and represented* pattern of behaviour. Becker more recently has suggested that 'the term "recurrent interaction patterns"... provides a more precise term for organizational routines understood as behavioural regularities' (Becker, 2005a: 818). If we make no distinction between repetition and recurrence, or interdependent action and interaction, this can be seen as equivalent to Feldman and Pentland's definition of routines: "repetitive, recognizable patterns of interdependent actions, carried out by multiple actors" (Feldman & Pentland, 2003: 95).

The work-practice perspective that we adopted in our field observation and data interpretation differs somewhat from this, and differs significantly from the cognitivist stance of routines research stemming from behavioural theories of the firm (e.g. Cyert & March, 1963) and instanced, for example, in the discussions of cognitive efficiency and (prior) representations of action in Cohen *et. al.* (1996). Rather than seeing the observed activities as displaying instances of repeated or recurrent pattern, we see them as displaying *ongoing order*. In designing our observational approach we understood ongoing working order as something manifestly oriented to *and worked on* by participants in work settings (for example in speech or gesture) and continually - and again, manifestly - maintained and (re)constructed as part of the flow of action. Thus, at the level of analysis, we replace repetition with *continuity*; and the construct of externally observable patterns with an alternate construct: manifest, mutual, participant orientation to the deliberate and collaborative performing of *ordering work*. This work and its outcomes take numerous mundane forms which, in the case that we present here, prominently include: story telling, the production, handling and verbal interpretation of visible representations, the placement of artifacts (notably representational artifacts, stored in specific, mutually accessible places) and the making of verbal agreements (eg concerning committed courses of action, the future disposition and commitment of resources, etc).

By focusing on working order we by no means drop the notion of pattern. Activities and actors seen in this way are themselves concerned with pattern and patterning in a strong and central sense: maintaining continuities, generating patterns that are consistent with existing ones, and discerning and referring (both indexically and normatively) to patterns, in the process of creating the ongoing organisation of current (and future) work and its artifactual infrastructures. What working order does, as distinct from pattern, is to give a central place in our perspective to agency and participation, rather than 'emitted' behaviours, observed externally. This perspective is typical of the sociological approach known as ethnomethodology (Button, 1991; Garfinkel, 1996; Suchman, 2000b; Suchman et al., 2002). Ethnomethodologically-informed researchers are centrally concerned with the manifest orientations of participants to what it is that they are doing as they work. We are predisposed to see practice as always, everywhere, already ongoing (as distinct from being initiated recurrently in discrete bursts) even though it is also episodic; and we expect to see producing and maintaining working order (including the opening and closing of episodes themselves) as an intrinsic and mundane component of the work that

participants do, in episodes of interaction, in interaction settings that are concrete, artifact-furnished, spatially-, temporally- and institutionally-situated.

2 Methodology

Our study was designed to engage with issues of practice in knowledge work. Aware that knowledge is handled in collective settings while handling artifacts, we chose to study practices in a sphere where non-textual forms of representation are known to be significant: the field of design, where sketching and co-working with sketch-artifacts and drawing-artifacts are known features of knowledge work (Henderson, 1998, 1999). Our study was designed also to engage with issues of evolution (it was conducted under the auspices of a programme on 'The Evolution of Business Knowledge'). We chose to examine practices of conceptual design in two differing design-based industry settings, on the basis that we would be able to see not only the evolving of knowledge forms (something which might have commonalities across industries) but also the evolving of product forms, product investments and product positions in the market (which might have distinct differences across industries). For these reasons we got the agreement of two design-based firms to closely observe streams of conceptual design activity, in an engineering company that manufactures process plant for the semiconductor industry and in an architectural practice. In this paper we work only with data from the former field site.

2.1 Units of observation

In the former company (here we call it HighTech, a pseudonym) we observed a process of decision making at the conceptual design level, for a new global release of an existing engineering product. Overall, the observation period was framed by an explicit course of action: a formal product development programme for a beta release which became know as ABC-10 (a pseudonym). We closed-out our field observation when all the significant dimensions of the ABC-10 product concept - including its introduction as a beta version into operational use in customers' sites - were settled (as indicated by the practical focus of participants) and the balance of activity had visibly shifted into detail design and operational delivery of the beta prototype. Observation settings were defined by a formally defined set of participants. We observed members of HighTech's Engineering Group who were connected with ABC-10, in episodes of interaction in any setting where they interacted with each other or with other HighTech staff. Especially but by no means exclusively we observed them in the formal settings of the ABC-10 programme, notably meetings of two formally constituted cross-function product development teams.

2.2 Observational strategies

The evolution issue was framed in terms of 'articulation work' (Strauss, 1988; Anderson & Sharrock, 1992; Schmidt & Bannon, 1992; Bannon & Bødker, 1997; Schmidt & Wagner, 2002) occurring through an unfolding series of interactional episodes within the evolving, overall, explicit course of action: the ABC-10

programme. Adopting an ethnomethodologically-aware perspective on work practice, in interactional episodes, we were concerned to observe and record the manifest orientations of participants to each other, to objects in the room, to offstage actors, activities and objects; and to *the work* in which they were mutually engaged.

A central observation-orienting device that we used in interactional settings was participants' orientation to representational artifacts, especially 'visual representations': drawings, icons, visual schemas, photographic or three-dimensional images, pictorial representations of arrangements of objects or activities in space or time. *Visual* representations, in this sense, were distinguished from other kinds of *visible* representations (which we also noted) including textual representations (eg reports, written specifications, documented procedural algorithms) or computable, algorithmic-symbolic representations (eg simulation models, spreadsheet models and software code). One significant implication of visuals as forms of representation is that, unlike explicit texts and computable models, they cannot easily pretend to be rules: visual representations are manifestly incomplete. To be used in collective settings, they must be spoken about, they become sites for the production of *speakable*, spoken, representations (broadly, 'stories'). Our fieldwork approach was thus designed also to capture these too.

Our observer was present in HighTech's premises for two days on average each week (a total of more than 50 observed days), days varying according to what was happening in a given week. He was allocated his own desk and wi-fi enabled laptop in a cube on the Engineering floor, a few steps from the ABC-10 programme manager's office and the cubes of the ABC-10 design manager and lead CAD designer. He was accepted as a shadow of the Programme Manager, taking a (back) seat in most kinds of meetings (with the exception of senior management meetings and meetings with customers), able to walk in and request a discussion with other senior occupants of offices on the Engineering floor (the Engineering Director, the Marketing consultant, the Key Product Unit Manager, the senior physicist) and elsewhere, and often hovering on the edge of cube huddles and office-door conferences involving any of the ABC-10 actors. He constantly carried an audio recorder and fieldnote book, often carried and used a camera, and was free to access the Engineering fileserver on which current and past project documentation was archived.

We commenced observation before a formal development programme had been declared and we left the fieldsite after an observational period that turned out to be 24 weeks. At this point working capital had been substantially sunk in prototype manufacture, and the strategic and operational frames for delivering the beta machine into the customer's site had been resolved. We left with a collection of records which included: 15 hours of audio recording (from formal meetings of participants, ad-hoc interactions between participants and informal desk-interviews with participants in numerous ABC-related roles); 850 digital stills (snapshots of interactions-in-progress in groups of two to twenty people, and close-ups of representational artifacts on paper, on PC screens and projected on wall screens); a 20cm stack of hard-copy

documents (formal process documentation, company newsletters, and some sketches made for us on request, as explanations); a partial email record of ABC-10 communications (received as a member of one of the ABC-10 email lists); and most centrally, a 200-page spiral-bound book of fieldnotes, bulging with inserted sketches and diagrams (eg meeting layouts with participant names), consisting principally of time-stamped notes of observed interactional sequences including verbatim quotes.

2.3 *Routines and the market - The location of work domains within an innovation or value-chain context*

There are several good observational studies in industry settings closely related to our own but differently located. In 'EquipCo', Bechky (2003a; 2003b) has studied the role of material artifacts (the prototype chip-making machines themselves) as boundary objects between communities of practitioners in design and manufacturing operations. EquipCo and HighTech manufacture for different segments of the chip-equipment market: EquipCo in wafer etching, HighTech in ion implantation. Howard-Grenville (2005) has studied routines (actually, representation-based practices of 'roadmapping') in a manufacturing-process development group (EnviroTech) at 'ChipCo', a company which almost certainly is one of the dominant customers downstream in HighTech's value chain. From a routines-related perspective (actually, a perspective on formally codified *representations*) in a different industry (auto manufacturing) D'Adderio (2001; 2003) has studied the glitches that may occur when different communities of practice - including, as in our own case, Engineering - contest the ownership of an operational system of formal representations (software systems for product configuration management: D'Adderio 2003) and when rationalisation of a formal representational system fails to effectively support working practice, again, including Engineering (simulation of product prototypes in software: D'Adderio 2001).

With regard to these empirical studies, and also the much larger body of abstract discussions of routines, we note that the settings have typically differed from ours in one or both of the following respects. On one hand, they have been set downstream of conceptual design, either in more highly routinised *operational settings* (administration, manufacturing, etc) or in handovers between the domains of development and operations, where the initiation of a stabilised regime of routinised activity and formalised codification is a focal issue. On the other hand, they have been preoccupied with the *genesis and evolution of routines* and with *process innovation* settings, involving the routinisation of knowledge work, the formal codification of knowledges and/or the introduction or change of routines - whether successful or otherwise. We take the view that the contribution and function (and thus possibly the nature and content) of routines need not necessarily apply in the same way in a setting further upstream in the innovation cycle: for example, as in our case, the critical phase of *product innovation* activity in which a logic of 'exploration' in R&D is translated into a working order of 'exploitation' via investment in an entire product- and revenue-cycle. We regard this as a matter for empirical study. We also take the view that it is equally interesting to study the contributions that evolved

routines actually make in an evolutionary setting (in our case, a product development process) as it is to pursue the question of how routines are evolved; and that this too is an empirical matter.

3 The setting and timeframe of the field study

3.1 The setting

The firm: HighTech

HighTech is a division of a global manufacturing company which designs, builds and supports installations of process plant for semiconductor manufacture. Design work is thus strongly science based, and it moves (along with its representational artifacts) between experimental work in HighTech's own labs on two continents, on-site trouble-shooting and commissioning in customers' fabs worldwide, and manufacturing (in HighTech's own clean-room assembly and test facility and in the factories of outsourced module builders).

One factor that influenced our choice of HighTech was that it seemed to be an organisation which is 'up to the ears' in routines (within a standards-intensive industry sector); and specifically, it had a prominent, mandatory, global standard process for product development (referred to here as 'PDP').

The product-design context: the ABC10 beta release

The ABC product family is a leader in HighTech's subsector of the semiconductor equipment market. It has a modular engineering form: a raw materials front end and operator interface, a central high-tech transport system for the material to be applied to silicon wafers, a 'target' chamber where silicon is processed, a clean-room interface where robots handle processed wafers; and an overall web of cables for control signals and high voltages. The innovation that constitutes the new ABC-10 version lies in the central transport system. Some of the design principles for this module are distinct from those underlying HighTech's main competitors' machine. However, the competitor's business organisation differs from HighTech's, which means that the two machines do not compete equally in terms of product pricing (the competitor can cross-subsidise this product range from other product sectors). This commercial fact, plus the imminent release of an upgraded performance version by the competitor, only a year into the working life of the ABC-09 release, places heavy pressure on HighTech to achieve a time to market and a lifecycle yield of gross margin on ABC-10 that are well beyond their previous hard-achieved best.

3.2 Chronology - 24 weeks of work and observation

Week	Key events
Week 1	Observation commences. Senior engineers discuss the potential for a product release based on recent lab results exploring new configurations in the transport module of ABC-family machines. This includes discussion of how to package the release to get it into leading customers' sites, occupying real estate in the fab (namely, retrofitting on already-installed ABC-family machines).
Week 4	Engineering discussions are centred on defining the interface between the old (ABC-09) and the new (ABC-10) modules of the machine.
Week 5	First briefing of 15-member Engineering design team for a new transport module.
Week 6	Formal 20-member kick-off of product development programme for a machine with a new transport module design. Very tight timeframe ('even faster than the last one'), eyebrows raised, questions asked about the market requirements specification.
Week 9	After a handover meeting with a further six-member Engineering team, detail design is started on high-priority, tight-timescale revisions on the front-end and process chamber modules of ABC-09, forward-compatible with the as-yet undesigned ABC-10 transport module which will sit between them.
Week 10	General Manager's rough whiteboard timeline sketch for the beta and alpha prototype schedules starts to circulate: 'John's blob chart' - a pdf image grabbed from the whiteboard after a senior management meeting a few days earlier.
Week 11	Senior CAD designer identifying long-leadtime items for ABC-10 prototype and retrofittable ABC-09.
Week 12	First weekly scheduled meeting of the lower-level, 12-member cross-function team for ABC-10.
Week 14	In order to get ABC-09 machines into customers' fabs at an early date, which are forward-compatible with the new, retrofittable ABC-10 transport module, development work is formally subdivided into three parallel subprojects. Two are led by the ABC-09 programme manager (who is responsible for cost-reducing the design from last year's fast-tracked product launch), one by ABC-10.
Weeks 14-22	Detail timelines for alpha and beta machines are evolved - Gantt charts displayed and revised showing projected lead times to John's blob-chart target dates.
Week 15	MRS (Market Requirements Specification - logically, the basis of a product design in PDP) not yet formally completed, and yet to be discussed with some stakeholders when the Christmas/New Year break intervenes in weeks 16-17.

Week	Key events
Week 18	Commitments: supplies of 10cm aluminium plate are procured for fabricating the retrofit-ready prototype process chamber. Bills of materials have been issued for orders for other long-leadtime prototype subassemblies - eg cable looms - modified from ABC-09 versions through detail design.
Week 20	ABC-10 makes its first appearance in the agenda of the fortnightly PDP review meeting.
Week 22	Accelerated timeline introduced for ABC-10 customer release.
Week 23	Calculation in cross-function team meeting of ABC-10 programme risk index and assignment of risk classification, using spreadsheet tool in the PDP wizard, 'live' in the meeting.
Week 24	Photos are circulated of the prototype transport module assembled in a supplier's factory. Beta test commitments with the customer are firm. Build and test details are being worked out. Conceptual design is over, time to close out the field study.
Week 31	Planned lab trials and customer demo 'marathon' of alpha prototype.
Week 48	Planned delivery of beta prototype.

4 Product stakeholders at work - Cross-function team meetings

Our six-month study generated a large and rich collection of observational data. In this paper we limit our presentation of material by adopting two data-focusing lenses. The first, applied in the present section, is a particular organisational setting: the cross-function team meeting. Our field records contain data from many observed interactional settings, including 'cube huddles' on the Engineering floor, regular scheduled management meetings of several kinds, regular team meetings within the Engineering group, ad hoc exchanges in office and cube doorways (especially the PDP programme manager's doorway) and fortnightly scheduled PDP review meetings. We have chosen to present material from the cross-function team setting because it is richest in diversity of actors and because it is most explicitly, exclusively and intensively focused on the conceptual design of the ABC-10 product. An analysis of activity in this work setting enables us to clearly focus the question: what kind of work do routines contribute to the strategically critical beta-prototype process for the ABC-10 product?

The second data-focusing lens, applied in Section 5 below, is a particular constellation of representational artifacts: the PDP 'wizard'. Analysis of this material will enable us to bring a sharp focus on the contributions made by representations to the beta-prototype process. This in turn provides a basis for a discussion, which connects the work done by artifacts (in Section 7), the ostensive aspects of routines (Section 8) and the implications of a 'performance' perspective on knowledge work, strategy and routines (Section 9).

This limited presentation of data forces us to omit details of at last one important nexus of routines. Through weeks 18-22 we saw the work in the cross-function setting becoming more focused, more fluidly dynamic and more widely extended. We gradually saw that this was associated with the work of 'cut-in' (see the second row of Table 1 below). The design of the machine, and the activities involved in making and shipping the beta machines, were being 'cut in' to HighTech's continuously ongoing, supply-chain operations (bills of materials in the MRP system, cells on the factory floor, shiftwork schedules, etc). Representational artifacts (especially timelines of various kinds) played a central role in this animation and expansion of activity (notably, 'John's blob chart' and its more formally codified offspring). Also, there was an increasingly visible complex of representation-mediated connections between PDP, product development and conceptual design activity, on one hand, and other, more highly routinised kinds of activity on the other (areas of practice such as procurement and outsourcing, assembly, testing and certification against industry standards, and global shipping). A presentation of this substantial, highly dynamic and analytically significant strand of 'cut-in' work needs to be left until another time and another paper. But this paragraph's brief summary figures in what we conclude below (Section 7.6) about the work being done by routines.

4.1 Formal stakeholdings and cross-function teams

When a product development programme is formally initiated in HighTech, the formal operating procedure for product development (PDP) specifies that the founding act should be to nominate individuals as representatives of a number of institutional stakeholdings: Engineering, Key Product Unit, Materials (procurement), Manufacturing, Marketing, and so on. To comply with PDP, these representatives must play a number of assigned roles in quality management in the product development process. Formally, these representatives are implicated in sign-off of both the product and the development process, some of them as 'suppliers' of elements of the product/product release package and others as 'customers' who will approve any given element of the package. Thus, for example, Marketing is a supplier of a 'Marketing Requirements Specification' (MRS) and Engineering is a customer for this; in turn, Engineering is a supplier of design specifications (developed and justified in relation to the MRS) which include the engineering performance of the machine, and both Marketing and the General Manager are among customers for this.

More informally, stakeholders and their nominees are expected to be involved in a process of regular meetings, typically weekly, for the duration of the development phase up to beta release (referred to in HighTech as 'MinShip' - a prototype that meets 'minimum shippable' release requirements) and subsequent general customer release ('CR'). Participants in these meetings form a 'cross function team' which debates, negotiates and agrees stage-by-stage actions and outcomes within the development process, under the chairing of the formal PDP manager for the product programme. Cross-function teams themselves are a form of work organisation that has emerged in this division of HighTech, over two or three years of active development in Quality Management. They are not a formally specified component of PDP (for example,

they are unmentioned in the PDP Handbook) but rather, a local organisational form which is adopted in this division to perform work which, again, is unspecified by PDP. PDP specifies the form of sign-off, by way of a set of post-hoc quality-assessment tasks. But it offers no specification for the operational form of work that has to done to achieve either an engineering design or a viable market release: for example, the Handbook does not specify any kind of engineering design methodology, project plan or form of work organisation. Thus the cross-function way of working on Quality issues, on one hand, and the formal evaluation and sign-off tasks specified by PDP, on the other, are two relatively independent organisational devices which are available within the institutional environment of HighTech, and which are brought to bear in practice in actually developing and approving a beta prototype and a beta product launch.

4.2 Formal tasks and story telling

Over a period of from week 11 to week 15 we began to register the degree to which the quite massive apparatus represented by the PDP Handbook was absent from cross-function meetings (and other ABC-10 venues that we were in, such as the weekly Beamline meeting). The task structure represented in such detail in the Handbook was visible in neither the work being done by the increasing number of actors who were being included in the ABC-10 work process, nor in references made by participants in ABC-10 meetings. At that stage we had not fully understood something which, in the present paper, we have already made clear: that PDP is mostly about the quality certification of achieved outcomes, as distinct from the specification of work that has to be undertaken in order to achieve a certifiable outcome (eg an acceptable engineering design or an acceptable beta-product launch strategy). As the paradoxical absence of PDP, in meetings convened under the auspices of PDP, became more visible, we began also to see a structuring of activity in these events, week by week, of quite another kind. Eventually we came to a description of this structuring in terms of a number of ongoing, concurrent strands of discussion and negotiation. Overall, we developed a sense of the cross-function team as a work setting where a certain kind of very active 'making' was taking place.

The identifiable strands of discussion and negotiation can be seen as addressing multiple, intended, non-exclusive outcomes of a collaborative, evolving course of action (the beta phase of the ABC-10 programme) among the team's members - who, in addition to being capable technical people (design and development engineers, procurement engineers, manufacturing managers, etc) are stakeholder nominees. We note that the seven strands of story-development which stood out are each characterised by a distinctive focus, on a particular aspect of the environment of ABC-10 work: machines themselves, and various stakeholdings in the life and work of the machine as a commitment of business assets. In Table 1 below we have summarised these as 'seven strands of storytelling' in ABC-10 cross-function team meetings.

Table 1
Seven strands of storytelling observed in ABC-10 cross-function team meetings

	The storytelling strand	Oriented to...
1	Making it work, making it fit.	The machine under design, as a novel, complex, engineered, physical artifact.
2	Making it in time, achieving 'cut-in' with ongoing activities in HighTech.	The supply chain for beta tools and the alpha tool.
3	Making it into the fab, gaining the 'footprint'.	The site of exploitation of the machine by the customer, as a major capital investment.
4	Making it similar, making it conform.	External regulatory regimes and operational/commercial regimes.
5	Making it different, leveraging HighTech's resources.	The competition: their machines, strategies, etc.
6	Making it strategic, making it to the next node.	Corporate business agendas: above all, level of gross margin on costs.
7	Making it legitimate, achieving sign-off.	Total quality: complying with the concern of corporate stakeholders, to verify and ensure that commitments of assets are made in approved ways and signed-off by approved people.

Overall, we observed that these strands of interaction were articulated through telling and elaborating (and challenging, amending, negotiating and confirming) 'stories' about the course(s) of action that participants were engaged in. There were stories about 'what this product will contribute to the business', 'how this product will be constituted, physically, financially and operationally to do this' and 'how we will organise this stream of events and outcomes to achieve a beta launch'. To emphasise the active nature of this, its utter strategic seriousness, and the highly focused and skilful attention that participants gave to this kind of activity, we might label it 'story development' rather than story telling. In other words, story development appeared to be a central and intrinsic aspect - perhaps even the primary mode - of product development work (certainly, in the formal setting of cross-function team meetings). The work that stories in general contributed to (different stories making differing contributions) included identifying, mobilising, interpreting and adapting both routines and the representational outcomes of routines, as resources in particular contexts.

1 Making it work, making it fit

The beta and alpha tools must work as novel, complex, engineered, physical artifacts: processing wafers and putting ions in silicon very precisely in microscopic dimensions, with acceptable quality, at acceptable speeds, with acceptable costs. The

process technologies (plasma physics, silicon physics) are arcane and subject to continuous exploration and mapping in HighTech's own labs and elsewhere. As subsystems of the complex machine are modified through redesign in each new version of the ABC machine - and thus, change their 3D shape - they interfere with each other physically and electro-magnetically. Getting a modified machine to work acceptably, even when very similar machines have been manufactured before, thus remains a challenging n-dimensional engineering jigsaw puzzle.

2 Making it in time, achieving 'cut-in' with ongoing processes

As fully operational prototypes the beta (customer) tools and alpha (HighTech lab) tools need a fully configured small-batch supply chain involving external module-building contractors and substantial procurement of materials. We observed that conceptual design activity lacked a settled sense of coherence and pace, until a timeframe was defined for the shipping of beta prototypes (around week 18). From that point, cross-function team activity manifestly fell into shape around the challenge of getting relevant material and staff resource into the right place in that timeframe.

3 Making it into the fab, gaining the 'footprint'

In this strand participants addressed their attention to the site of exploitation of the machine by the customer, as a major capital investment: operational capabilities, lifetime cost, logistics and economics of installation and commissioning. The machine must be made desirable, acceptable - and preferred - in the customer's worksite ('the fab'). Getting and maintaining the footprint - literally, a historically defined, dimensioned area of precious fab 'real estate' - is a basic premise of marketing in this industry.

4 Making it similar, making it conform

HighTech's products must comply with external regulatory regimes (industry standards, mandatory certification). There also is powerful pressure to conform with existing operational and commercial regimes in customers' industries (since requalification of an updated and improved tool against a customer's process recipes, for example, is a high-cost disturbance for a customer). Departing minimally from previous, already certified designs and processes is the least risky way of making the machine conform.

5 Making it different, leveraging HighTech's assets and resources

A new product release must do things that a HighTech machine has never done before. This is in direct tension with the 'similarity' criterion, above. HighTech does have choices that can be made, regarding how far the new machine differs: in component and subsystem design, in architecture and functionality; in sourcing and cost; and so on. The essential focus here was on competitors: their machines, pricing strategies, product range, market position, installed base, sectoral strength, and so on.

6 Making it strategic, making it to the next node

'The next node' is a roadmap planning concept in the semiconductor industry, referring to the next expected transition in product and process technology. There is a persistent issue in HighTech, directly expressed in terms of gross margin, regarding whether the business unit making the product will be in existence at the next node. The business environment is highly competitive, and both permanent and contract staff show themselves highly aware of this. In the conceptual design setting, we saw the mission of Cost Reduction being constantly brought forward (notably by Materials - the procurement function) as a proxy for Gross Margin; which is a proxy for the survival of business units and jobs. In the ABC-10 beta launch, an acceptable (and previously unattained) level of gross margin had to be achieved - or very strongly prefigured - in the beta prototype.

7 Making it legitimate, achieving sign-off

This seventh strand is concerned with making the tools (and the paths to achieving the tools; and the future commercial and financial paths 'subtended' by the beta tools) legitimate as *commitments of assets*. This was the Total Quality agenda; operationally, it was a matter of complying with the concern of corporate stakeholders, to verify and ensure that commitments of assets are made in approved ways and signed-off by approved people. This strand contrasts with the other six by being largely retrospective: a matter of accounting acceptably, ex-post, for actions taken and resources committed - a formal and highly significant *evaluation event* in the cycle of product and business capital. The other six strands are largely formative or proactive: focused on organising beta and alpha *tool events* (a machine, ready for use in a location). The greatest degree of routinisation was observed to lie within this seventh strand of practice. Further material relating to the sign-off strand of activity is presented in the next section, which deals with the PDP wizard.

5 Representations at work - The wizard

As we began our field observation we were aware (from earlier conversations with HighTech managers) that product development activity in HighTech was defined globally as a business process, via standard operating procedures (and central among these, compliance with a mandatory, formally specified process model, referred to as PDP) and formal documentation (a large and detailed PDP handbook). As a mandatory process, PDP carried an extremely powerful sanction to secure participation and compliance across the multi-divisional, multi-site corporation - namely, that a product division cannot receive revenue from a new product (and thus bears all costs of development up to that point) until it has been formally certified as a product release (CR: customer release) via the sign-off machinery of PDP. We discovered that PDP was partly enacted through participation in a set of procedures which were hard-coded - as workflow, forms, classifications and data structures - in a corporate-standard, universally available, Lotus-Notes application: the PDP 'wizard'. Sign-off can only be formally achieved by completing specified documentation, explicitly held in and accessed through the wizard database.

5.1 *An apparatus of representational artifacts*

In the workplace, we observed that PDP manifested not so much via the book of *specifications* (the PDP Handbook, available on a corporate fileserver), but rather via a *working apparatus of representational means*: the 'wizard'. We learned that each product development programme must formally initiate a PDP process and establish a programme wizard. 'Has he created the wizard yet?' was a question that people asked to determine the status of a product moving from research to development. Over time, we were able to see three key contributions made by a wizard. First, a wizard furnishes master copies of checklist-type documents in which nominees for specified stakeholder roles are formally recorded. These were used in the formal 'kick-off' phase of the ABC-10 product development programme. This activity was concentrated in a period of a few days, in Week 6. Second, a wizard furnishes masters of the materials and tools which are mandatory in submitting for and achieving compliance with the requirements of PDP phase-exit: document proformas, metrical algorithms, and records of completed (and not-yet completed) quality-certification tasks, organised in a prespecified hierarchy. Finally, as a workflow machine linked with a documents-in-process database on a network server, a wizard automatically performs document distribution functions that are involved in sign-off. This is a massive and mandatory, proceduralised and automated artifact-centred (documentary) apparatus. Nominally - *ostensively*, we might say, in the language of Feldman and Pentland - PDP 'is' the process (the routine, or family of routines) for developing products in Hightech; and the wizard is PDP's ostentatious and mandatory artifactual form in the workplace. And here we found ourselves facing what seemed to be a paradox, as follows.

At Week 24 we exited the company, because the conceptual design phase was manifestly completed. Tonnes of 10cm aluminium plate had been procured, cut and welded (in another country) to make process chambers for the alpha and beta machines. Massive high-voltage cable looms were being fabricated in a supplier's factory. The three main complex modules of the machines were under assembly in suppliers' factories and one of them was ready for shipping to a reserved piece of precious real-estate on the HighTech clean-room factory floor for final test-assembly. Transcontinental shipping commitments had been made with the beta-customer, and installation and commissioning timeslots and real-estate footprints were scheduled in the customer's fab. In other words, the concept of the ABC-10 machine, and the machine's launch into the market as a beta prototype, and the machine's contribution to HighTech's business strategy, were so fully developed at Week 24 that they expressed themselves in this very substantial commitment of business assets and physical materials across the face of the globe and across dozens of companies: financially, the commitment ran to hundreds of thousands of dollars. And yet, when we looked at the PDP wizard in our last few days on site, we saw that the wizard's own completion statistics showed that the wizard was 98 per-cent empty. Ninety-eight percent empty! A massive material and financial commitment to a product's insertion into the market; and an empty wizard? We had to think hard about this: whatever the work is that a PDP wizard does in product development, it's not the

work of producing conceptual designs and commitments to beta prototypes. By Week 24 those kinds of work had been done, and they had been done using some other kind of means.

Along the way we had gathered clues about this 'absent presence' of PDP-as-the-wizard. Activities involving the wizard (completion of its hierarchically organised task-completion proformas) were being treated by actors in the ABC-10 development process - and being explicitly referred to - as deferred, subsequent tasks, *following on* from the activity of conceptually configuring a product and materially configuring and 'cutting-in' a beta launch. These activities were also referred to as *overheads*, burdens and administrative chores: "Come in and see me doing this one night at 9-o-clock"; and even "a waste of my time". We were in the audience for one formal presentation, in a fortnightly PDP review meeting, where a product development programme manager explained how various working materials from a development project had been converted into legitimate wizard material ("populating the wizard") at a late stage in the PDP timeframe, as development was hardened into beta commitments and beta sign-off (MinShip) approached. At Week 24 in the ABC-10 timeframe, sign-off was still something like 24 weeks away. Obviously there was still lots of time for populating the wizard and enabling it to do its work, downstream of conceptual design.

Obviously, too, this was a normal distribution of effort across project time. We began to see that treating PDP and the wizard in this way was not in fact a breach of formal requirements. The PDP process handbook provides explicit and mandatory specifications for the roles of representatives in the formal approval of product development processes and outcomes but, significantly, it does not specify how to get from A (roles) to B (outcomes). Neither work method nor work sequence is specified. The wizard is designed to contain and present representations of achieved *outcomes*: on one hand, summary indices of quality, and on the other, certificates of approval, co-signed by formally registered signatories. These outcome representations are only loosely related to any practical course of action that may be taken in achieving them. Managers then have a high degree of discretion in the actual conduct of *product development*, as distinct from *product sign-off*.

5.2 *Representations and representatives - Formal routines and formal authorities*

The start-up resources of the PDP wizard had been used in week 6 to launch the program. At Week 24 the remaining resources (almost the entire content of the wizard) still awaited their use, in the end-of-phase accounting and evaluation process which would not close-out until roughly week 48, on our timescale. The PDP kick-off meeting for ABC-10 in Week 6 had been a very full room, with an unusual number of higher-ranking actors. There was some contention over the dramatically short timescale being laid out for ABC-10 by the PDP manager, and also the machine configuration, with questions regarding whether a machine of that kind could meet some of the market challenges (at that point - and indeed, even as late as Week 18 - no finished MRS had been produced). The kick-off meeting was an inaugural

gathering of representatives of stakeholder interests; and the checklists of the wizard were used in the meeting - literally, completed on a laptop and displayed on a projection screen - to register the nominees of those stakeholder interests, for the formal purposes of PDP. Thus, right at the start of its existence, the ABC-10 wizard displayed its basic role, as a collection of *representations of outcomes* of activities conducted by stakeholders in ABC-10. And the first representation to be created in the wizard was a representation of *representatives*: a map of formal authorities in the context of ABC-10's lifecycle as a HighTech product-in-the-making.

From this point, three significant things were available to the development programme manager. First, he was now authorised to convene those representatives in PDP meetings. Second, he was authorised to commit resources to ABC-10, the most immediate and practically significant of which were hours of representatives' time, in cross-function team meetings. It was no small matter, to have authority to add one more 60-minute meeting to HighTech's crowded weekly schedule. And third, he was guaranteed legitimacy for the outcomes of the development process, to the extent that due process was conducted with those nominated representatives (including eventual certification in the wizard). In a context of corporate politics and legitimacy, then, the early work done by the PDP wizard was highly significant, even if it was in a sense trivial - filling-in a proforma checklist on a laptop, in full view, in a meeting.

What those representatives then went on to do, in cross-function meetings over the next eighteen weeks, was highly dynamic and was accomplished with means that lay largely outside PDP. In Section 4.2 above (the 'seven strands') we have described how meetings were taken up with story telling. The stories - as strategy stories - certainly were linked strongly with the missions, responsibilities, authority and committed courses of action of PDP stakeholders (different representatives having different authorities with regard to particular strands of story telling). But the work of story-making and commitment-making lay quite outside the representational domain of PDP's artifactual representative: the wizard. Many representations were deployed in cross-function meetings: Powerpoint presentations were always provided as the basic, explicit reference material for segments of each meeting. These (ad hoc) Powerpoints had no status whatsoever within the formal apparatus of PDP. They formed a representational apparatus of working material quite distinct from the prespecified representations which populate a wizard. And the work that they supported was the work of story-making (in the meeting) and commitment-making (with regard to courses of action which would stem from the meeting). Having ensured that relevant authorities were identified, and thus were likely to be in the room for ABC-10 working meetings, PDP seemingly had little further contribution to make to the beta product until it approached sign-off. Certainly, the work of conceptual design and beta resource committing - far advanced at Week 24 - was done with other resources, prominent among which (in our observation) were *speakable representations* (strategy-stories which represented interests and commitments of corporate stakeholders), *visible representations* (notably Powerpoints) and *human representatives* of institutional authorities.

6 Routines at work in ABC-10 work settings

In this section we adopt a definition of routine that is consistent with the widely accepted ones, with regard to the prominence of pattern, the participation of multiple actors and the interdependence of actions (across actors, across work settings and across situations in time). However, our perspective differs in two specific respects.

The first difference concerns *repetition and recurrence*. We discussed this in Section 1.2 above, and noted that our own approach centres on continuity and the mundane (re)production of working order. The second difference concerns *formalism*. We feel that 'pattern' in a broad sense is too inclusive, embracing simply any form of behaviour patterning. We ourselves are very concerned to be clear about the structures and structuring of action. But we are not convinced that it is wise for the 'routine' construct to be made to carry all the burden of this theorising. Thus we have chosen to work with a range of constructs which handle, in a variety of ways, the diverse forms of order that can be observed in conceptual design practice in HighTech. We set out with a preselected focus on certain kinds of artifacts (visible representations), and the ways in which such artifacts are ordered, and mobilised in the (re)production of order in episodes of interaction in conceptual design work settings. In those work settings we found our attention drawn powerfully to other forms of order and production-of-order, notably the narrative ordering of the emergent practice of the ABC-10 beta prototype and the beta launch: story telling, story development.

These other conceptual tools (coupled, of course, with an appropriate observational approach) are well able to handle many informal dimensions of interaction, practice and working order. Thus, we feel able to adopt a narrowed working definition of 'routines' which focuses on the more formal aspects of practice in the organisational setting. In the present section, then, we restrict the term 'routine' to forms of patterning in action and interaction (for example, the flow of events) which are explicitly *prespecified* or which employ *forms of representation* which are explicitly prespecified. It is probably not accidental that many of these forms are also *mandatory*. Thus, our working definition of routines in the description and analysis that follows is: forms of interaction that are patterned in conformance with explicit specifications, and/or which make prominent, required use of forms of representation which are explicitly specified. By focusing on these 'formal routines' in HighTech, we do not lose focus on informal patterns and patterning (because these are kept in the analytical frame by constructs such as narrative, the mobilising of visual representations - and of course, the (re)production of working order). And as it turns out, we gain in discrimination, because some of the work settings we observed in HighTech showed quite different profiles of formal routine, as distinct from other, less formalised, forms of order and ordering work.

We present two instances of formal routine and formal representational artifacts being prominent in ABC-10 work settings: the ABC-10 kick-off meeting, and regular generic PDP review meetings.

6.1 *The kick-off meeting*

The kick-off meeting for the PDP programme was the most formal event that we observed in any setting associated with ABC-10. First, the flow of the meeting was organised around representations formally specified by PDP and held in the wizard: a checklist of programme stakeholders. Names of nominees for these specified roles were entered into a proforma provided by the wizard, visibly displayed on screen and entered field-by-field scrolling down the form, as part of the live business of the meeting. Second, participation in the meeting was very wide; it constituted the fullest showing of ABC-10 stakeholders that we saw at any point during the 24-week period, in any work setting including generic PDP reviews and ABC-10 cross-function team meetings. Third, the kick-off event itself was formative in a formal way: by virtue of completing this formally specified element of the PDP procedure, the programme manager was able, subsequently, to legitimately call on and deploy both financial resources and the intangible resources taken up by participation in cross-function meetings, in forms of activity some of which were not themselves formally specified by PDP (notably, cross-function team meetings).

At the same time, half or more of the kick-off meeting was taken up with activity which was not specified by PDP, or by any other formal routine of which we were aware. The programme manager presented images of the projected form of the ABC-10 machine, and a bullet-pointed rationale for the design and launch of the machine. This was done with powerpoints in a way which was ubiquitous in all kinds of formal meetings and many informal ones too: an ad-hoc presentation sequence of slides assembled ad-hoc by the presenter, including numerous pre-existing representations, mobilised as part of the presentation of a narrative about the composition of the ABC-10 machine and the rationale and timing of its launch. None of these were recognisable as formally specified by other routines; most were typical of forms of representations used in other venues such as Beamline meetings, product-unit management meetings, engineering teleconferences and cross-function design reviews.

6.2 *PDP review meetings*

Generic PDP review meetings were held every two weeks, in a regular timeslot. Their central aim (a strong 'ostensive' aspect) was to achieve planned and formally scheduled phase-exit events for PDP programmes. Meetings were convened and led in a formal chairing style by the PDP process manager (a formal quality management role, occupied by a person who has no specific involvement with any actual PDP programme). All development programmes currently active under PDP were required to present and discuss progress at these meetings. The flow of each meeting was organised in segments, each of which centred on the presentation and discussion of a 'dashboard' representation that was specific to this venue. It was a composite of three distinct representations: (i) a graphical timeline (showing critical specified events in the lifetime of a PDP programme, on a week-by-week timeline, with the current week highlighted); (ii) a scorechart matrix showing status (good to bad, represented by

standard 'smileys') against six specified dimensions of responsibility; and (iii) text bullet points to highlight critical issues. The dashboard itself did not seem to be specified in any formal description of PDP, but the use of the dashboard - a highly formalised representational artifact - was fundamental to the organisation of activity in this particular work setting, which was convened formally to achieve critical, specified PDP outcomes. These meetings were formally minuted, had a formal, pre-circulated agenda and pre-published the dashboards for each programme to be discussed. Thus, in this work setting, formal procedure and standardised representational forms were closely coupled, with the latter providing a strong means of ordering the flow of the meeting.

7 Context, artifacts and an evolving order of work practice

This is the first of two discussion sections, leading to this paper's conclusions. In the present section we focus on the work being done by artifacts - especially, representational artifacts - in the conceptual design activities observed in HighTech. This discussion makes one kind of connection with the notion that routines have 'ostensive' and 'performative' aspects. It also develops an interpretation of context, fulfilling one of the central aims of this paper. In Section 8 we focus on routines as dispositions and assemblies of resources. This leads us to consider both the dramatically different kinds of resources that are involved in achieving innovations and commercial successes, and the forms of organisation through which *commitments* (of resources) are made and maintained in the evolution of HighTech's ABC-10 product.

7.1 'Context' as a way of thinking about pattern in an organisation

A basic construct in thinking about routines is pattern. In our present analysis we adopt a particular perspective on the patterning of activity. We address live work practice as displaying and being constituted through a complex system of 'working order' (in fact, a system of multiple orders of practical organisation) which is continually and routinely organised and maintained by participants. That is, producing and reproducing order is understood to be a mundane and intrinsic aspect of work as collective action. Routines are commonly addressed as repeated patterns of behaviour. In our chosen perspective, *behaving* (by individuals, in response to stimuli) is replaced as a foundational construct by *working* (collaboratively, by acknowledged participants). We do not mean to write a psychology article here, but we do want to highlight the possibility that these distinct perspectives offer differing resources in developing our thinking about the work that routines do.

One feature of our work-practice/multiple-order perspective is that it directs attention naturally and forcefully to what we regard as a central and under-theorised construct: 'context'. In this perspective, a basic feature of the work being done in any setting is the recognising, displaying, producing, negotiating and maintaining of context(s) - for action here/now, in an episode of interaction, in a workplace. In this view, context is not something external, prior and independent which conditions something which -

independently and contingently - is being done by an individual (for example, performing a routine). Rather, the relationship is the inverse of this: when a routine is performed, it contributes as part of a system of multiple resources and multiple orders of practical organisation, which are being mobilised in the doing of work, which centrally and mundanely includes the active, 'live', shared management of context by participants.

Operating within this frame of interpretation, in this subsection we offer an analysis of dimensions of context which can be seen to be present in HighTech's employees' interactions in conceptual design. We note:

i) The temporal-evolutionary context of episodes - stories about 'The Big Picture'.
ii) The material-artifactual context - representations in the work setting.
iii) The local-focal context - differentiated venues (locations) for interaction.
iv) The spatial-institutional context - things that are understood to happen offstage.

We do not suggest that this is a complete breakdown of 'context'. Nor are we proposing these four categories as an exclusive model or theory-of-context (though we are quite sure that equivalent categories will generally be significant in an analysis of interaction context in a corporate institutional setting). We offer this framing as a way of presenting, simply and pragmatically, some of the things we observed to be manifestly relevant to participants, in furnishing them with resources for doing the work of beta-phase product development, in observed work settings.

7.2 *Temporal-evolutionary context (The Big Picture) - Strategy stories and large scale courses of action*

A large part of the activity of cross-function team meetings (described above, for example, in terms of seven strands of negotiation and storytelling) involves orientating to, and articulating with, multiple ongoing courses of action on different scales. Some of these - in fact, all of the identified 'seven' - are highly strategic and explicitly evolutionary. They concern the relationships that HighTech needs to maintain and develop with the dynamic outside world of semiconductor manufacturing (eg market share, product leadership, footprint in the fab, transition to the next node). These courses of action also concern the active, purposeful and justifiable ordering and re-ordering of those resources and assets which are at the disposal of HighTech's managers; specifically, in our observed settings, the assets that will be organised into the beta release, and into the subsequent product lifecycle which will follow if the beta phase is signed off. These courses of action include core missions of the corporation - highly intentional, large-scale courses of action which span the entire corporation.

Courses of action on this scale - for example the evolving (or at least, aspired-to) practice of radically increasing gross margin and guaranteeing it over an entire product lifetime - afford *stories* which we observed to be mobilised as resources by the cross-function teams, in articulating their own, emergent, local course of action: the conceptualisation, manufacture and beta release of ABC-10. Other courses of action furnish *audiences* for the accounts that can be produced using these story-

resources. Thus, a large-scale course of action in HighTech (namely, disciplining and guaranteeing local activity in worksites and divisions corporation-wide, via explicitly formulated canons of Quality and best practice) owns PDP, a global standard operating procedure. And as we have shown in this paper, one of the things that PDP does, as a formal system of routines, is to formally construct audiences for the stories constructed in cross-function team meetings (both in the room 'live', and across the global document-distribution network of the PDP wizard).

7.3 Material-artifactual context (Things that are to-hand in a work setting) - Representations and artifact-memory

Representational artifacts are prominent in conceptual design work settings in HighTech. As researchers of 'the evolution of business knowledge', this is the main reason we chose to observe an engineering conceptual-design setting in the first place. Engineers and CAD designers sit down to talk around drawings; cross-function team meetings and workgroup meetings are never held without Powerpoint presentations being brought, displayed and spoken-to by nominated speakers. In these ways, in an interactional episode, material artifacts furnish immediate context for participants' action. They are visible, manipulable and usable as resources in various ways. For example, they can be collectively read, they can be taken as occasions for story-telling, they can be gestured-to (thus providing landmarks and mutual orientation as work proceeds: artifactual 'memory'). Artifacts thus afford 'speakables' - things to speak about, occasions for story-telling. By the same token, they afford indexicality: participants may gesture at them as part of the process of establishing mutual orientation to 'the work we are doing here'. In informal interactions - for example, cube-huddles of engineers and CAD designers - representational artifacts were frequently modified in the course of the episode; the CAD designer would tweak the CAD model at his workstation, or the ABC-10 programme manager would annotate the chart on the table between him and the CAD designer. But in more formal settings (ie regular, scheduled presentations, such as beamline meetings, cross function meetings and PDP reviews) the representational media that were central (ppt presentations containing embedded jpgs, spreadsheet views, and so on) did not afford the possibility of direct changes in the representation (the CAD model, the spreadsheet) in that work setting. Typically, specifications and agreements regarding such changes, in a subsequent work activity in some other work setting, were negotiated as outcomes of the current meeting.

7.4 Local-focal context (What we are doing here/now) - Venues

As in any formal organisation, events of certain kinds furnish a repertoire for formally-convened activity in HighTech: the ubiquitous 'meetings'. In an ordinary week on the Engineering floor there are beamline meetings, engineering management meetings, cross-function product-team meetings, PDP review meetings and KPU (key product group) meetings. Each conducts its own business and constitutes part of a division of labour. These events are strongly patterned - for example, with regard to timing they are routinely scheduled: beamline at 10am Monday, etc. Each meeting is

attended by a customary or mandatory selection of people representing various hierarchical roles and functional silos. They have a format and a usual selection of forms of input: presentations of lab data in beamline meetings, for example, in contrast with spreadsheets comparing quarterly projections of engineering and commercial cost reductions, in cross-function team meetings. Because of the strong patterning, these events would naturally be seen as part of the phenomenon of routines. However, we would like to distinguish them from routines, and for this purpose to give them a name: *venues*.

Venues furnish formal occasions for interaction, and the standard 'shape' of a particular venue affords stories, audiences and artifacts across a customary range which is characteristic of the venue. A PDP review meeting, for example, operates with specific representational artifacts (e.g. a particular kind of timeline representation) that do not appear routinely (or ever) in a PDP-convened cross-function team meeting; and both the procedural format and the membership in a PDP review differ from those of a cross-function team meeting (more proceduralised, involving representatives of multiple product-development projects). A venue furnishes a 'package' of resources for its participants' interaction which may well include a set of routines. The PDP review venue, for example, is characterised by the repeated enactment of a review-template (around a specific timeline representation) for each project. In contrast, the cross-function team venues for ABC-10 had ad-hoc rather than standardised agendas and procedural sequences. Once the PDP programme had been initiated (with a formal kick-off meeting which completed a prespecified proforma-listing of role-holders in the programme-process) it was rare to see a formal routine performed in a cross-function meeting. We saw this once, when a risk-evaluation spreadsheet tool from the PDP wizard was run in a meeting - which also was the only situation where we saw a representation being modified hands-on in a cross-function meeting,. This normally was a presentation venue rather than a hands-on venue with regard to the representational artifacts primarily used ('frozen' Powerpoints as distinct from the 'live' spreadsheets or CAD models of other work settings: see Whyte *et al* (2007)).

We suggest that a useful distinction can be made, between a venue and a routine. A venue is a particular form of gathering - an interactional event - which routinely and formally occurs (thus, scheduled meetings in a formally recorded calendar) and which routinely furnishes particular resources for those participants who are convened in that 'place' on any occasion. Some of these resources are the physical furniture of a physical place: projectors and screens, wi-fi and LAN connections, flip-charts and whiteboards, whiteboards marked 'PLEASE LEAVE: RS'; and so on. Other resources are 'cultural' (in the sense of 'to do with meaningful, recognisable and acceptable action'): examples include registers of speaking and forms of address, context-specific lexicons and stories, roles brought to or allocated in a venue. A routine, on the other hand, is a container, holding resources which prominently include a specified or expected model of process, and which is mobilised in 'places', but it is not itself a place. Some of the resources held in routines, as with venues, are material artifacts.

But they need not be as immobile (and thus 'place-like') as those that mark out a venue.

Venues and routines can and often do combine. For example, a particular routine can be performed on a scheduled basis, and thus serve as a place-in-time where activity can be convened. (Equally, and in contrast, some other routine may be a contingently mobilised response to irregularly occurring conditions.) In this way a routine can become a venue. Conversely, however, a venue is not necessarily constituted by the enactment of a given routine. A particular venue may be furnished with a prominent set of routines which routinely are mobilised in the conduct of business in that venue. Fortnightly PDP reviews are an example in HighTech. Cross-function meetings are a counter-example, where business is ad-hoc, determined by the convenor. Formal events all employ some (informal) routines - for example, the Powerpoint presentation routine is ubiquitous in HighTech: assume the presenter role, connect a laptop to the projector, display ppt slides, talk-through the sequence. But this is a broad genre of activity across large sections of practice in HighTech (and indeed, *genre* may be a more powerful concept to draw on than the broader 'informal routine', when addressing forms of activity involving representational artifacts). It does not characterise any particular kind of venue, being enacted not only in cross-function meetings but also in KPU meetings, beamline workgroup meetings, 'all hands' briefings by top managers, design reviews, and so on.

7.5 *Spatial-institutional context (Who works on what, where) - Things that happen offstage*

Beyond the immediate artifactual context of an episode of interaction, wider geographies of physical and institutional space were manifestly relevant. We characterise these here broadly as geographies of work-movement (which includes artifact movement: documents, pieces of machinery, raw materials, etc; and human-movement: on foot, in planes and trains and cars). These geographies of work-movement map work around the building, through the manufacturing supply chain, across the administration of the corporation, out there in the networked on-site delivery of customer services in fabs. These geographies furnish participants in a setting with a common repertoire of speakable and gesturable references to actors, locations and work that are to be found 'offstage', in some other time or place. They furnish indexical resources, which enable participants to establish a relationship between 'us, here, doing this, in this venue' and other things done elsewhere.

Thus, for example, the following geographies furnished indexical resources for the conduct of interaction in conceptual design settings on the HighTech Engineering floor: the machine downstairs (an earlier model in the ABC line, operated on a shift basis by technicians in the applications lab); offices of HighTech in Silicon Valley, Texas, Boston (where experts or managers had their workplaces and pieces of experimental machine were being worked with, or forms in the wizard would be signed); the manufacturing sites of outsourced module suppliers for the ABC-10 prototype and the physical materials involved in the beta machine (massive slabs of

10cm-thick aluminium, cumbersome looms of high-voltage or instrument wiring; being worked on, being moved around the globe) in the Netherlands, China, England, Ireland; the installed base of ABC-family machines (and their associated, on-site, human, HighTech 'servants') located in fabs in the USA or the far East.

All of these furnished 'indexical speakables'. For example, 'Boston', 'the machine downstairs' and 'the aluminium for machine ABC10-99' were all invoked at some point, in rooms on the Engineering floor, as references to elements in a web of ongoing practice. These elements are distributed in an extended, material, geographical-institutional space 'offstage', available for indexical reference to all who are present 'here'. At the same time (through the very process of invoking them, and working the references into the present process of story-negotiating and resource-committing) they are related to what is being done here-and-now in the current venue.

7.6 Routines elsewhere and representations as work-glue

One final point of emphasis. Across the work-landscape of ABC-10 there exist many differentiated domains of practice; and they vary substantially in prominence of routines. We have shown - somewhat to our surprise - that the massive, ostensive apparatus of formal routines in PDP does not figure prominently among the resources mobilised in a large and pivotal component of product development work. The most prominent resources being mobilised in observed conceptual design work settings were of other kinds, including 'speakables' (such as strategy stories belonging to diverse large-scale courses of action across HighTech) and 'visibles' (many kinds of representational artifacts not belonging to PDP). To put the sharpest possible framing on this, we can say that what was doing a lot of the work in conceptual design was *not routines, but representations*. Having registered this fact, we then need to say that very many of these representations were made available (for the ad-hoc, informal usages of the cross-function team) by *routines elsewhere*.

Thus: the Powerpoint patchwork that is brought to a cross-function meeting is a container for many representations that have been generated in work elsewhere which is rather strongly routinised and formally codified. These other areas of work include, for example: financial reporting and planning (eg spreadsheets of quarterly cost-reduction projections), engineering detail design (eg machine layouts, design costings), standards compliance (S2/S8 certification) and supply chain and manufacturing operations (cell occupation schedules for the HighTech factory, Gantt charts for scheduled deliveries of individual ABC-09 or ABC-10 machines, etc). These ongoing courses of operational and tactical action continually generate an ecology of representations, which then is constantly and mundanely drawn on to generate the Powerpoints that are assembled ad-hoc for today's update at the ABC-10 cross-function meeting.

Thus we might say, as regards the balance between routines and representations in the strategically important work settings that we have analysed here: representations do

the work *here*, in this low-routine setting; and routines elsewhere do the work of ensuring that representations are *available* here.

8 Architecture, routines and dispositions of resources

We are developing an evolutionary interpretation of observed conceptual design activity in HighTech, in terms of courses of action, being articulated episodically in work settings. Various resources are mobilised in the course of doing the work in the setting, and at the conclusion of an episode, commitments of resources have been negotiated. Thus dispositions of resources also are evolved. This constitutes an evolutionary mechanism through which a working order of practice is maintained, elaborated and modified. Working order is established and managed on both a local scale (the work of the ABC-10 cross-function team itself, through the 24-week span of conceptual design work within the beta release phase) and a large scale: the commitment of assets (ie working capital) and resources (eg representational artifacts) to manufacturing operations for the beta prototypes in the first instance, and customer-released production models subsequently, across a full product cycle.

In the previous section we described the architecture of conceptual design practice as being made up of a number of differing orders of 'context', all simultaneously present and acting in the cross-function team work setting. The emphasis there was on storytelling, and on order(ing) in the sense of sense making. In the present section we will concentrate on what kinds of components it is that are organised within the architecture. Our analysis in this paper has been in terms of articulation work being performed in work settings via the observable mobilisation of resources of various kinds. In this chapter we draw the connection between 'resources' as identified in this analysis, and routines. Thus our emphasis here is on working order and the disposing (and redisposing) of resources.

There is a sense in which we are offering an interpretation which is thoroughly 'resource based', and this seems appropriate with regard to the relationship between evolutionary economics and resource-based theories of the firm. We note, though, that a resource in an ethnographic/ethnomethodological analysis of interaction differs quite a bit from the resource construct that typically prevails in economics. In our language, a formal (eg balance sheet) asset is certainly a resource for interaction, but the overwhelming majority of (informal) resources are not assets of a financial accounting or commercial kind.

8.1 The 'ostensives' of work in cross-function teams

The ostensive aspects of routines are the descriptions that people resort to when they need to speak about and refer to work which is organised by routines. Without assuming anything about the extent to which particular work is organised by routines (as distinct from other forms of resource-organisation), we may review the prominent 'ostensives' of the work settings that we have analysed in this paper.

First, we have noted the prominence in HighTech conceptual design work settings of ways of speaking about (specifically, constructing narratives about) what participants and others do: either in general or specifically, in the immediate context of speaking. We have observed them to tell stories which, in the present analytical context, we can regard as speakable representations of work (*'speakables'*) on a number of levels.

Second, these speakable representations and representational resources (for example, lexicons of terms, or classifications) can be contrasted with other representational resources which are visible (*'visibles'*). We began our field observation with a focus on what we referred to as 'visual representations' (which came from a prior awareness of the significance of visual as distinct from textual or numerical representations in the handling of knowledges in engineering design work). We observed that the classical form of engineers' hands-on visual reasoning (sketching) occurred very little in cross function meetings, and a rather large amount of work was done by talking around representations in publicly displayed static formats (overwhelmingly, Powerpoints). Thus we distinguished these 'visibles' from engineers' *visuals*. The importance of visibles in cross function meetings was that they were made available in the process of producing and negotiating speakable representations: stories and agreements.

Thirdly, as we have described in Section 7. 5 when discussing the work landscape, participants in meetings were able to make significant use of indexical references not only to artifacts and actions in the room, but also to actors and locations elsewhere, 'offstage'. To contrast with speakables and visibles, we can refer to these representational resources as *'gesturables'*. One of the things that venues do, as distinct from routines, is that (because they are 'places' in space and time) they furnish gesturables - indexical references - as well as speakables and visibles (which routines also furnish).

Finally, there were occasions - notably rare - when the formal representational apparatus of PDP was deployed in the room. These representational artifacts were presented as visibles (projected on screens from laptops). But unusually, they were manipulated in the work setting, and not simply spoken about or spoken from. This kind of usage occurred only twice in our observations: once in the kick-off meeting (a checklist of stakeholder roles in the first case) and once in a critical meeting that evaluated the risk of the ABC-10 project (a spreadsheet of risk indicator values). In these instances the appearance of PDP ostensives (bits of the wizard) in the cross-function work setting signalled a particular kind of work: 'for the record', legitimate, publicly negotiated and recorded within the wizard. We might distinguish visible resources of this kind by applying the term *'formal accountables'*. One of the things that formal routines in the ABC-10 context do - and which they bring to the venues where they are mobilised - is that they furnish formal accountables.

8.2 *Resources furnished by routines - The routine as a cultural 'kit'?*

In the particular settings that we have analysed here - primarily, cross-function team meetings - we rarely observed 'performances of routines' (in the sense of formally specified activities; or activities that required the use of formally specified representational forms). Rather, we observed performances of *work*, articulated through mobilising resources which included resources afforded by routines. Some of these routines belonged to the formal domain of activity (new product development - formally identified as the PDP domain) and were enacted in the room. Most of them belonged to other formal domains (financial planning and control, materials procurement, manufacturing and supply operations, etc) and were enacted in other locations, so that it was resources *that they had produced* that entered the work setting (notably, in our analysis here, representational artifacts of many kinds). In the highly dynamic, manifestly 'evolutionary' and apparently improvisatory work setting of the cross function team, speakables from PDP were much more in evidence than visibles and formal accountables. For example, some of the basic *categories* of PDP were ubiquitous (eg 'MinShip' and 'CR') and detailed episodes of interaction were quite frequently taken up with placing a particular event or resource under discussion into an appropriate category within PDP-speak, as part of the larger ongoing work of developing the *legitimate* story of the ABC-10 beta prototype and its entry into the fab of the beta-test customer.

In the light of our evidence and our chosen observational-analytical focus, we are inclined to view a formal routine such as PDP as a 'kit' of cultural resources, and especially, of specified (sometimes, mandatory) representational forms, some of which are mobilised as visibles in collective work settings. The representational forms include formal specifications (for example, for stakeholder roles, or for the computational logic of formal quality assessment - but not, in the case of PDP, for sequences of *actions*). Specifications can sometimes be embedded in algorithms (eg pre-programmed spreadsheets and quality metrics) or automated workflows (eg distribution lists for customer-supplier document exchanges on specific PDP assessment tasks) which, in turn, control the movement and distribution of visibles and formal accountables. At the same time, a formal, large-scale routine (or system of routines) like PDP belongs to a large-scale course of action; and this course of action itself furnishes speakables (strategy stories, lexicons, classifications) which also form part of the 'cultural kit' that a routine affords in work settings.

8.3 *Authorities and accounting for resource commitments*

We cannot leave this discussion of the work done by formal routines, in evolving and durably organising systems of resources, without commenting on the centrality of authority and accountability. As we noted in Section 5.2 above, the authority of PDP itself, as a large-scale, strategic course of action, mandates and legitimises particular commitments of HighTech resources in particular venues. Venues include cross-function team meetings, PDP reviews and phase-exit sign-offs, and the resources concerned are primarily those of staff time, within an always complex, crammed and

contested calendar-order of formal meetings. At the same time, PDP mediates and invokes authorities that own other courses of action. We noted how the kick-off event in the ABC-10 PDP programme invoked and enrolled the authorities of managerial hierarchy and functional-silo staff organisation. This authoritative episode then translated into a working order of venues (cross-function teams, PDP reviews), artifacts (the wizard as a collection of representational artifacts), automated, artifact-embodied processes (distribution arrangements, calculation of metrics), mandatory forms of accounting (sign-off within a standard task structure) and negotiated accounts (stories developed through interactions between nominated stakeholders, in and out of formal PDP-convened venues). The durable architecture of large-scale courses of action and managerial authorities predates and outlasts the short-term, evolved working architecture of ABC-10.

One of the things that PDP formally specifies is the 'political' composition of certain critical events which must occur in legitimately agreeing and signing-off the disposition of resources and assets that constitutes a product-in-the-field. One way of seeing these events is as audiences for the authoritative stories which eventually will be generated by work on the beta release of ABC-10: what we're making, what it will do, how we are doing it, why it's acceptable, and so on. While little of this work seems to have been done using the ostensive apparatus of PDP (the wizard), it was framed in the first place by a highly formal PDP event - the kick-off meeting; and was conducted throughout - meeting by meeting, room by room, Powerpoint by Powerpoint - under the authoritative auspices of the properly constituted programme and the properly-representative cross-function team. And in the final analysis, the formal framework of PDP really counts. Around Week 48, in a series of phase-exit assessment events, the locally-evolved storytelling capability of the community of ABC-10 stakeholders comes together with the formal apparatus of representations held in an almost completely full wizard, and together these are mobilised to secure (or abort) the durable commitment of assets and resources to a product lifecycle. We are by no means proposing that this kind of formal post-facto accounting is 'what routines do'. But we do feel that authority (to make commitments), authorities (as human representatives of institutional interests) and accounting (for commitments made) are major elements in the conduct of the kinds of formal organisations which, like HighTech, are 'up to their ears in routines'.

9 Conclusions

9.1 Architecture, context, artifacts, resources

We set out to analyse evolution and work in settings of conceptual design within new product development. In particular, we have sought interpretations of context and architecture which will help to develop these constructs in further research on routines; and in observation and analysis we have adopted a central focus on the contributions that are made to work and to evolution by artifacts - notably, representational artifacts.

We have described multiple, co-present forms of context in the work of the ABC-10 cross-function teams in HighTech, and have shown the important ways in which the material-artifactual nature of context (objects in the room, places in space) contributes to the capability of cross-function teams in story development, and hence, product development and asset commitment. We also have gone into some detail regarding the kinds of resources that are worked with in these settings: notably (because of our theoretical and methodological approach) representational artifacts and other representational resources, but also, authorities (ie *representatives* as distinct from *representations*) have insisted on being noticed as resources that make a critical contribution to the work - especially in settings where formal routines are most ostentatiously being mobilised.

We have taken up context, architecture, artifacts and representations as pivotal terms in the literature on routines. But as will be clear at this point, we have done an ontological shift. In our reading, much of the literature on routines - perhaps unaware - reifies routines as discrete pieces of organisational machinery (akin to the algorithmic routines of a software programme), enacted singly, within a uniform functional model of what routines per se do, as pivotal elements of innovative, competitive organisation. In contrast, we have observed and analysed strategically significant activity in a routine-rich organisation, in terms of multiple, ongoing, evolving courses of action, and the mobilisation in work settings of multiple forms of interactional resources (notably, representational resources). Within this picture, we find that different routines do different things, and - interestingly - that the work done by routines is not necessarily achieved in the settings where the routines are enacted.

Thus we have demonstrated that routines - in our adopted sense of *formal* routines - make particular contributions to the strategic process we have observed, and they contribute a particular 'kit' of resources to the work being done which bites at certain points, on certain aspects of the work. Equally, however, we have shown that much of the important work *in this setting* (including the massive articulation of assets across a global division of labour) is done, not by formal routines but by other forms of organised resources of a different order of formality. We have distinguished these by referring, for example, to *venues* (which for example are explicit and patterned but not formally specified, and which have spatio-temporal qualities), and to the repertoire of *speakables, visibles and gesturables* that are afforded by geographical and social space, and mobilised in conceptual design work settings. We feel that this is a helpful strategy, since these other constructs ease the burden on the term 'routine', and enable a greater degree of thoughtful discrimination between the many kinds of things that are going on in actual practical settings when commercial assets are managed and knowledges are worked.

One aspect of the ontological shift - something that comes with the ethnomethodological commitment and ethnographic vision - is that 'routine' often comes to mean *mundane, commonly done, intrinsic to everyday work*; as distinct for example from procedural, specified, mandatory or formally codified. We have tried to be careful with distinctions of these kinds, and among other things this helps is to distinguish

between the kinds of things that are prominent in the cross-function PDP team setting and in other settings such as supply-chain management, assembly and testing or financial control. Another important dimension of the shift is that context ceases to be a prior, external, accidental and passive 'background' to 'the focal work' (eg 'a performance of a routine') and must be understood as something continually (re)produced as an intrinsic and constitutive element of live interaction: as part of the work itself. Thus, evolution is not external to work (for example, in the prior diversification and selection of routines, which then organise work), but intrinsic and current, 'at the workface'.

9.2 Evolution, pattern, order

Our approach in this paper has led us to an interpretation of pattern in organisations which differs from the usual one, but it is one that has a strong intrinsic connection with evolution. In fact, we are happy to offer our interpretation as a thoroughly 'resource based' theory of (activity and evolution in) the firm. The perspective that we have adopted addresses evolving as something which occurs through a massive, multiply distributed architecture of work practices (including 'knowledge work' and purposeful strategic activity), event-by-event, in actual workplaces, in working relationships with material artifacts and other resources for interaction.

Within this perspective, the problem of explaining the durability of 'patterns' can be replaced by a focus on courses of action (which, by definition, have *duration*). The characteristics of scale (in institutional-geographical space) and reach (in time) that accrue to courses of action are to be accounted for through specific *material organisations of resources* of multiple kinds, each of which has its own potentials for durability and travelling. This is, of course, the kind of analysis which is familiar in actor-network accounts of scientific and technological development (Callon & Latour, 1981; Latour, 1986; 1990; Law, 1986; see also Feldman & Pentland, 2005).

A social order or 'working order' perspective on pattern in work brings agency (of participant-actors) into strong focus; but at the same time it invokes structures (of resources, organised in courses of action) which are continually mobilised, maintained and modified in the course of everyday activity. Our case of beta prototyping in HighTech provides a nice example - almost a paradigmatic case of 'dynamic capability' - of the dual process of evolving *the order of work here-and-now* (in the live project, in the room), and at the same time, evolving *an order of resources and assets for working with* in other times and places, which extends far into future time and remote organisational and geographical space.

9.3 Routines, representations, ostensives

The construct of the 'ostensive aspects' of routines makes an important distinction between what is said and written about what people do, and what people do. The detailed mechanics of this complex practical relationship are exposed to further scrutiny by adding the third construct of 'artifacts' to the ostensive/performative

dualism. Our study displays various features of this relationship in the setting of conceptual design and new product development. We have noted that what is said and written *about* routines - notably PDP, the formal (family of) routine(s) that formally 'own(s)' product development in HighTech - played a small part in the actual rolling out of a prototype product, to the point at Week 24 where conceptual design, and many practical and financial commitments, were complete. We note also that in later weeks approaching Week 48 the formal specifications of PDP as a quality process and of its representational artifacts - especially, the wizard and the PDP review 'dashboard' - would play a prominent, and eventually pivotal, role in the work of delivering the prototype, putting it to work and (critically) approving its MinShip release.

While the ostensives of *the routine* played a small part in the activity that we observed, ostensives *of work* were centrally and continuously active: work being done 'here', work being done elsewhere. There was a repertoire and a landscape and a lexicon of venues and locations of work, and ongoing commitments and courses of action - all of these were continually spoken of (and also represented visibly and gesturally), as an intrinsic part of the work of designing, delivering and releasing the beta prototype. Our study thus emphasises the important contribution that is made to this kind of strategic, evolution-focused work by representational resources, and among these, by representational artifacts. It so happens that many of the representations and representational resources that did the most work were of an informal rather than a formal kind (in the sense that they had not been specified for use, nor were their formats in any way formally specified). We have handled this here by developing other constructs - venues as distinct from routines, speakables/visibles/gesturables as distinct from formal specified and formally encoded representations - rather than packing these dimensions into the portmanteau term 'routine'.

Although the work done by representations *of* routines in our observed span of activity was of limited scope, the work done by representations *from* routines (elsewhere, within an architecture of multiple practices and courses of action) was highly significant. Earlier we referred to representational artifacts as 'work glue', and while we by no means wish to overstate the claim we feel that we have strong evidence for a rebalancing and reconceptualising of the relationships that operate in practice between routines and representations. The routines literature has focused far too much on representations in their limited and specific roles as ostensives - prior specifications or rules, or post-facto descriptions - of routines, and far too little on the work that they do in enabling *ostensive references to ongoing work*, here and elsewhere, by participants as performers, in work settings.

9.4 *Future research*

We wish to highlight three dimensions for further research.

First, we have been impressed by the diversity of routines, in reach, in scale, in what they actually contribute to a strategic, evolutionary process; and even, in where their contributions are mobilised (not necessarily where they are enacted). Thus we would like to encourage research which examines: (a) differing contexts of routines *in practice*, (b) differing *architectures* (ways in which orders of scale and reach are achieved through the organisation of multiple kinds of resources and their commitment in multiple courses of action); and (c) the mechanisms and material forms that enable different orders of durability and reach for different *kinds of resources* (eg the speakables and gesturables, the visibles; the formals and mandatories).

Second, we have been struck by the connection that exists, in the case of PDP, between the mobilisation of formal routine and the exercise and invocation of *formal authority*. It has surfaced here, for example, in the relationship within ABC-10 work settings, between *representations and representatives*. Authority (or related constructs such as governance) does make an appearance in the routines literature (for example Dosi, 1995; Coriat & Dosi, 1998) but this often seems to be tied to economists' familiar rationalist or cognitivist constructs (for example, rules) rather than being open to a properly performative analysis. In particular, we believe that there is fertile ground for routines research in the work that is required in formal organisations, by way of formal post-facto accounts of courses of action and commitments of assets, on one hand, and prior, specified provisions for formal accounting, on the other.

Finally, we believe that our study provides good evidence that empirical research on routines can helpfully be organised through a focus on the work that *representations* do. This must especially be so when focusing on 'knowledge work' and dynamic capabilities: design, strategic management, planning, monitoring and steering, investment decision making and the disposing of assets. Much of this work is representational work, or exploits representational artifacts and other representational resources (including story telling). Certainly, routines research needs to break away from a limited cognitivist focus on representations *of* routines (for example, 'representations of action' in Cohen et al., 1996), and to become more open to the work done by representations *as artifact-resources*, on one hand, and the work done by routines as kits of resources (including but by no means limited to their ostensive representations), on the other.

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