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Design Practice: Routine Creativity

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Abstract

When designers practice they apply their knowledge and skills to create new things. Even when they employ the results of previous work, such as in reconfiguring or repackaging an existing product, they are being creative. Everything they do from the slightest modification to the grandest project has properties of originality and vision. For some people creativity is embodied in artistic sensibility or even genius, typical of Shakespeare or Picasso. Designers are routinely creative and shape the human world in everything they do.

The aim of this research understand and explain designers - what makes them tick, what motivates them and why they do things in the way that they do. A research approach specific to people, being designers, and the social science framework associated with Pierre Bourdieu has been rigorously engaged. Designers have been spoken to face-to-face and given the opportunity to raise their concerns so that their engagement with design production is illuminated and considered.

A series of interviews has been carried out with practising designers. The early interviews exposed areas of interest that could best be investigated by targeting older designers who could recount the changes in design production they had witnessed during their working lives. This life history approach has yielded social as opposed to technical descriptions of design practice and has identified significant technological and organisational changes that have affected designers in the past 30 years.

The design habitus is a system of dispositions that enables designers to act as they do and be successful in such a complex, interactive activity as designing. Designers display the habitus through their practice and their interactions with other people, with the products they design and the machinery they use when designing. They make distinctions about the products of their activity based on criteria within the design field; these criteria are developed and passed on through designers' continuous physical engagement with the objects of their work and their design colleagues. Their attitude to technology is typified by a willingness to embrace the new; they create new things themselves and this leads them to adopt new tools and adapt them to do their job.

The move from the traditional design office equipped with drawing boards to the high technology computerised office of today has led to radical changes in design practice.

Rather than report these changes as dry chronologies of technological advance they are presented here as a detailed social history of computer aided design (CAD) technology using the words of the individuals involved. Emphasis is given to the changes in the phenomenological experience of design activity and the development of the habitus.

The organisation of design activity is more exposed with advances in technology. Designers are now more likely to be members of project teams rather than monolithic design departments. The dominant model for business is the distributed enterprise where different companies, acting in concert, direct their specialist expertise to a project. The limits of designers' involvement are fixed by exchanges of capital in the form of money or intellectual labour and are set up by exchanges of symbolic or cultural capital in the form of reputation or education.

Theories of labour market organisation and postmodernity have been explored and extended. The social approach to design has addressed the concerns of individual designers, exposing their detailed habitus, the cultural capital they embody and value, and their position in the productive system.

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Personae Vitae

Seventeen interviews were carried out involving 28 people not including the researcher. For technical and other reasons the first interview was removed from the analysis. Quotations from the data appear throughout the text; they are indented and given in double quotes. Quotations from other sources are in single quotes. The interviews generating data are listed below.

No.	Alias	Company	Location	Business
2	Dave	Stitchbind	Slough	Print finishing equipment
3	Eric	Lambert Cawthorne	Scotland	Electronics
	Frank	Lambert Cawthorne		
	Gordon	Lambert Cawthorne		
4	Harry	Coating technology	Manchester	Coating Equipment
5	Ian	Technology Design	Melbourne, Australia	Consultancy
	Jennifer	Technology Design		
	Kevin	Technology Design		
6	Luke	ABC Design	Melbourne, Australia	Consultancy
	Martin	ABC Design		
7	Mike	Enzyme Design	Melbourne, Australia	Consultancy
8	Nick	Concert Design	Melbourne, Australia	Consultancy
9	Odette	Genus	London	Electronics
	Peter	Genus		
10	Quist	MVT	Dundee	Banking equipment
11	Robert	MVT		
12	Steve	MVT		
13	Tony	Cooper Clarke	Derby	Aero engines
14	Udo	Cooper Clarke		
15	Vernon	Cooper Clarke		
16	William	Cooper Clarke		
17	Yan	Rathbone Johnson	Peterborough	Printing and bakery equipment

1 Introduction

Design is fluid and eclectic; the people who make it so are designers. This research is an examination of the practice of design - the designing part of design - by approaching design from a designer's standpoint. The striking novelty of the products of design is the outcome of designers' work; they innovate everyday. Their creativity is routine.

'I do not pretend to expound a process of design. The technique of this new branch of the engineering art is still too fluid; while so far as experimental results are concerned it is probable that more have been published than have been digested.' North, 1923

North was right in 1923 and his remarks remain true today. To understand engineering designers requires more than recourse to the arbitrary and artificial technical doctrines imposed upon them by design researchers. A more comprehensive understanding results from the breaking of artificial disciplinary barriers to inquiry and instead develops through embracing ideas from other fields and cultures.

The observation of design by academics is directed to find value in and add value to their doctrines. But designing is not a doctrine and will not be made by researchers to conform to the distinctions of their disciplinary boundaries, no matter their academic currency. Academic engineers and sociologists whose first commitment is to the preservation and exclusivity of the hard won principles that they profess might find it surprising that an engineer might employ the research method of sociologists

On the one hand design is reduced to a series of checklists and flowchart prescriptions by writers such as Hubka and Eder (1996) and Pahl and Beitz (1984). Checklists are of grand help when ascertaining the accuracy and completeness of a design document such as an engineering drawing before it is released to manufacture. But they do not and cannot capture the intent embodied in it nor the series of compromises, guesses and intuitive understanding behind it.

On the other hand when sociologists have turned their attention to designers they have applied the theories and criteria to which they are predisposed. Braverman's (1974) de-skilling thesis is so pervasive that it is applied wherever organisational or technical changes occur. The dogmatic application of labour process theory to design misrecognises drawings as the objects of design labour and thereby misses the opportunity to examine the practice of designers.

The idea of an engineer approaching design from a sociological standpoint has the advantage that the language and predilections of designers are accessible. Designers will more readily reveal their secrets to someone who is not an outsider. The challenge is to be truly reflexive and avoid the problems identified by Bourdieu:

'A former theologian turned sociologist who undertakes to study theologians may undergo a sort of regression and start talking like a theologian or, still worse, use sociology as a weapon to settle his past theologian's accounts.' Bourdieu and Wacquant, 1992, p.253

If the researcher is vigilant enough then the orthodox academic view can be contested. Such an approach, as Bourdieu says, puts the researcher to the test as much as those being researched (1999, p. 611) and makes it a personal and individual quest.

1.1 Bourdieu

The social science of Pierre Bourdieu has been adopted because it has a conceptual fit with the problems of explaining design practice. He has argued for the logic of practice to be understood as a game where explicit knowledge and strict application of the rules is never enough for success. Design practice fits this analogy well; designers play the game to the limits of the rules, and apply them with originality.

The designers interviewed here did not have recourse to flowchart representations of the rules but instead described their activity from and open yet regular attitude that they adopt with out making it explicit. They value their skill at designing, what Bourdieu calls their embodied cultural capital (Bourdieu, 1986), and seek to preserve and develop it, in line with Bourdieu's theory.

Further, in his more recent work (1999) the development of sociological narratives enables the discussion of practice as lived experience. After the fact rationalisations of design practice are replaced by an examination of the underlying, unarticulated dispositions that designers have to distinct courses of action supported by the descriptions given by them.

While Bourdieu is an established authority in his native France his reception in English has, until recently, been limited to educationalists and art critics, taking on his work in Reproduction (1990) and Distinction (1984) respectively. His growing acceptance might be ascribed to a backlash against the neo-liberalism of mainstream anglophone sociology, especially when taking account of his political writings (1998b, 2001) and his criticism of the neo-liberal regimes of Blair, Jospin and Schroeder.

Bourdieu's theoretical framework is a coherent whole and although he is most frequently associated with the important concept of habitus other concepts developed by him are used here. A detailed analysis of the design habitus provides a link to the notions of illusio, whereby designers recognise and make a commitment to the game of designing. Bourdieu's idea of cultural universal is used to establish designers' authority to make judgements. The changes in the equipment they use and their working environment are related to the notion of cultural arbitrary. Significantly, the forms of capital supply a structure to the interactions of design industry, showing how capital is used and exchanged by designers to their profit.

Bourdieu's theory is experiential and the responses of designers to the changes in their phenomenological experience of space and time are linked the work of Harvey (1990) and his ideas of space-time compression. MacKenzie and Spinardi's (1995) recognition of tacit knowledge in engineering is linked to habitus theory and the disposition of the designers to preserve and augment their knowledge and control.

The findings provide a valuable counter to the pessimistic predictions of labour process theorists, applying Braverman's thesis willy-nilly, that designers would lose their autonomy and become subject to increasing management and technological control. Instead designers have increased their control of the tools they use and evidence is presented that management enthusiastically conceded autonomy to designers as technical changes were introduced.

Methods have been applied that are appropriate to avoid the prejudice and predilections of those who have studied design before and of the researcher, being a designer. Information has been sought primarily by speaking to designers in the place that they design. The research answers must be grounded in the evidence and a program of inductive analysis embracing the ideas of Glaser and Strauss (1967) has been engaged. Categories applied by this method must be guided by existing theory otherwise they become bland and lack sophistication. Category and theory are continually revisited in the construction of both. For instance, the category representing the interactions of designers with other people has been lent structure by Bourdieu's theory of capital exchange.

1.2 Presentation

The application of grounded theory depends upon writing memoranda and notes and revisiting the data. The chapters that follow were generated by this process. Rather than illustrating this or that theoretical point in each chapter, narratives have been developed based on the analytical categories. The aim has been to gain a comprehensive view of design practice through case study accounts that demonstrate a variety of theoretical positions. The respondents' words used in the text were selected from the mass of data to best exemplify the category being developed.

The most simple category comes first and is presented in Chapter 5 dealing with the respondents' relationship with the products they design and the criteria they apply in distinguishing good and bad design schemes. The tension between the social construction of these criteria and the intrinsic properties of artefacts is exposed and discussed. Bourdieu's habitus theory is employed to explain how designers learn the rules for distinction in design and how they develop and pass them on.

Habitus has been used as an organising concept throughout the analysis of the design practice reported by the respondents. The explanatory force of the concept has been used to describe aspects of designers' lives from their entry into the profession in Chapter 8 to their worries for the future of it in Chapter 9. The use of computer aided design (CAD) technology in design practice from its introduction to contemporary distributed working over the internet is explained in Chapter 6 through the positions taken by designers and the dispositions of their habitus. A central finding is that designers immediately sought to take control of the technology by wresting it from their manufacturing colleagues and applying it to their own ends.

The designers' phenomenological experience of space and time has altered dramatically throughout the introduction and advancement of new technology. The detailed social history of the introduction of computer technology into design presented in Chapter 6 illustrates these changes. Several instances are given where the turnaround time of a new product has been drastically reduced. A case study is presented in Chapter 7 of rapid prototyping using stereolithography. The reduction in lead time provided by the use of this method over the previous manual one when combined with data communication technology provides a vivid example of and extends David Harvey's (1990) theory of time-space compression.

Bourdieu's notion of cultural capital is complementary to habitus. Chapter 9 comprises a detailed examination of the exchange and transformation of the forms of capital that designers hold. Recourse to theory has reduced a complex category detailing the web of interaction in design to a single, clear explanation of symbolic capital exchange. The structure of the labour market that places some designers as consultants and others on the staff of large manufacturing organisations makes these exchanges especially apparent.

First the state of knowledge and prevalent theories of design are reviewed. More general theories of utility to this study are then introduced. In Chapter 3 Bourdieu's theoretical edifice is examined with reference to the present study.

2 Theory

The body of theory relevant to this thesis can be split into two areas. The first area includes those theories that explicitly address engineering design and are traditionally associated with designers and designing. The second encompasses more generic theories that have been adopted selectively to inform this study, but are not normally applied to design research: theories of organisation, of phenomenological experience of space and time, of technology and, centrally to the thesis, the theory of practice advanced by Pierre Bourdieu. Mainstream engineering design theory is taken first to provide some context, establish the state of knowledge in the area and so that some of its assumptions and taken for granted notions can be discussed.

2.1 Engineering Design research

Researchers of engineering design often set out to influence the way designers do their work and the ways that design managers organise designers and design labour. In rare cases designers themselves will advance theories that stem from their experience and practice. But most design research has been conducted by and written about by academics using various methods to examine design practice. The research can be split into four broad areas: systematic design, cognitive science, management science, and studies taking a social science approach.

2.1.1 Systematic Design

The school of systematic design is exemplified in Pahl and Beitz' masterwork *Konstruktionslehre* (1977), translated into English as *Engineering Design* by Wallace (1984). The main forum for systematic methods is the Workshop Design Konstruktion (WDK) and their series of International Conferences on Engineering Design (ICED).

Systematic design treats engineering products and processes as hierarchies. For example, all products are placed in the linear hierarchy: system, plant, equipment, machine, assembly and component (Wallace, 1984, p.20). Process is split into four areas or 'phases': task clarification, concept formation, embodiment design and detail design.

The design process is presented as a flowchart representing a series of procedures to be followed in each 'phase'(see e.g. French, 1992). Feedback loops are shown to allow for iterations of the procedures. Task clarification is the development of a specification for the product, what it should do, and in what environment. Concept design consists of reducing the overall operation of the product into a series of functions, which are then organised into function structures; when these have been established a search for solution principles is conducted using standard thinking techniques similar to those given in Dixon (1966) such as brainstorming (see e.g. De Bono. 1977). Pahl and Beitz (1984) also introduce the idea of 'discursive' methods alongside these 'intuitive' methods through the introduction of comprehensive classification schemes of product features.

The embodiment phase is given the most extensive treatment. The result of the previous phase - the product concept - is developed into a series of preliminary layouts based on function carriers – parts of the product that perform certain functions in the function structure. The preliminary layouts are evaluated against a series of checklists to produce a definitive layout. Basic rules, principles and guidelines for embodiment design are given. These include exhortations to clarity, simplicity and safety in design, an awareness of the behaviour of engineering structures and the materials they are made from and a series of what has since been called design for X. Pahl and Beitz include design for allowable deformation, for standardisation, for production, and for minimum risk. The final embodiment design, or definitive layout, is then evaluated against a checklist. Detail design - the final phase - deals with the development of the definitive layout into product documentation including engineering drawings, parts lists and material specifications.

The systematic school has its origins in the undergraduate machine drawing and design texts (e.g. Abbott. 1930) that were produced to support the growing number of engineering degree courses offered by Universities in the early 20th century. The contemporary equivalents are texts such as the one by Hurst (1999) giving a general introduction to design principles for an undergraduate audience. Other undergraduate texts, such as Ulrich and Eppinger (2000), place more emphasis on the business aspects of design.

During the Second World War and the years surrounding it the underlying philosophy of scientific management, if not in the strict Taylorist principle, was applied to design culminating in the design methods movement of the 1960s, centring, some would say, on Jones and Thornley's (1963) conference and Jones' (1966, 1980, 1995) classic text. This movement was paralleled in Germany with the works of Rodenacker (1970) and Eder (1966). A number of separate movements arose from these attempts to apply rational method to design activity: in Architecture through the work of Alexander (1964), and in

Engineering Design through Cross (1997) and French (1985, 1992). In all cases enthusiasm for the strictures of rational method has since been tempered and Alexander (1988), Jones (1995) and Cross (1990) have all distanced themselves from the rigid systematic approach.

The most striking aspect of the systematic approach to design is its ultra-rationality. In one sense modernity is identified with a belief in the rational and the triumph of truth and science. That the systematic school has its origins in modernity in this sense is comprehensively demonstrated in Hubka and Eder's Byzantine *Design Science* (1996). They advance the thesis that 'Designing is a rational activity' (p.50) and moreover that it is and requires a 'science'.

The fundamental fallacy of systematic design is that it produces better designs. The major criterion for measuring design quality is through the use of systematic methods, a post hoc circularity of judgement where the method supersedes the product. Preposterous claims have been made that link the systematic approach to Japanese and German prosperity

' . . . the Japanese and the Germans are reputed to make better product in shorter time. . . These countries have also produced and formalised the most important systematic methods.' Eder, 1996, p.128.

The message is clear: adopt systematic methods and economic prosperity will follow.

Systematic design is under attack from so many quarters it is surprising that such a large number of academics subscribe to it. It is reductionist and simplistic, reducing design to a series of abstract exercises. The roots of this reductionism precede Taylorism and are at the heart of the modernist scientific project. It is perhaps unsurprising that the proponents of such an approach are academics in the main faced with the task of promoting the chaotic and unpredictable activity of design to an undergraduate audience whose other studies are marked by scientific exactitude. Reducing design to series of seemingly rational steps as in a calculation makes sense for normative engineering education in the laboratory and classroom. Novice designers are encouraged to follow a prescription, to see design as a 'problem' (as some people see research): 'task clarification' underplays the role of marketing, sales and other considerations contributing to the success of a product beyond platitudes about 'fitness for purpose.'

Systematic design is not driven from within industry but from within academia. What Bourdieu has called the 'scholastic fallacy' (e.g. 1990a, p.112) is evident in the retrospective, seemingly comprehensive empirical basis for the method. The examples given are almost always product or assembly based and the after the fact analysis displays the example as a product of a perfectly rational process, ignoring the uncertainties, hopes, hunches, desires, compromises, complications and influences that it embodies. The designer, who Hubka and Eder (1996) refer to as an 'operator', is reduced to an epiphenomenon - at best an empty vessel to contain and carry the method, at worst a wraith like figure stalking the edge of explanation, whose influence can only be glimpsed out of the corner of an eye.

Ferguson (1992a, 1992b) is perhaps the most scathing about the systematic approach. Along with Bucciarelli (1994) he has employed a designer focused empirical method and points out that:

'Design is not, as some textbooks would have us believe, a formal, sequential process that can be summarized in a block diagram. . . many designers believe that design should work this way, even if it doesn't' Ferguson, 1992a, p. 10

Bucciarelli (1994, Chapter 6) provides an example where an outside design consultant attempts to impose a systematic method on a design group but is in a state of blissful unawareness of other constraints, allegiances and rivalries that colour the subsequent discussion and contribute to the failure of the method. Pahl and Beitz (1977) do not have a checklist to cope with skull-duggery and subterfuge. The designing reported by Bucciarelli was a messy, subjective, and irrational process of negotiation among people who placed precedence on maintaining their own position in the social pecking order rather than on conformity with a precise specification of the design process.

A final point is that some of the examples given are just plain wrong. One of the examples given by Pahl and Beitz (1984, p.210) is a shrunk fit hub onto a shaft also fitted with a key and keyway. They argue that for the transmission of torque from the shaft to the hub only one of these fixing methods is needed: either a shrink fit or a key but not both, since this conflicts with their conception of 'clarity' in design. They ignore that fact that the shrink fit is to give radial location for the hub, which may be attached at its periphery to a precision gear wheel or a cam, and that the key is to give circumferential location for the hub so that the gear wheel or cam might line up accurately with the shaft[1].

Systematic methods embody a large amount of engineering knowledge and should not be ignored on grounds of over-rationality. They have provided a framework for discussion about design that has been adopted extensively and when placed in the proper context some of the methods have proved useful in practice.

2.1.2 Cognitive science

The cognitive science approach to design originates with Allen Newell and Herbert Simon who, during the late fifties and sixties, undertook a program of research built on the idea that the human brain might work like a computer and introduced the Information Processing System (IPS) model of human thought (Newell and Simon, 1972). They stress that this metaphorical device is a sensitising concept - an idea to help with the understanding of thought processes and not a matter of fact (p.870).

In design, studies using the IPS model centre around what Hubka and Eder (1996) have called protocol studies but are more generally known as think-aloud methods. Subjects are given tasks and asked to enunciate their thoughts as they occur. This method has been used to study how people read (Rankin, 1988, Nunan 1992, Chapter 6). The main studies of design have been conducted at Oregon State University (Stauffer and Ullman, 1991, Stauffer et al., 1991) and in Germany by Ehlenspiel and Dylla (1989, 1993). These culminated in an international study at the Technical University of Delft (Dorst, 1995) where senior design researchers were asked to analyse transcripts of think-aloud design tasks.

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[1] A concrete example of this is in a printing machine where subsequent coloured dots must coincide with micron accuracy. In the gear train the amount of clearance possible in a transition or location fit between shaft and hub could be in the order of 50 microns, which, when translated through a lengthy gear train leads to a loss of accuracy at the printer head. The accuracy of location provided by the key in such a situation cannot be duplicated by other methods (with the exception of expensive splines, or traditional tapered keys and wedges) such as machined line up marks.

The Oregon State University (OSU) studies attempted to adapt Newell and Simon's IPS model to the activity of designers; the conclusion reached was that designers use some operations in the IPS model, as interpreted by the OSU team, more than others. The intention of the OSU study was to improve the 'automation' (Stauffer and Ullman, 1991, p.113) of design tasks using the IPS model. Using the analogy of a computer as a metaphor for human design activity and then seeking to transfer that computer based metaphor onto a computer is an obvious and unchallenged piece of circular reasoning.

More recently Klaubert and Blessing (1997) have undertaken a protocol study that uses a different theoretical framework, which emphasises communication in design. They point out that interpersonal communication is fundamental to design activity. Their use of the protocol method is limited to extracting sets of heuristic guidelines for use by other designers.

2.1.3 Management science

Management science approaches to design centre around ideas like total quality, business process and concurrent engineering. The latter takes design as a focus arguing that design should be 'the central dogma of engineering' (Jo et al., 1993, p. 4). Concurrent engineering (CE) is the design of the product and the manufacturing process at the same time implying that designers have previously not been aware of manufacturing constraints and have not taken them into account when designing. The scenario is one of 'over the fence', where the design function in an organisation finishes designing something and passes it over the fence to manufacturing.

Some themes of CE are the focus on various 'customers' and the product life cycle:

'Concurrent engineering broadens the focus to account for the concerns of 'customers' not previously considered – those along the entire life cycle of an artifact, i.e. marketing, design, manufacture, distribution, operation and disposal.' Wood and Agonino, 1996 p.361

The central message is that all of these areas can be brought together through more effective communication (Wood and Agonino, 1996 p.367) and this can only be done with the use of computers and data sharing information networks. The technical literature around this subject is immense (for two examples see Fohn et al., 1994, and Urban et al., 1996). Studies of the imposition of CE techniques on companies also emphasise the importance of communication:

'communicate 'til it hurts' Brooks and Foster, 1997

It may be, however, that designers are already aware of the need to communicate and other factors are limiting their ability to do so. Ziemke and Spann, 1993, have identified the role of concurrent engineering techniques in the success of various products during the Second World War – before the expression had been coined. They attribute the subsequent loss of expertise in rapid, responsive designing for product life cycle to a post-war tendency to over- bureaucratisation, departmentalisation and specialisation.

The total quality approach is a mixture of techniques, some taken from so-called Japanese Just in Time methods, which initially focused on the reduction of defects in manufactured products. Methods for improving quality in manufacture include statistical process control (SPC), and Kanban - where manufacture cannot continue until a defect has been repaired.

The quality approach has been extended into design where potential defects can be 'designed out'. The work of Taguchi and the Quality Function Deployment (QFD) technique have extended the total quality approach to focus on customer requirements. The idea is that customer requirements can be identified, more or less scientifically, using survey or similar methods, and mapped directly onto product features.

Business Process Re-engineering (BPR) is related to the concurrent approach. Its major premise is that organisational bureaucracies hinder communication. Successful companies were once small companies with close knit teams of people committed to the success of the company and with strong personal bonds which encouraged close communication. As the companies grew, organisational bureaucracy replaced the community structure and allegiances to the company were replaced by allegiances to departments, which are in competition with each other for the company's resource. Re-engineering involves removing middle layers of the bureaucracy and fostering a multidisciplinary, team-based environment, encouraging communication between organisational functions, and reducing management costs (Hammer and Champy, 1993).

The impact of management science approaches on design is difficult to pin down. Business process re-engineering has possibly affected managers more than front line designers. The total quality approach has increased the requirement for audit and traceability of actions, decisions and supplies and in some implementations the concomitant increase in paperwork has diverted effort from mainline work to the imperatives of chasing up and signing off.

2.1.4 Social science studies

Some studies of design have been undertaken with different theoretical frameworks based in social science and history. The main proponents of the social science approach to design are Bucciarelli (1988, 1994), Ferguson (1992a, 1992b) and more recently Henderson (1999); some would add Schon (1987) to this list because of his constructivist stance and studies of architects. Vincenti (1990) and Petroski (1994) have undertaken major historical studies of engineering that reveal the distinctive state of engineering knowledge.

The most significant study is that by Bucciarelli (1994). He describes three participant observation based case studies in the Northeastern USA. His basic theoretical unit is that of the object world - an individual reality that the people engaged in design construct for themselves around the product they are designing. He likens the complex web of a distributed enterprise organisation to a natural ecology and provides insights into how a small event in one place can have massive consequences in another. Using his theory of object worlds he provides graphic examples that demonstrate that the systematic approach is invalid in the heat of the moment, in the day-to-day activity of design that is carried on in an environment of conflicting constructions, where nothing can be held to be objective or absolute. His theoretical standpoint is ultra-constructivist and relativist, almost Feyerabendian. He brooks no reality other than that constructed by the people in the study, ignoring any intrinsic properties of the environment they are in, or the products they design.

The value of Bucciarelli's approach lies in its reflexivity; he is an engineer taking a limited but valuable sociological approach to an area that had not been studied before in that way. Coming from a constructivist Chicago School sociological background led him to focus on interactivity and communication; from these principles he has constructed a complex theory of the interdependence and interconnectivity, not only of design, but of the whole engineering enterprise.

Ferguson's (1992a, 1992b) approach emphasises the tacit and non-rational content of design:

' While engineering drawings appear to be exact and unequivocal, their precision conceals many informal choices, inarticulate judgements, acts of intuition, and assumptions about users.' p.4

He places great emphasis on the skill of the designer, gained through 'sensory experience' and embodied in ' an integrating mind's eye for understanding'. p.3

He represents the product as a thread connecting the people who design and make them and influencing how they interact. The fundamental point he makes is that the underlying nature of engineering does not change with new forms of organisation or with technology but lies within the skill of the engineer and the 'mind's eye.' He uses the example of calculating the 'ideal' efficiency of an engine:

'An 'ideal' efficiency can be useful, but informed judgement must decide just how far calculations involving idealized processes can be depended upon in making design decisions.' p.6

Henderson's (1999) study is a two site non-participant observation with a focus on computer representations used by designers. Her educational background is in fine art and she built on this to use a symbolic interactionist method focusing on visual representations of products. She took various product representations, from sketches to CAD files, defined them as symbols within her interactionist scheme and mapped the communication system in the companies she studied.

Vincenti (1990) and Petroski (1994) both use historical examples to show the distinctive nature of engineering knowledge. Petroski uses a series of case studies of failures in engineering structures to show how the lessons of failure advance engineering knowledge. He also attempts to show that engineering knowledge advances through a series of paradigm shifts brought about by catastrophic failures in a manner similar to that proposed by Kuhn (1970) in his theory of scientific knowledge. His cases are narrow and many examples could be quoted that run counter to his theory; he omits the social relations involved in engineering, misses the motivations of those involved and the impact of the failure on them. Rolt's (1989) case study of Brunel's problems with the steamships Great Eastern, Great Britain and Great Western give more of the social context to the technical failure of these ventures.

Vincenti (1990), taking a more academic approach, scoured the archives of the National Advisory Committee for Aeronautics (NACA) and proposed the theory that knowledge progresses very differently in engineering than it does in the natural sciences. Engineering knowledge is validated by the facts that aircraft fly, with certain performance parameters, and not by recourse to truth, validity, or other concerns of the natural sciences. He traces the roots of the engineering experimental tradition through the work of Durand and Lesley, and the kinds of knowledge required for engineering design and manufacture. He rejects the view that scientists produce knowledge for engineers to use and asserts that engineers are knowledge producers, too, but in their own terms.

Vincenti's work is perhaps the most valuable counter to the systematic school. Pride of place is given to the historical genesis and development of engineering ideas and practices and it is through these that engineering can be understood. Aircraft do fly more or less as intended and more or less for the reasons expected but that they do fly has much more to do with the engineering knowledge they embody than in the systematic methods applied to their design.

2.2 Sociology of CAD

In the late 80s a number of sociological studies examined the then current introduction of CAD into design offices. These studies reflected the preoccupations of industrial sociologists at that time and therefore encompass particular conceptions of labour process theory, skill, de-skilling and technological determinism.

The argument that the introduction of CAD into drawing offices would lead to the de-skilling of designers was triggered by an obscure paper by Cooley (1971); he argued that CAD de-skills designers and leads to the fragmentation of their work. Cooley's view of design is tinted by a romantic view of pre-industrial and early industrial design work (1988); in his view of the introduction of CAD he lends the technology an unjustified capacity for de-skilling that is representative of technological determinism at its extreme.

Arguments for de-skilling and Taylorisation of drawing office work are rebutted variously by McLoughlin (1989), Senker and Simmonds (1992), Löwstedt (1989) and Lee (1992). McLoughlin says:

'CAD drafting systems change the skills required to draw but they do not significantly transform the engineering knowledge and expertise required to actually use the systems.' 1989 p.37 and 1990 p. 224

The point that everyone misses, by focusing narrowly on the technology, is to what purpose designers draw, and the assumption that the only product of design work is drawings is never challenged. The viewpoint that designers exercise no more than drawing skills leads to the expectation that changes supposed to help them make drawings inevitably reduces the skill required. When such a mechanistic view of design production as this is prevails it is perhaps inevitable that researchers will apply mechanistic theories to it. McLoughlin almost recognises this risk but he does not challenge his own doxic view of design. The distinction should be made between the perpetration of a drawing with pencil and paper and the purpose, act and action of a designer making a drawing. Drawings are considered in the present study variously as enabling the intellectual processes of designers, expressing design knowledge and intent, as geometry definition, as a contract to manufacture, but most importantly as central to the habitus. Drawing is embodied in designers, regardless of the technology used.

Further, no evidence is presented to support the assertion that managers, in cahoots, were conspiring against and seeking to reduce the value of designers' skills. Lee (1992) plays down management motive in using the technology to de-skill:

'management neither intended, nor were they in practice specifically using the technologies to de-skill the work of engineers.' p. 105

Cooley's (1971) thesis recruits some support from the work of Baldry and Connolly (1986) who, though they discovered little evidence of de-skilling, base their endorsement of Cooley on their finding that introduction of CAD had led to a 'fragmentation' of drawing office work. The evidence they cite is that the CAD equipment being housed in a separate room, which is often dark and air-conditioned, necessarily leads to a breakdown in the social cohesiveness of the design office. McLoughlin (1990) found that CAD installations were not always located away from the main drawing office. He reports one case where the CAD equipment was located in the main drawing office to promote and further the management aim to integrate CAD more quickly into mainstream design work. In another case the more Machiavellian intention was to avoid the creation of a cadre of highly skilled CAD users who deliberately would not integrate with the main office and might use their higher skill and familiarity with the equipment as a bargaining chip in future negotiations with management.

Baldry and Connolly (1986) also argue that the introduction of shift working to increase machine utilisation leads to 'temporal fragmentation'. Most of the authors considered shift working in their studies and, whether they found it or not, attempted to examine the power relationship between a management who supposedly wanted to impose it and implicit worker resistance to it. Schmidt (1992) devotes an entire paper to shift working. Löwstedt (1989) found no instances of shift working in Sweden and put this down to a resistance to change in both workers and management. Lee (1992) found shifts to be popular in Britain but limited to certain technical staff in Canada; she attributes this to the difference in status of professional engineers in the two countries. In Canada engineers are scarce and have a great deal of power. Management there did not even put the question about shifts to engineers for fear of antagonising them. McLoughlin (1989) reports various approaches to shift working by both sides ranging from a building in of a shift working agreement to the overall negotiations with unions about the introduction of new technology to the after the fact attempts by management to impose shift working to increase machine utilisation. In all cases he reports that the unions responded with demands for high shift premium payments that management was not always prepared to concede. Baldry and Connolly's (1986) finding that all the companies in their sample thought shift working inevitable is not borne out by subsequent studies.

The fundamental problem with all these studies is that they are predicated on the assumption that the introduction of new technology necessarily imposes a rationalising influence on the labour process. Taylorisation, machine utilisation and de-skilling are applied to design work as if they are universals and are to be applied de facto. These notions presume that it would be the intent of a rational management to down grade designers' work. The reality of the evidence is that managers were bewildered by the exercise of CAD and challenged by their management of its introduction. McLoughlin (1990) points out a

'new managerial responsibility for the provision and maintenance of a CAD service' (p.228)

and

'when new technologies are adopted organisational structures are made more complex rather than simplified and new conflicts and rivalries emerge.' p. 229

Senker and Simmonds (1992) identify one such conflict between senior management who have strategic knowledge about the business of the firm and junior managers who have technical knowledge about the capabilities of the new systems. They also discuss the conflicts arising from independent departments confronted with the integrating capability of the technology in the form of common data formats and data transfer.

'Managers experienced considerable difficulty making the necessary organisational changes, or even in recognising the need for them.' p.95

They blame management ignorance of the technology:

'Such difficulties arose largely as a result of senior managers' failure to undertake the necessary CAD-related training' p. 95

McLoughlin (1990) concurs with this view:

'Drafting staff therefore enjoyed a new found 'skill superiority' over their supervisors who no longer fully understood the work of their subordinates.' p. 229

He extends this view of management ignorance to senior management where:

'the problem with CAD is precisely that conventional approaches to the financial justification of the investment focus purely on quantifiable productivity improvement within the drawing office.' p.233

Anyone investigating the introduction of CAD would find rough edges, resistance and unpredictability but this is not indicative of a management conspiracy. It can better be explained through management's horror of change, confusion at the threat to their control, bafflement at the technology itself, rather than by a purposeful aim to exploit staff. Correspondingly, in the bipartisan and simplistic sketch of the management relationship with the unions, an accompanying perplexity on the part of the unions in the face of new technology is evident from the unions' sponsorship of these sociological studies. Being so funded, and so briefed, a sociologist would recognise a familiar and welcome line of argument, and not engage in a wider view of the relationship between management and union and their own participation in it.

Most of the studies also look at the justification, financial and otherwise, offered for the implementation of CAD. Baldry and Connolly (1986) found no measurements of productivity before the technology was introduced so no comparisons could be made. Senker and Simmonds (1992) outline the

'severe problems in the relationship between accountancy and engineering management' p. 94

that are peculiar to Britain. Lee (1992) concurs with this view while contrasting it with the comparatively high status of Canadian engineers who can negotiate more authoritatively; the engineers

'could always find ways of 'fooling the beancounters.'' p. 109

She (1992) concludes:

'In neither country, however, did engineers actually have to demonstrate that they had achieved their projected targets for return on investment.' p.109

None of the sociologists challenged the dogma that machine utilisation leads to improved productivity or, more importantly, profitability.

This flurry of sociological interest in design work in the late 80s probably offers more insights into the concerns of sociologists at that time than into design office work. They took a monolithic view of engineering production that separated it from business and they did not test this preconception. Although they did interview designers, managers and CAD users, they did not attempt to understand their subjects and the sociologists' interpretations are given precedence over those of the people under study.

This collection of papers provides evidence of a tendency in industrial sociology at that time to rely on a set of agreed problematics that were to structure the field of inquiry rather than to approach their research in a free and inquiring manner. Reflexivity, even in the sense understood before Bourdieu and Wacquant (1992), is absent; the researchers here failed to challenge their own position in the field and their preconceptions of it.

The value in these papers lies not in their conclusions but in the presuppositions shared by the researchers and in some cases the researched. The idea that drawings are the only products of design and the attempts by various managers to measure and influence productivity by this measure alone is a telling one and provides an illustration of the fragmented specialisation of engineering and industrial production at that time. Even so, evidence from the current study indicates that even early implementations of CAD were, in some cases, more sophisticated and involved a business-wide view rather than one focused narrowly on the drawing office, its occupants, their efficiency and unidentified control and management goals.

2.3 Organisation

Designers' work is organised, through the division of labour formed by their own and other peoples' constructions and perceptions. That is to say the division of labour is itself a social construction perceived and acted upon by those within it. People at work act in concert and their action can be viewed as organisation. Designers' own experiences and constructions of the organisations they work in can be illuminated by conceptions of work organisation developed by sociologists. These embrace especially the classical ideas of bureaucracy, advanced by Weber (1968), extended by Gouldner (1954), and taken yet further by Burns and Stalker (1994), among others, into organisation theory. Two labour market theories that employ the categories of core and periphery in labour theory are also linked to the current study along with concomitant ideas about 'flexibility.' Finally the categories of labour process theory as extended by Braverman (1974) and his de-skilling thesis are related to ideas about skill, technological determinism and the social construction of skill.

Organisation theory has its origins in Weber's (1968) analysis of government bureaucracy. He proposed an 'ideal type' of bureaucracy that has four characteristics: a hierarchy, a system of rules, a system of offices that are recognised as separate from the incumbents, and a system of appointment to those offices based on formal qualifications. It is important to make the distinction between the political theory view of bureaucracy as government by bureaucrats and Weber's explanation of government through bureaucracy as a system. Weber's scheme has been criticised on empirical grounds because no instances have been found of systems conforming to the ideal type. This is a trivial criticism because the scheme is, as he says, 'ideal.' Stronger criticism has surrounded the inevitability of bureaucracy, its objectifying nature and its representation as an extreme rationalism.

Sociologists have adapted Weber's ideas to the study of industrial bureaucracy and have extended the theory to show how bureaucracies are socially shaped. Merton (1957, pp.196-197) points out that bureaucracy fulfils for the non-manual worker the tendency in capitalism to remove ownership of the tools of production from the worker. Gouldner (1954) explains how bureaucracies are operated upon by those within them and how the rules are shaped to conform to peoples' shared values, illustrating clearly that the rules and offices have a social basis and a social meaning. He shows that offices are not separated from their incumbents in his examination of succession, when, for instance, a new person fills the vacant position of plant manager. He further shows that it is the nature of bureaucracy that makes this so. Although Gouldner's work is mostly noted for his typology of 'mock', 'representative' and 'punishment' forms of industrial bureaucracy, the most important aspect of his work is the face to face methods used to examine bureaucracy as experienced and operated on by those in it.

The theory of bureaucracy has become just one approach to the wider sociological project of organisation theory, which itself also comprises management theory. Part of Burns and Stalker's (1994) study outlines a theory of 'organic' and 'mechanistic' systems of management related to the market conditions a firm operates in. They conclude that if the market is volatile then organic management systems are required, if it is stable then mechanistic systems are more appropriate.

The dichotomy of core and periphery has been used variously by different researchers in organisation theory and can be the cause of some confusion when the gaze is widened to encompass the labour market. In organisation theory Edwards (1979) explains these concepts in relation to monopoly capital. Core firms are large conglomerates, multinationals – big business. Periphery firms are smaller, and generally provide services for the core. In labour market theory core workers are permanently employed people and the periphery are casual, sub-contracted workers and specialised consultancies.

Labour market theory is concerned with the structure of the labour market and organisation theory with the structure of the enterprise. For labour markets the concern is with 'flexibility' and the prospect that a workforce comprising a small core of dedicated, specialised employees supported by a larger periphery of multi-skilled, less specialised workers allows for an increasing flexibility in configuration, numerically and physically, of organisational forms. Hakim (1990) has developed her core and periphery work from a framework proposed by Loveridge (1983) and presents statistical evidence of a decreasing core and a correspondingly increasing periphery in the UK. However, she found little evidence of any conscious effort on the behalf of the management of firms to increasing casualisation and reduction of the number of core workers. Pollert (1988) finds little evidence for a core and periphery split and attributes the statistical trends to increasing casualisation in the public sector. Additionally she finds the core and periphery theory of flexibility in labour markets simplistic and lacking in explanatory force.

In the current study the strongest correspondence is with Edwards' (1979) theory of global business organisation. The accordance with labour market theory is weaker - all the respondents here are core employees, being permanently employed. The designers who work as consultants, are by strict definition periphery workers, nevertheless enjoy most of the attributes and benefits of permanent employees. The labour market in design is not split on simplistic core and periphery lines.

In Edwards' formulation core firms usually operate in monopoly markets, either by virtue of their size due to mergers and take-overs or through collusion with other firms in the market. What used to be called a cartel is now euphemistically called a strategic business partnership. This gives rise to monopoly capitalism. Two main features of core firms that Edwards identifies (in Chapter 5) are the low risk of business failure and the high rates of profit. He also illustrates how core firms expand to control all aspects of the business process.

For Edwards, business and operational functions that the core cannot provide or that would be too expensive to keep in house are left to the periphery. Specialist production is left mainly to the periphery and extra mass production capacity can be quickly had when it is needed. High rates of profit are attainable in the periphery but only come at considerable risk.

A characteristic of the core firm is the form of control used in the management of the concern. Edwards identifies the technical and the bureaucratic forms of control. The technical form is loosely based on Taylor's scientific management and involves machine pacing of work and limitation of the workers' options by technical means and the layout of the plant. This form of control is most suited to mass production. The bureaucratic form of control is identified with the imposition of a social rather than physical structure and offers security of employment based on a visible ladder of opportunity and promotion based, theoretically at least, on seniority.

Edwards' formulation can be criticised on the basis that it ignores the essential negotiations and compromises in any management system. Gouldner's (1954) study shows how bureaucratic rules are variously implemented and interpreted by special interest groups among workers and management and how they are shaped by the value systems of those involved. The imposition of bureaucratic rule is not always strictly one way. In the same way the technical form of control can only be realised through negotiation around the technology, its meanings for both the introducers and the users of it. Technology limits possibilities but does not determine them. Rather its capabilities are, like the rules of a bureaucracy, the subject of continuous negotiation and re-negotiation. An overly rational view of technology masks the conditions of its use and its history. The examination of the introduction and use of CAD technology by designers in this study shows clearly the impositions, limitations, negotiations and constructions surrounding the properties of the technology and its use.

The form of control in a periphery firm ascribed by Edwards is entrepreneurial control. The concern is so small that every employee has a personal relationship with the owner and the culture of the company is based on the personality of the owner. He acknowledges that these firms are a continuation of nineteenth century capitalism but they now have to cope with the power of big business as well as the 'impersonal mechanisms of the competitive market' (1979, p.72).

An emerging form of organisation is that of the distributed enterprise. In a primitive form this is characterised by the geographical distribution of core firms around the world. The distribution takes advantage of local attributes to increase profit – proximity of raw materials, low-cost labour, access to specific specialist knowledge, climate, political stability, taxation regimes and so on. The more complex form is where a number of firms from both the core and periphery associate in an enterprise that is economically and geographically distributed. Developments in communications technology have allowed this to happen more easily.

The distributed core firm can also take advantage of the relative simplicity of the entrepreneurial form of control. Having smaller business units around the globe gives them autonomy as if they were periphery firms. The way that the various business units in the distributed enterprise associate gives a feel of different departments in the same conglomerate working together. It is often the case that some partners in the distributed enterprise are part of the same conglomerate working in conjunction with periphery firms.

In design the periphery firm can be a design consultancy providing specific design expertise to a distributed enterprise or a business unit of a large multinational providing similar specific design expertise. Information technologies enable the construction and facilitate the operation of distributed enterprises. The designers in this study work for different kinds of business units in the core and in the periphery and the organisational forms can be seen from their perspectives.

These formulations of structure are useful as guiding constructs but the intention here is to test them against the lived experience of the respondents and investigate the effect of location in the labour market on the subjective responses of designers. The meanings of terms like flexibility and job security can be better examined through peoples' personal responses to them and theories based on statistical interpretations can be illuminated through individual experience.

2.4 Postmodernism

Related to these new forms of productive organisation are ideas of postmodernism. Postmodernist thought celebrates plurality, ephemerality, and flux. Certainly the distributed enterprise represents plurality in drawing a range of partners together. It is ephemeral because the configurations involved are fleeting and because the world in motion, the flux, will never be repeated.

David Harvey's (1990) examination of postmodernity uses a range of examples to illustrate these trends. However, he is less convinced by arguments for a break with the previous movements of modernism and sees the new configurations as extensions of older ones used by capitalists as strategies for accumulation. Harvey takes a historical materialist approach following Marx and argues that such an approach:

'helps us dissolve the categories of both modernism and postmodernism into a complex of contradictions expressive of the cultural contradictions of capitalism. We then get to see the categories of both modernism and postmodernism as static reifications imposed upon the fluid interpretation of dynamic oppositions.' p.339

Harvey's analysis of postmodernity is comprehensive and provides a picture of how economic forces shape cultural and social life. He illustrates new configurations of production and capital and how they affect the organisation of life.

Harvey uses specific examples from the fields of the cinema and architecture to provide particular insights into postmodernist thought. His picture of the postmodern economic field is based on macroeconomic data and less on detailed analyses of production. The discussion that follows in Chapter 5 gives such a detailed examination of the introduction of CAD technology into design production and supports Harvey's macro-economic arguments about reductions in the turnover time of capital and time-space compression.

The central idea of Harvey's book is 'flexible accumulation' - a model of advanced capitalism that is post-Fordist, but not postmodern, since it still has all the attributes of modernist capitalism.

'It rests on flexibility with respect to labour processes, labour markets, products, and patterns of consumption. It is characterised by the emergence of entirely new sectors of production, new ways of providing financial services, new markets, and, above all, greatly intensified rates of commercial, technological, and organisational innovation.' p. 147

He gives a range of macroeconomic data to support this argument centring on changes in the structure of the labour market. Two key concepts, or properties of flexible accumulation have illuminated the present study: reduced 'turnover time' and 'time-space compression.'

Flexible accumulation is characterised by a reduction in the turnover time of capital, the circulation of capital, as explained by Marx in Volume 2 of Capital (1976b), is more rapid. As the rate of turnover increases so must the rates of production and of consumption. He associates the acceleration of production with new technologies and new forms of organisation. On the increased pace of consumption he says:

'The half-life of a typical Fordist product was, for example, from five to seven years, but flexible accumulation has more than cut that in half in certain sectors (such as textile and clothing industries), while in others - such as the so-called 'thought-ware' industries (e.g. video games and computer software programmes) - the half life is down to less than eighteen months.' Harvey, 1990, p.156

He goes on to illustrate how the spectacle, as a form of instantaneous consumption, is the ultimate manifestation of this turnover reduction. He has in mind the mass marketing of memories, trips of a lifetime and events of popular culture, in sport and art, where the products are short lived (fireworks spring to mind) but the experience is the selling point, buttressed by memorabilia and the typically postmodern form of both art and low culture: photography.

This acceleration of turnover is reflected in the experiences of the respondents in the current study, both in the organisation of the enterprises in which they find themselves and in the technologies they use. The changes in technology are perhaps easier to trace than the developments in organisational configuration. The impact of new technology on design activity is central to this study and, therefore, the ways in which configurations of computers for computer aided design and manufacture (CAD/CAM) or the relatively new production technology of strereolithography taken together with the participation of the people concerned have reduced turnover time, are described in detail.

A second and related attribute of flexible accumulation is the change in the phenomenological experience of space and time, what Harvey (1990) calls 'time-space compression.'

'Space and time are basic categories of human existence. Yet we rarely debate their meanings.' p.201

He links this idea to the increased pace of decision making and developing technologies in transport and communication:

'The time horizons of both public and private decision making have shrunk, while satellite communication and declining transport costs have made it increasingly possible to spread those decisions immediately over a wider and variegated space.' p.147

Concrete examples of both the rapid pace of decision making and of geographical diversity are provided by this study. More importantly the development of the respondents' perceptions of space and time through their engagement with, among other technologies, those of communication, are analysed in detail. The phenomenological experience of time in design has changed most notably for designers where the product life cycle now has a different structure, is shorter, and they must come up with new ways of innovating and decision making to cope with it. Not only do they react to perceived pressures to time compression they actively promote it by engaging and inventing methods and technologies to allow them to get products to the market in a shorter time.

Harvey supports his thesis with his own examples but these do not include detailed examinations of the social processes underlying the changes he describes, nor does he allude to any of the actors performing the changes. His theory can be seen more clearly with the benefit of detailed examples from engineering where the actors are developers as well as users of the technologies to which he ascribes such power. Today's designers use technology providing almost instantaneous transcontinental communications along with rapid production and transport technology in new and fluid configurations of design and engineering production. These are concrete examples supporting Harvey's macro-social and macroeconomic explanations.

2.5 Development of theory in this study

The approach taken in this study runs counter to much mainstream engineering design research. After the fact rationalisations of design practice are replaced with as it happens explanations of design practice. Narratives are presented in designers' own words so that the immediacy of their practice is made evident and designers themselves are made central to the explanation of their action.

The naïve technological determinism that some sociologists of technology subscribed to during the early days of CAD technology is challenged by the detailed social history presented by the respondents. Contrary to pessimistic predictions of de-skilling and a reduction in autonomy designers have increased their control over the equipment they use in their work. Further, they have exercised their design judgement in influencing and defining the use of new technology in design practice.

On the other hand theories of core and periphery labour markets are advanced by the current study especially by introducing ideas about exchanges of cultural capital. Design judgement requires a large amount of embodied cultural capital and designers working as consultants, on the periphery, can command high premiums for the application of it.

Harvey's phenomenology of time-space compression is also supported by the current study. Harvey's exposition uses macro-economic data and examples from the cinema and architecture and is further tangled with the linguistic baggage surrounding the term postmodernism. A case study of the social organisation of rapid prototyping provides a micro-social example of time-space compression and in doing so builds on Harvey's theory.

3 The theoretical framework of Pierre Bourdieu

Bourdieu's theoretical framework can be used to explain how it is that designers have attitudes or dispositions that allow them to be and also make them designers. These properties are passed on from generation to generation of designers through their contact with each other and the objects they work with and on, in what Bourdieu calls a mode of cultural reproduction. They gradually attain an attitude that moves from an idea that design might be worth doing to one where it is the only thing worth doing. Attributes such as these are part of the habitus, which in its various forms is one of the central concepts of Bourdieu's theoretical work.

It is wrong to treat the habitus separately from other key concepts in his work, such as field, capital, and illusio. The main thing to consider with Bourdieu is his overall project of sociology. So, while he cuts through traditional sites of sociological controversy, such as the distinction between structure and agency, objectivism and subjectivism, he also criticises sociologists for focusing too narrowly on these internal conflicts, and not on their objects of research. This attitude is central to his ideas about reflexive sociology.

Calhoun, LiPuma and Postone (1993) sum up the differences between objectivism/structuralism and subjectivism/constructivism:

'Subjectivist viewpoints have as their centre of gravity the beliefs, desires, and judgements of agents and consider these agents endowed and empowered to make the world and act according to their own lights. By contrast, objectivist views explain social thought and action in terms of material and economic conditions, social structures or cultural logics. These are seen as superordinate to and more profound than agents' symbolic constructions, experiences and actions.' p.3

Several writers have addressed this dichotomy with Bryman (1988) concluding that the split between the two approaches is false and especially so when related to questions of method. Giddens addresses the issue by explaining that social structures may constrain human action but they do not determine it (Giddens, 1993, pp.719-721). He has also developed his own approach – structuration theory (1984) – in which he argues for a duality of structure where social structure is at once the medium and the outcome of social action. He adds the essential element of time or history to structure and emphasises the 'continuity and transmutation' (p.25) of social structures. Social action takes place within a continuously changing structural context but still has a conscious intent.

Engineering generally, and design more peculiarly, are highly structured activities. Engineers are also powerful agents of change in society; it is their business to bring about the new. Striking examples can be found from the field of travel where aircraft and motor transport technology have changed the way people, especially in the West, organise their lives and their societies. At the same time engineers work in a profession with recognisable routes of entry, a hierarchy and opportunities for career paths.

Bourdieu's approach has developed through confronting questions thrown up by his own studies to work out the false conflicts in the seemingly disparate approaches surrounding structure and agency. He especially addresses the problems of a Levi-Straussian structuralism as Calhoun, LiPuma and Postone (1993) put it:

'Bourdieu explores the ways in which objectivism (especially structuralism) depends on understandings and orientations it does not make explicit even to itself and how a version of subjectivism neglects to explore adequately the objective social conditions that produce subjective orientations to action.' p.3

It is an over-simplification to reduce Bourdieu's thought to the trinity of habitus, field and capital but he does it himself:

'[(habitus)(capital)] + field = practice' (Bourdieu, 1984, p.101)

These three concepts are fundamental to understanding Bourdieu's work and each will be briefly examined in relation to the current study.

3.1 Habitus

The idea of habitus is the most pervasive of the three but should not be viewed in isolation. It is not a new concept: Bourdieu does not claim to be the inventor of habitus but, fairly, attributes it to his reading of Husserl (Bourdieu, 1990b, p.12). Lane (2000), in his biographical and critical analysis of Bourdieu's work, traces the concept back to St Thomas Aquinas and through him to the Greek and Latin classics (p.41). He identifies Bourdieu's introduction of the concept into his work in a 1963 book Travail et travailleurs en Algérie (Bourdieu, 1963) where Bourdieu had related a variety of sociological methods to overcome the subjective objective opposition:

' 'habitus', a concept which sought to describe the way objective or material conditions of existence were internalised into a structure of subjective dispositions, a set of practical expectations or anticipations, an 'attitude towards time' which reflected the 'objective future', the 'field of effective possibilities' open to particular agents or groups.' (Lane, 2000, p. 27 with quotes from Bourdieu, 1963, p.346)

The concept is developed throughout Bourdieu's work, in The Logic of Practice (1990a) he gives a detailed definition:

' . . . systems of durable, transposable dispositions, structured structures predisposed to function as structuring structures, that is, as principles which generate and organise practices and representations that can be objectively adapted to their outcomes without presupposing a conscious aiming at ends or an express mastery of the operations necessary in order to attain them.' p. 53

The dispositions of designers at once allow them and constrain them to design the way they do. The structured and structuring nature of design activity is recognised as being embodied in the designers through their habitus but without the designers having to be reflexively aware of it. This is further explained in In Other Words (1990b):

' . . . types of behaviour can be directed towards certain ends without being consciously directed to these ends, or determined by them. The notion of habitus was invented, if I may say so, in order to account for this paradox.' pp.9/10

Different types of habitus are embodied in individuals - class habitus, sexual habitus, occupational habitus and so on. Bourdieu has used the idea of habitus variously in his studies of artists, critics, sociologists, Algerian and French peasants, among others. The chance, here, is to study the engineering habitus and what its properties and constituents might be.

In various places Bourdieu relates the habitus to three other fundamental ideas: hexis, doxa and praxis. Hexis is bodily; that is to say it is manifest in the way people physically experience social action. It is in the way people walk and talk and in the way that they feel about situations. His first employment of hexis was in his study of marriage ritual when he returned to the Bearn society of his childhood. Young peasant women had taken positions in the expanding female labour market in local towns and, having had a taste of sophisticated urban living, returned to view their male counterparts as clumsy and rustic. Bourdieu develops the idea of hexis in contrasting the physical deportment of town and country folk. It is also manifest in displays of emotion, linked to feelings of well-being or unease. By this emphasis on the body Bourdieu aims to correct the Western philosophical traditions over-rationalist positions, as in Levi-Strauss's view that the circulation of women in marriage is the circulation of signs and not bodies (see Bourdieu, 2001, p.44/45).

The biologist Peter Medawar uses the example of the 'aha' moment in science that brings with it a physical and emotional high that is not merely the result of an intellectual experience of achievement or the solution to a puzzle. Designers are certainly familiar with this feeling, which accompanies the stages in a design project, from the initial acceptance of an idea through development and seeing it in the shops or motoring down the street.

In addition designers have a physical attitude - the way they carry themselves and their bodily attitude when they work. This is evident in the photographs of drawing offices and in stereotypes of the pencil behind the ear and extending to how they hold a pencil or a rule. The physical attitude has changed due to the introduction of computer technology and its development can be seen through stories of the arrangement of the technology and of the designers in relation to it.

Doxa encompasses things that are left unchallenged in a field - like common sense - that are taken for granted. Doxa is a powerful concept that Bourdieu has used to good effect to critique social science and its conduct as well as in his research.

'Doxa is the relationship of immediate adherence that is established in practice between an habitus and the field to which it is attuned, the pre-verbal taking-for granted of the world that flows from practical sense.' Bourdieu, 1990a, p.68.

In this sense Bourdieu distinguishes his work from that of those concerned with ideology perceived in too rationalist a manner as specific consciously worked out arguments that lock together in mutually consistent patterns. Bourdieu is concerned with a pre-reflexive rather than a calculated and monitored activity.

That designing is treated as a separate activity is the most obviously doxic notion in design. As Braverman (1974) has pointed out the separation of conception from execution has historical roots in the division of labour in the industrial productive system. By examining the historical situation of the design field its doxa can be better understood and questioned. Breaking with assumptions perceived as representing common sense is fundamental to Bourdieu's research and in making the break the doxa in the field under study are revealed and challenged.

All fields have modes of language and expression internal to them and in design these modes are expressed verbally, in writing and visually. The identification of these doxic instruments as well as their historical development is a legitimate object of research. The commitment to a field – the feeling that the game is worth playing, in Bourdieu's term the illusio, is based on a pre-reflexive belief in the game's unarticulated doxa.

Individuals can take positions within the field, align themselves with certain factions or groups and in doing so can seem to challenge the doxa. The first Mini car, in the 1960s, with its transversely mounted engine, front wheel drive and gearbox lubricated by the same oil as the engine, was heterodox in that it challenged the orthodoxy of automobile design of the day. However, this heterodoxy served to reinforce the structure of the field; the doxa that cars should be designed and that doing so is worthwhile was not contested, but was strengthened through these innovations.

If doxa are the langue of practice, then praxis is the parole. Praxis is actual, heat of the moment doing. Hexis and doxa are brought together to substantiate the practical action of a field. Praxis is in the doing and can be thought of as a kind of inbuilt strategising where the options are weighed up and decided unreflexively in the heat of the moment, between the blows of the hammer.

People do things as if it is the only thing to do and this is especially evident in design where some activities are so routine that designers do not even notice them. When challenged as to why something might be so, in form or in operation, they cannot articulate properly the reason although they might think that there must be one.

In brief, aspects of the habitus that help to explain its operation are hexis, doxa and praxis. They represent the bodily, the sub-reflexive, and the active respectively and can help the study of people's action through the framework of habitus.

A fundamental premise of this thesis is that designers have a distinctive habitus that sets them apart from other professions, allows them to act in the way that they do and also restricts their action, or constrains them to certain modes of thought, expression and action.

Some design researchers (Schon, 1987, Bucciarelli, 1994) have identified the role of uncertainty in design. Bucciarelli (1994) examines the role of uncertainty, through vague, incomplete or ambiguous specifications and indeterminacy – the impossibility of accurate performance prediction prior to test and production, is inherent to design. Bourdieu says that: 'the habitus goes hand in glove with vagueness and indeterminacy' (1990b, p.77). Designers therefore act according to Bourdieu's formula where:

'The conditions of rational calculation are practically never given in practice: time is limited, information is restricted etc. And yet, agents do do, much more often than if they were behaving randomly 'the only thing to do'' (1990b, p.11)

So, while operating within this sea of uncertainty designers act with regularity, not from a juridical rule like standpoint but from an open, flexible, yet regular attitude which is spatially and temporally situated.

Bourdieu refers to the habitus in many places as a 'feel for the game' (e.g. 1990b, p. 148):

'the feel for the social game that makes it possible to take for granted the meaning objectified in institutions.' (1990a, p.27)

A central idea of the habitus, though, is in how it is developed and passed on. In Distinction (1984) the feel for the game is described as a 'cultural competence' (p.66) and the different modes of reproduction in the habitus lie not just in the cultural competence but in the manner of their application.

'The competence of the 'connoisseur', an unconscious mastery of the instruments of appropriation which derives from slow familiarisation and is the basis of familiarity with works is an 'art', a practical mastery which, like an art of thinking or an art of living cannot be transmitted solely by precept or prescription . . . learning it presupposes . . . repeated contact with cultured works and cultured people.' p.66

This cultural reproduction is about a system of strategies that groups use to 'perpetuate' their existence and 'their position in the social space' (1990b, p.74). Designing may be an inherent human activity (see Cross, 1990) but the practice of designing in the social world requires an education in the principles and regularities at work within that social world. This education can only be achieved through physical contact with the people and objects surrounding and involved in design.

Sometimes this idea of perpetuation is taking too literally, the habitus is far more flexible both as a concept and as an embodied disposition to action. Calhoun (1993) argues that:

'Bourdieu's theory is at its best, therefore, as a theory of reproduction, and at its weakest as a theory of transformation.' p.72.

However, in Bourdieu's most controversial work – Homo Academicus (1988) - he does offer a theory of transformation showing how, in the 1968 crisis in French education, the French elite rode the wave of change and still maintained their position. The consequence was that the educational and social system was radically changed but the people at the top were still on top.

This study will show how the design habitus transformed its practices in accommodating the introduction of new technology in the form of computer aided design and manufacture (CAD/CAM) and data storage and retrieval, and indeed, appropriated these very technologies and directed their development to the ends of its inhabitants.

The habitus is a mediator for change. It can deal with shock to the system such as the French educational elite found when their junior colleagues and students took action in 1968 or when the first computers were introduced into design offices. The field can be transformed but only through the mediating influence of the habitus.

Bourdieu's view of habitus can bring together and make coherent many threads of classical sociology such as entry into a profession and the development of a professional ideology. It can be used to explain the dispositions of both sides in Donald Roy's (1952, 1954) work on the peculiar economic and social organisation of a machine shop. Becker's (Becker et al., 1961) work on student doctors is a case of the inculcation of both a student habitus and a medical one. For instance the students' unofficial trading in cases in order to gain a wide range of experience for themselves contrasts with their attitude to their teachers who they expect to be distinguished but narrow specialists. Burns and Stalker

(1994) report the clash of habitus between two men who 'take pride in their work' but work slowly in order to get the job right and management concerned with efficiency, speed and effective machine utilisation. When the foreman says:

'It appears to me they are just made that way' p.255

he reveals that it is an embodied disposition of the men that is causing the concern. Burns and Stalker (1994, like Gouldner 1954) also deal with the production and protection of status by individuals and reproduction of the status structure with the collusion of these individuals in a clear case of the habitus at work.

Becker and Carper's (1956) notion of the 'acquisition of ideology' where they identify a specific moment in a person's life where they acknowledge that their chosen métier is worth doing is a more specific case of Bourdieu's assertion that part of the habitus is that the game is worth playing. In his analysis of the Barthes-Picard affair (1988) he points out that the two have more in common than they would admit in that they both believe that the field of literary criticism is worth fighting over.

In the same way engineers must recognise the activity of engineering as worth doing, that the field of engineering is where they want to be. The same could be said of all professions. Some specific cases will be presented of individuals' entries into the engineering profession in order to show the diversity of circumstances that can lead to entry into the profession. The realisation that the game of engineering is worth playing, in Bourdieu's term the illusio, is part of the accumulation of an engineering habitus.

The ultimate role of the notion of habitus in this study has been as a sensitising concept informing data analysis and making it critical. The identification and analysis of the habitus in action is an underlying concern and all data analysis has been undertaken with this in mind.

In summary, Bourdieu's formulation and development of the idea of habitus is a powerful one and can explain a range of social behaviour while overcoming the difficulties of traditional structuralist or hermeneutic approaches. The framework provided by habitus lends itself to the study of designing and designers. That said, it is dangerous to isolate the habitus from the rest of Bourdieu's theoretical oeuvre; he employs a theory of capital to explain the structure of social fields.

3.2 Capital

Fowler (1997) points out that Bourdieu's theory of capital:

'owes much to the need to move beyond a crude economic reductionism in Marxist thought.' p. 20.

In an uncharacteristically didactic paper Bourdieu points out that:

'Capital is accumulated labor' 1986 p.241

This could be taken for a pretty standard Marxist analysis. But he develops the idea of capital in two ways; firstly as a representation of the structure of the field and secondly as:

' a force inscribed in the objectivity of things so that everything is not equally possible or impossible.' 1986, p.241/242

echoing Marx's own formulation that capital is:

'Not a thing, but a social relation between persons which is mediated through things' Marx, 1976a, p.932

According to Bourdieu capital presents itself in three 'guises': economic, cultural and social. Economic capital can be directly converted into money. It can be held in the form of stocks and shares, commodities or property, in which case it may be regarded as being institutionalised since property rights are guaranteed externally by the state or some other institution.

Cultural capital also takes three forms: embodied, objectified, and institutionalised. It takes time to accrue and is therefore only available to those with the time to acquire it. Bourdieu makes great play of domestic transmission of those dispositions through the family and how they give some people seemingly natural advantages. He remarks on the effects of this transfer of cultural capital from generation to generation on the structure of society.

Embodied cultural capital is acquired at personal cost; it cannot be done second hand, and cannot, like economic capital, be instantaneously transmitted. It can therefore have scarcity value from which profits might be accrued. It is constituted from culture, ways of talking, of acting, manners, and, being embodied, is part of the habitus.

Formal qualifications and honours constitute cultural capital in its institutionalised form. In the case of an aristocratic title, the capital can be passed on, but in most cases institutionalised capital resides with the individual and dies with them[2]. Academic qualifications take time to acquire but are conferred at a specific moment in time. Bourdieu points out:

'The material and symbolic profits which the academic qualification guarantees also depend on its scarcity'. 1986, p.248

Objectified cultural capital is found in those things with which people surround themselves. These might be works of art, cultured books, fast cars, or the trappings of technocracy, such as cellular telephones and the latest computer technology. Objectified capital is transmissible in terms of ownership but not in appropriation. Someone may own a great work of art but not possess the necessary culture to appropriate it, or appreciate in the way that an aficionado might. That is they do not have the means of consumption.

Bourdieu makes the corresponding point that the lack of material ownership of their own means of production gives engineers an ambiguous relationship with it. They do not own it in the economic sense but they possess the cultural capital to be able to use it (1986, p.247). This competence is the bargaining chip, with which they can negotiate the price for selling their labour. If the levels of skill required in the means of production are reduced, competencies are more easily acquired, and as the cultural competence loses its scarcity value the balance of power shifts to those who own the means of production. Which is another way of putting Braverman's (1974) thesis. The converse, which Braverman missed, is that increasing the skill level allows those with the cultural capital to appropriate the means of production without owning it materially, and shifts the power balance towards them in what Bourdieu has called a 'dialectic of distinction and devaluation' (1984, p.135).

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[2] The difference, in the British system of honours, between a baronetcy and a knighthood, is a particularly striking example.

The struggle takes place between different groups, each one trying to maximise the value of their capital and the profit they derive from it. It is a struggle mediated by the habitus; for engineers it is about how they use the dispositions they already have in the habitus and appropriate changes in these means of production by developing them through their engagement with the materials of production.

Social capital is quite simply membership of a group. Bourdieu gives a detailed definition of a group:

'Social capital is the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalised relationships of mutual acquaintance and recognition - or in other words, to membership of a group.' p.248

In Bourdieusian terms the group is recognisable as such by the people who are in it and the people who are not. The recognition is mediated by acts of exchange. The membership of the group is embodied in the habitus.

This point bears on research method. If a sample of a given group is to be constructed for the purposes of research the correct way to go about it is to ask people who may be in or out of the group to identify its members. Starting with a preconceived list of characteristics is precisely the wrong way to go about sampling because these characteristics do not define the group.

Bourdieu outlines how in modern societies the traditional modes of reproduction of groups through family connections have been replaced by other social networks such as clubs, neighbourhoods and schools. These networks have their own calendar of occasions, meetings, elections and gatherings where exchanges take place and the group is perpetuated. The industrial workplace is one important social network that Bourdieu did not explore, where these exchanges take place and groups are perpetuated.

All capital, economic, social, and cultural, is symbolic when it is recognised as such in a relationship. Symbolic capital is exchanged though gifts and ritual in what Bourdieu has called 'symbolic economism'. He points out this economy where the conversion of material capital into symbolic capital and back again sometimes hides the true nature of the exchange. 'Symbolic economism inspires acts that are very directly material' (1990a, p.121) and 'the ingenuity and energy' devoted 'to disguising the truth of economic acts.'

(p.114). Capital can be converted or transformed from one form to another and it can be transmitted from one person to another.

3.3 Field

Bourdieu uses capital to explain the structure of fields. He says:

'A capital does not exist and function except in relation to a field.' Bourdieu and Wacquant, 1992, p. 101

By this he means that the system of social relations that constitute a field must allow for the different types of capital held by the agents acting in the field to be recognised by them and exchanged between them. He sometimes uses the analogy of a game; just as the habitus is a 'feel for the game' the field is the arena where the game is played out. Different to a game, where rules outlaw certain actions, actions in a field are only recognised as relevant by the actors alone, being subject to and an expression of the doxic part of the habitus. The field governs itself without recourse to umpires or referees because the actors have stakes in the game and they also recognise the intrinsic importance of the game, what Bourdieu calls the illusio – the recognition that the game is worth playing.

'The value of a species of capital hinges on the existence of a game, of a field in which the competency can be employed.' p.98

The analogy of a game only stretches so far in that the players in a field do not consciously choose to play a game. A game is a game for itself but a field is a game in itself. In a field:

'Players agree, by the mere fact of playing, and not by way of a 'contract', that the game is worth playing, that it is 'worth the candle', and this collusion is the very basis of their competition,' p.98

A further aspect of field is that it structures the social space using systems of relations.

'To think in terms of field is to think relationally' p.96

Bourideu's use of field employs a double meaning to extend the analogy: the field is like a magnetic field where objective forces apply to the actors and also a field of play, as in a game, or struggle, as in a battle, where the actors bring to bear their own influence and can change the structure of the field.

Interactionist social theory can be likened to particulate mechanics in physics where events can only be explained by the collision of entities and the changes of state that follow. Social theory in terms of field takes a more Maxwellian view where the behaviour of entities is governed by their position in a field (in the physics sense- gravitational, magnetic etc.) as well as collisions with other particles. So the behaviour of social entities can be explained, or indeed has to be explained both in terms of their position in the social field (the social space of possibilities) and in terms of their action and influence on the field.

His use of field is most evident in his application of correspondence analysis as a research method. This involves mapping out the field in terms of types of capital on one axis and of the volume of capital on the other. The third axis is time, but Bourdieu tends to take 2D snapshots of fields at certain times and trace their transformations in time. He does this most famously in Homo Academicus (1988) when he maps out the field of French social science and the arts and in the English version he puts the names of the actors at representative places in the field. The object of research is not the structure of the field but its construction.

Like all fields, the engineering field must be understood as history. The engineering habitus is embodied history - the accumulation of engineering knowledge and practice passed on and transformed through generations of engineering practitioners. The engineering field is this history objectified - the capitals that engineers have and the systems of relations and interactions that allow the exchange of them.

In his studies of artistic production Bourdieu advances the idea that the field of production is structured by an opposition between the 'field of restricted production' and the 'field of large-scale production.' The former he describes as:

'a system producing cultural goods (and the instruments for appropriating these goods) objectively destined for a public of producers of cultural goods' Bourdieu, 1993, p.115

In the plastic arts it is structured around the artist-dealer-critic nexus and as Johnson points out:

'the stakes of competition between agents are largely symbolic, involving prestige, consecration and artistic celebrity.' Johnson, 1993, p.15

The field of large-scale production, also called the expanded field, is:

'specifically organised with a view to the production of cultural goods destined for non-producers of cultural goods.' Bourdieu, 1993, p.115

Engineering is almost always carried on in this field; its products are abandoned to the market for consumption by other people who will apply their own criteria of distinction.

Evidence for a restricted field in engineering, is limited although the space race and various land speed endeavours might qualify. It could be said that the symbolic capital accumulated by the superpowers during the space race was exchanged for economic capital in many ways. In the same way land speed records are not broken without commercial sponsorship or patronage; the symbolic capital exchange attached to such records is also 'directly material' (1990a, p.121).

Fields are defined by exchanges of cultural and symbolic capital and not by their products. Design contains inherent notions of quality: what makes a 'good' design and what makes a 'good' designer. The way that designers apply criteria of distinction to their designs and the designs of others may be thought of as constituting a restricted field.

The most important thing about field is that it is not static, it is the site of struggles, pacts, schisms, collaborations and changes. Just as the habitus is reproduced and transformed as it is passed on through history, so too is the field.

Bourdieu's ideas of habitus, capital and field along with related ideas about doxa, praxis, hexis and illusio form a coherent theoretical system and he emphasises two aspects of his approach to theory. The first is that concepts cannot be viewed in isolation and must be seen in a system of related ideas. The second is that theory can only be understood in use, that is in its application to empirical problems through research.

'concepts have no definition other than systemic ones, and are designed to be put to work empirically in systematic fashion. Such notions as habitus, field and capital can be defined, but only within the theoretical system they constitute, not in isolation.' Bourdieu and Wacquant, 1992, p.96

3.4 Reflexivity

Bourdieu's approach to theory is necessarily inextricable from his method. Perhaps his most important contribution to social science is not his theory but his exhortations to reflexivity. His position, outlined in An Invitation to Reflexive Sociology (with Löic Wacquant 1992), is that sociologists should always be aware of their own habitus when going about their business. That the doxa of sociology be challenged is of primary importance to Bourdieu. Preconceptions, language and categories are imposed by the structure of the field, are misrecognised and taken for granted.

In Homo Academicus he quotes Charles Peguy:

'Historians don't want to write a history of historians. They are quite happy to plunge endlessly in to limitless historical detail. But they themselves don't want to be counted as part of the limitless historical detail. They don't want to be part of the historical order. It's as if doctors didn't want to fall ill and die.' Peguy quoted in Bourdieu, 1988

He implies that sociologists do not want to analyse themselves or to question their most deeply held beliefs; particularly, that they do not like to see themselves as determined by social structures.

Bourdieu and Wacquant expand their view of reflexivity and relate it to definitions used by other social thinkers (1992, p.37/38). They expand on Gouldner's (1970) concerns, warning against his introspection, and go on to say that the individual sociologist must be aware of their own position in the wider social world by moving from the individual sociologist to the whole field of sociology and the:

'limits of knowledge specifically associated with the analyst's membership and position in the intellectual field.' Bourdieu and Wacquant, 1992, p. 39

They explore the biases caused by a lack of reflexivity. The first source of bias, and the subject of most of their warning about reflexivity, is the researcher's social origins and position in the social world. The second is the bias caused by the position of the researcher in the 'microcosm of the social field' (p. 39). They continue:

'that is, in the objective space of possible intellectual positions offered to him or her at a given moment, and, beyond, in the field of power.' p. 39

The third bias stems from the intellectualist stance of the researcher. In essence, the fact of researching, the recognition of the game of social research, with its rules and playing surface, is encapsulated in the idea that social life is a spectacle and can be analysed. This goes right back to The Craft of Sociology (1991) where Bourdieu, Chamboredon and Passeron argue that the instruments of social research are part of this intellectualist stance, and are so taken for granted that they are almost invisible to the researcher.

In summary reflexivity in the sense that Bourdieu uses it requires analysis of:

'not only the preconstructed representation of this world but also the cognitive schemata that underlie the construction of this image.' Bourdieu and Wacquant, 1992, p. 247

Bourdieu turned his intellectual gaze on his own profession and his own social world in his monumental account of the French intellectual scene (Homo Academicus, 1988). Albeit narrower, this study is a similar attempt by an engineering designer to apply the instruments of sociological inquiry to initiate the construction of the field of engineering design. Bourdieu has some warnings for those trying to cross disciplines in this way:

'A former theologian turned sociologist who undertakes to study theologians may undergo a sort of regression and start talking like a theologian or, still worse, use sociology as a weapon to settle his past theologian's accounts.' Bourdieu and Wacquant, 1992, p.253

It is precisely in this cross-disciplinary inquiry that Bourdieu's reflexivity can be most useful. The doxa of inquiry are not the only ones to be challenged, the doxa of the objects of inquiry, being shared with them, must also be called into question.

3.5 The Weight of the World

Bourdieu's most recent work, The Weight of the World (Bourdieu,1999), is a collection of short essays and interview transcripts representing the collective work of a group of sociologists working together. People who shared a habitus with the object of research were selected to be interviewers and partners in the research, recognising that having something in common makes people more open to inquiry and allows for the things that they share to be examined.

'The Weight of the World has acquired a reputation as an untheoretical work.' Fowler 2002

But it is profoundly theoretical in two ways. Firstly it brings together all the threads of Bourdieu's work in a single study, with a wide-ranging empirical constituent. Secondly it brazenly confronts the reader with the object of research; the impact of the words on the page cannot be glossed by theoretical position taking. The new mode of economic reproduction with its accompanying rhetoric of 'flexibility' in working practices, which Bourdieu has examined elsewhere (Bourdieu, 1998b) is graphically illustrated in the experiences of workers at the Peugeot plant.

His use of the direct words of his respondents is part of his project to expand the range of voices that are given the right to be heard. The discourse legitimated by the establishment, whether the state or academia, makes paternalistic assumptions about people and what is good for them. In The Weight of the World, the researcher, along with the reader, is made to realise that if they had exactly the same experiences as these people, if they 'were in their shoes' (Bourdieu, 1999, p.626), then they too would be racist, violent, disaffected, despondent or anorexic.

It is here that this research, breaking with the traditions of design research, has its closest and strongest affinity with Bourdieu's project. The object has been to give voice to designers, to explain their dispositions, not just in the present, but also their collective history as told by them. This is in contrast to mainstream research that either ignores designers completely, or takes the paternalistic and patronising attitude that academics know better than them, and aims to make managing them easier.

The goal has been to give voice to designers and explain their actions in their own terms and on their terms. Bourdieu's theoretical framework has been of great utility in this endeavour.

4 Method

The methods adopted for this study have been chosen to suit two purposes. The first is to be harmonious with the object of research - to sense, feel and know the design habitus by disclosing the distinctions it makes, hearing the discourse it employs, uncovering the mechanisms for its transmission and reproduction and, more generally, to detect its concrete manifestations in the community of those who regard themselves as designers and are so regarded by others.

The second is to be sensitive and aware of preconceptions, assumptions and other properties of the research act that come from its being pursued in the environment of academia. The condition of researching, what Bourdieu calls the scholè (1990a, p.112), requires both the time to think, or leisure, and the environment of the academy. This condition encourages researchers to think in certain ways, to unconsciously limit the range of intellectual stances that they are willing to admit. Most important, for Bourdieu, is an awareness of this condition so that the 'scholastic fallacy' (1990a, p.112, 1998a, p.126) can be avoided. With this guidance, highly structured interviews or surveys that might depend upon or otherwise promote preconceived ideas concerning designers and designing have been rejected. The purpose was to discover and bring the concerns and opinions of the respondents to the fore and not subordinate them to the predilections of sociologists or design researchers.

The respondents were selected because their own perceptions of their position placed them in the field of design and other people regarded them as inhabiting it. In this way the need for the researcher to suppose who might qualify as being designers was avoided. A diverse group of respondents is the result. Not all of those interviewed have formal engineering qualifications. Some are members of professional bodies and others are not. Studies with an entirely different focus and using other methods might, appropriately, have had recourse to a constructed list of attributes, possibly including education, class, age and so on, and would have discovered a group conforming to the stereotype so defined.

In the same way, the initial interviews were not constrained to a list of prearranged questions, but were unstructured. Respondents were given free rein to discuss what they found important so that when, for instance, they spoke about their educational background they reflected their concerns and not those of the researcher. Areas of interest were identified after the interview and further approaches could be made to follow them up with the transcript in hand.

Data analysis was by an inductive scheme owing much to grounded theory. In this analysis areas of interest were identified from the initial data and then recourse was made to theoretical positions that could explain phenomena, or positions held by the respondents. The research site could be re-visited if it became necessary to gather supporting information. This process of data acquisition depended upon a constant shuttling to and fro, from initial data, to theory, back to research site and on to more first interviews with newly identified respondents.

The research object has been pursued with rigour through careful attention to a method that centres on the concerns and preoccupations of the respondents. The normative preoccupations of design research have been put aside, recognising the position of the researcher in the scholè and to avoid the pitfalls of the scholastic point of view.

4.1 Social science method

When engineering design researchers have taken a social science approach (Hales, 1987, Bucciarelli, 1994) it has been without reference to the vigorous debate about research methodology within the social sciences.

'Techniques from the social sciences need to be employed'
Stauffer et al., 1991, p.363

'Another important area for today's design science, in co-operation with psychology, philosophy, sociology, and ergonomics, is research on human interactions and qualifications for creative engineering design.'
Beitz, 1994, p.132

'Because of the essential human element, the field research techniques developed in the social sciences will be useful for gathering data.'
Wallace and Hales, 1989, p.556

Engineers researching design have traditionally used the methods of the natural sciences. In doing so they have come to realise that the methods of social scientists could be more suitable and appropriate for some areas of design research. Notwithstanding these exhortations method is given scant attention in the design literature.

The attempt has been made within the social sciences to give them equal status with the natural sciences by on the one hand adopting the methods of the natural sciences and on the other trying to develop ideas about inquiry that are specific to the social sciences. The development of methods intended to be more suited to social inquiry has created and fuelled a vigorous and perhaps divisive debate. One focus of the debate is the division between exponents of quantitative and qualitative approaches. Social researchers (e.g. Bryman, 1988) realise that this debate is sterile and argue that different approaches can sit side by side each informing the other. Bourdieu goes further:

'The traditional opposition between so-called quantitative methods, such as the questionnaire, and qualitative methods, such as the interview, conceals the fact that they are both based on social interaction which takes place within the constraints of these structures. Defenders of these two methodologies ignore these structures, as do the ethnomethodologists, whose subjectivist view of the social world leads them to ignore the effects exerted by objective structures not just on the interactions they record and analyse but also on their own interaction with those who are subjected to their observation or questioning.' 1999, p.608fn2

Bourdieu's most significant contributions to sociological theory have been intended to overcome the divisions between subjectivism and objectivism. In Weight of the World (1999) he gives his clearest definition of a method for overcoming these divisions. He emphasises that the research relationship is a social relationship (p.608) and care should be taken to avoid 'symbolic violence'. Interviewers are carefully selected to have something in common with the interviewees. 'Neutrality' is recognised as an imposition on the research relationship. He promotes interviewing as 'active and methodical listening' (p.610).

The focus in this study of designers and designing is on people who design. The search is for the qualities of the human element in design. Interviews have been open ended for there are no a priori notions of these qualities or attributes of designers that might be suitable for analysis by statistical methods. The project is not as extensive as Bourdieu's but it does share some common attributes especially that:

'the questioning quite naturally tends to become a double socioanalysis, one that catches and puts the analyst to the test as much as the person being questioned.' p.611

A singular feature that is emphasised in the Weight of the World is the relationship of the researcher to the researched; Bourdieu calls it 'participant objectification.' In this study the researcher is a designer and can therefore get close to the respondents. Bouridieu also has something to say about the treatment of the transcriptions: they should not be treated as pure, standalone texts but must be situated by constructing the field using secondary data gathered by other methods.

4.2 Observation

Social scientists studying groups of people commonly choose to observe the subject-group, either as participants in the group's activity or enterprise or as impartial, external observers. Observational study was formalised by Malinowski (1922, 1932, for example). His work has contributed important terms and concepts to social science method; he drew the distinction between participant and non-participant observation and emphasised the effect of the researcher on the researched. For non-participant observation Malinowski talks about 'pitching one's tent', the tent being a symbol for the external stance of the researcher. This is exactly what Malinowski did when researching tribal cultures. He also describes his attempts to 'live without white men' and enter into the culture he sought to explain as a participant in it.

Bucciarelli (1988) was a participant observer when studying designers in a company making photovoltaic cells, Hales (1987) made a structured study into the design of a test rig for the power industry as a participant. Marples (1960) undertook a famous non-participant study of designers in the nuclear power and chemical industries.

Observation in this study was limited to the site visits when the interview was conducted. The visits typically lasted a whole day and the interviews took up a significant fraction of this. General information was gathered about office layout, company size and organisation from gatekeepers and other company personnel.

More importantly, detailed and specific information illustrating material from the interview could be followed up more easily on site. So when both Yan and Tony mention Techtronix 4014 terminals, somebody at Yan's company was able to find one in the subterranean bone yard where they kept obsolete or curious computer equipment. The detailed exposition of the work of a stereolithography technician was made possible by talking to these people on site, through contact with the respondent's subcontractors, and taking their direction to the literature about the technique.

Observational methods are more appropriate for studying wider organisations, locales and milieux. Gouldner's Patterns of Industrial Bureaucracy (1954) is a classic example of observational methods put to good effect. Gouldner studied the organisation as a whole and not any group of individuals within it. None the less, he makes striking contrasts between the habitus of the miners and that of the surface workers. The object of this research is the habitus of engineering designers and not that of the companies or industries they work in. The study is from and of the point of view of the individual designer, as opposed to an academic researcher's standpoint, which is the case in purely observational studies. Designers themselves have been sought out and interviewed with the intent of examining their perceptions and concerns and not those of the wider company or enterprise.

4.3 Identification of respondents

One of the properties of the habitus is that it recognises itself through exchanges of different forms of capital that define the group (Bourdieu, 1986, p.248). This property was relied upon to identify respondents having the engineering design habitus. Respondents had to identify themselves as engineering designers, and also be identified as such by other people, and by their employers or clients. Potential respondents were rejected if they were not recognised as active designers. It would have been possible to interview engineering managers and members of personnel departments to get their particular perspective on design and designers. The definition of design was left to the field itself and not to notions of it which were harboured by the researcher.

Everett Hughes (1984) gives the most forceful argument in support of this selection method in his explanation of what it is that defines a (ethnic) group; he outlines the normative view:

'Almost anyone who uses the term would say that it is a group distinguishable from others by one, or some combination of the following: physical characteristics, language, religion, customs, institutions, or 'cultural traits.'', p.153

He goes on to invert this definition:

'An ethnic group is not one because of the degree of measurable or observable difference from other groups; it is an ethnic group, on the contrary, because the people in it and the people out of it know that it is one; because the ins and outs talk, feel and act as if it were a separate group.' p.153/154

This study is not about ethnicity but Hughes definition applies to all groups and has been used to find respondents who are members of the group of engineering designers. The possession of social capital that is part of the habitus is sufficient to identify members of a group. The group is defined and its boundaries are fixed by acts of capital exchange.

'Exchange transforms the things exchanged into signs of recognition and, through the mutual recognition and the recognition of group membership which it implies, reproduces the group. By the same token, it reaffirms the limits of the group.' Bourdieu, 1986, p. 251

In this study the respondents identified themselves and were perceived as being designers by the gatekeepers who controlled access to them. The search for respondents did not start with the idea of a sample representative of designers, for at the beginning no evidence had been gathered to indicate what the notion of being representative might mean. So, rather than using a list of presupposed characteristics of engineering designers, or even a list of locations obtained from e.g. the Engineering Council, respondents were identified appropriately with the assistance of a group of people who had an interest in the study of engineering design and in their constructions of the field.

Candidate interviewees were identified through contact with the Royal Academy of Engineering's Visiting Professors in Engineering Design scheme. As the study became more focused the profile of the ideal candidate was circulated to anybody who expressed even a remote interest in the research in the form of a circular or flyer (see Appendix B).

Part of Bourdieu and Wacquant's 'properly social dimension' of research is how to locate 'reliable and insightful informants' (p.228) and this is a problem only answered in the hurly-burly of the research act. Once the group and their field have been identified by their own recognition of it the decision has to be made about which ones to talk to; this can only properly be done through a continuous to-ing and fro-ing from interview, research site, theory, concept and category.

Computer technology emergent in the late 60s transformed design practice on a broad front when it was introduced in the early 80s. Designers have evidently accommodated a revolution in the methods they employ. The significance of this shift was identified early in the study and it was considered important enough to actively seek respondents with direct experience of it. Respondents were sought who had been present and instrumental in the transformation of the field over that period and could provide an historical situation and construction of that transformation. These respondents were designers in their fifties, who had gone through a graduate apprenticeship or HND[3] education. They probably worked in one of the big industrials (GEC, Ferranti, Plessey, Metro-Vickers), companies that would have made an early investment in CAD technology. These designers had a wide range of experiences; they were in the privileged position of having undergone and themselves contributed to a fundamental change in the organisation and practice of design. Moreover they were in a position to witness the accompanying changes in industrial organisation in the past thirty or forty years.

Lincoln and Guba (1985) call this purposive sampling, they advocate:

'Continuous adjustment or 'focusing' of the sample' p.201

It is part of their approach to 'emergent' research design where the methods and procedures are not defined at the outset but are decided upon with regard to research questions as they emerge during the conduct of the study. The roots of the idea go back to inductivism and the grounded theory approach of Glaser and Strauss (1967) where there is a continuous shuttling to and fro between formulating concepts, data analysis and data gathering; that is, between theory and method.

The chronology of this process began with the idea of a design habitus, and evidence collected by interviewing designers indicated a huge shift in design practice due to the influence of computer technology. The theory of habitus can accommodate changes in practice - 'It is durable but not eternal' (Bourdieu and Wacquant, 1992, p.133). Subsequent inquiry was directed at uncovering the mechanisms by which the designers influenced and accommodated changes in their practice, the effect of these changes on their habitus and the mediating influence of it. Individuals were not confronted with blunt questions about their personal contribution to changes in their work but were allowed to independently raise their own concerns and develop them through being interviewed.

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[3] Higher National Diploma

The ideal place to stop data collection is when no new insights are being offered by the respondents but the location of this point is difficult. Even small numbers of interviews and site visits generate large amounts of data and the management of this is difficult even with the help of computerisation. In this study a point was reached where the categories were not being advanced by further interviews.

These considerations are not new and this study compares well with a number of other similar studies into other fields considering that this is a single researcher study. Carter and Kirkup's study, Women in Engineering (1990) comprised interviews with 37 women. Many of the interviews were conducted over the telephone with no opportunity to examine the sites of their respondents' action, or to collect secondary data there. Nevertheless they make strong conclusions about gender and engineering, about the woman engineer's habitus and about the objective structures affecting their lives. They also make general conclusions about engineering itself and the ethical and moral choices made by engineers. Mackenzie and Spinardi's award winning study (1995) used interviews with 52 people in three locations over a period of three years. Some of the interviews were conducted in groups and they had some periods of intense activity sometimes interviewing more than ten people in three days. With such an intense schedule they came away with a significant amount of data allowing them to extend the theory of tacit knowledge in design and extend the hypothesis that nuclear weapons could be 'uninvented'.

In each of these studies sufficient information was gathered to advance the knowledge of the field under investigation. Further investigation using the methods employed yielded little advance and the limits of the interviewing method had been passed. New methods must be employed to extend the conceptions that have been taken from the interview method. For example, a systematic quantitively based study of issues surrounding the routes people take into the profession of engineering might illuminate some of the issues uncovered here.

With a strategy for identifying respondents the interview method was used to acquire information in a form that could be used to disclose the design habitus at work. No preconceptions were initially taken into the field, and 17 unstructured but formal interviews were undertaken involving 28 people.

The study could not have been carried out without the support of the companies where the designers work. They have been generous with their time and contacts. The designers interviewed provide the central story and through contact with their colleagues in personnel departments, computing support and purchasing further information has been gathered about obsolete computing equipment and stereolithography, for instance. The opportunity to interview designers in Australia was fortuitous; the design community there is small in number and specialised but they are still part of the global design habitus. Indeed some of the adjustments they have made in response to their remoteness, such as the use of electronic data exchange, have become part of general design practice throughout the world.

4.4 Data gathering

4.4.1 Conducting the Interview

Interviewing may seem an obvious choice but the method is diverse and must be conducted with the object of research in mind. According to Fontana and Frey (1994) interviewing is the most common method in ethnographic fieldwork. Robson (1993) says:

'When carrying out an enquiry involving humans why not take advantage of the fact that they can tell you things about themselves.' (p. 227)

Though this is self-evident, the method is under-represented in mainstream design research where more formal, mechanistic, and highly structured methods have been used. It seems that design researchers are unwilling to engage designers in any kind of dialogue, being inhibited by a positivistic conception of the remoteness and objectivity of the researcher. A spectrum of interviewing strategies is available to the researcher, with interviews categorised by methodologists along a continuum from structured to unstructured.

4.4.2 Structured/unstructured

A traditional structured interview has a specified schedule of questions and alternatives with a predetermined order; usually the time and place for the interview are prearranged. A totally unstructured interview has the appearance of a conversation and can be serendipitous - a chance meeting in a corridor or next to the coffee machine, for example. While this kind of interaction can be dismissed as anecdotal, the data is valid and, with rigorous recording methods that make explicit the nature of the data, it is useful in research. The continuum of possible interviewing methods is bounded by the extremes of completely structured and totally unstructured interviews. Unstructured interviewing is often associated with exploratory or descriptive research, also usually carried out near the beginning of a research study. Structured interviewing is associated with testing explanations or predictions that have been thrown up by preliminary research.

Unstructured interviewing was chosen for several reasons but firstly because the research was exploratory. No preconceptions were taken into the field and the identification of areas of interest was left to the respondents. The aim was to get them to talk about those things which, through their habitus, they found important, to express themselves in terms and vocabulary of their choice, and thereby gain insights into the habitus.

A claimed advantage of structured interviewing is that it can be designed to eliminate any bias that the interviewee may have, whereas with a less structured approach bias may become apparent and efforts must be made to control it. This claim is under attack from several quarters. No interaction can ever be entirely free of bias and any attempt to remove bias implies that the relationship between the interviewer and the respondent is unequal. The inference taken is that attempts to remove bias involve an imposition of a framework owned and developed by the researcher on the research setting. This makes the interaction one way and unequal.

A more structured approach than this might have used a set list of questions for each respondent but still allowing for time in the interview for them to give voice to their own concerns. This approach would have been problematic because it would have been difficult to design a set of neutral questions with no preconceptions in the first place. A sociologist concerned with class might ask about parental occupation, one interested in the impositions of organisational structure might inquire about job title, hierarchy, and so on. However, such information as appeared theoretically valuable could be easily garnered after the central interview; it is an easy thing to make a telephone call and ask someone about their educational qualifications or their age. Once data had been accumulated and the research process was underway areas of interest were identified that could be extended to respondents who had not thought them important enough to mention at the first meeting. More often however, follow up contacts were made to clarify areas of confusion or terminology that arose during the transcription and analysis process; examples of this range from the expansion of acronyms or abbreviations to the study of the new production process of stereolithography.

In some cases the respondent did expect a formal list of questions and had difficulty forming a narrative without a great deal of help from the interviewer. To help in these situations a deliberately vague and open-ended schedule was drawn up (Appendix A) simply as a prop, or a distraction to help reticent respondents to formalise the interview for themselves. The schedule is shown for completeness and not as an instrument of research. Senker and Simmonds (1992) used a similar technique in their interview study of CAD operators:

'. . .interviewees were given considerable freedom to discuss whatever was foremost in their minds . . Some prompts, however were used to keep the comments flowing.' p.97

By appearing with a set of questions the interviewer overtly takes the lead in the interview and the respondents may interpret the situation as demanding a certain set of responses, a certain tone, or attitude to the interview. This attitude is difficult to overcome because after all 'It is the investigator who starts the game and sets up the rules' (Bourdieu, 1999, p.609). The aim in the central interviews was to give the lead to the respondent and allow them to speak about the things that they found important, giving a secondary place to the agenda of the researcher. Unstructured interviews reproduce the concealed nature of the habitus and this is entirely the point of this research.

No method can be entirely neutral and objective because the setting and the language used inevitably reflect symbolic power. As the research progressed and knowledge increased, the researcher being better informed could avoid exchange of previous findings with the respondents. The researcher did not reveal things about the research that could have influenced the respondent or encouraged them to say things that they might have thought the interviewer wanted to hear. However, as an 'insider' to the group of designers the researcher was able to form a relationship based on equality through shared language and experience. The respondents were sophisticated and knowledgeable and it was possible to build trust. Biases are revealed in the course of the interview but they form a critical part of the data and are to be studied and analysed rather than eliminated.

Sociologists have concerns about the role of the interviewer as a person and the relationship between the interviewer and the respondent. These are best expressed in the work of some feminist researchers. Feminists (e.g. Reinharz, 1983) talk about looking for 'shared experiences' and 'shared appreciations' between researcher and researched and among researchers. The researcher and the researched become the same thing. Feminists consider experiences from a woman's perspective, believing that in a male dominated world women's experiences are undervalued and ignored. There has been no specifically feminist research into engineering design. It would be interesting if a feminist researcher were to look at the experiences of women designers and to analyse design in feminist terms. Nevertheless the relevant idea of feminist research is that it:

'. . . would not create artificial distinctions between the production and uses of knowledge, between thought and feeling, between subject and object, or between expert and non-expert'
Fee, 1983, p. 22

And Robson (1993) summarises that it:

'rejects the view that . . . knowledge is necessarily produced by experts who then pass it on to non-expert consumers in a one-way non-interactive manner.' p. 65

While feminist researchers have sometimes ignored the power relations outside gender which pervade the field of the research process, they nevertheless articulate an important concern for the present research.

The unstructured approach relies more than the structured one on the interviewer's knowledge, experience and ability to improvise in the formation of questions. In this case the interviewer is a design engineer and shares a 'feel for the game' and plenty of common ground with the respondents. The position in the group as a designer and outside it as a researcher is a special one and provides a condition for 'nonviolent' communication (Bourdieu, 1999, p.610). In this recent work Bourdieu has advocated an approach that not only carefully selects the respondent but also the interviewer.

'When a young physicist questions another young physicist (or an actor another actor, an unemployed worker another unemployed worker etc.), as someone sharing virtually all the characteristics capable of operating as major explanatory factors of that person's practices and representations, and linked to them by close familiarity, their questions spring from their dispositions, objectively attuned to those of the respondent. Even the most brutally objectifying questions have no reason to appear threatening or aggressive because the interviewee is perfectly well aware of sharing with the interviewer the core of what the questions induce the other to divulge, and of sharing, by the same token, the risks of that exposure.' Bourdieu, 1999, p.611

Already having access to the language and practices of designers can provide data that would not be available to a researcher from outside the group and it sets up a relationship of equals eliminating symbolic violence. Interviews based on a discourse set up by the researcher, such as in market research, or where the grandiose professor is perceived to be descending from an ivory tower, involve inequalities. The intention here has been to approach people on equal terms, to aim for 'nonviolent' communication through 'social proximity and familiarity.' (p.610)

This process produced responses that were of importance to the respondent at the time of the interview setting. Perhaps unsurprisingly many respondents spoke about the same things. For instance, most of them outlined their educational background without explicitly being asked to do so. Depending on the context specific lines of enquiry and discussion were followed to explore more fully the respondents' perceptions of the features of the technologies and social structures with which they operate and may constrain or enable them in their work. It may be that this method has not been more widely adopted because researchers may be put off by the need to adlib in a live, tape recorded situation. However, interviewing is a skill and a skilled interviewer is a valuable resource for the research community.

The interviews were usually conducted in a formal setting at a pre-arranged time. This structuring helped with access to the interviewee and put the interview on a formal footing giving more of an opportunity to consolidate the ground rules on issues of confidentiality and so on. Even so, the schedule was as unstructured as possible and the interviewees were asked to talk around themes that interested them, or that they found important. More importantly the habitus was allowed to work in order to give the respondents the opportunity, in the presence of a peer, to show off their expertise, and demonstrate their contribution to the field and mastery of it.

In short, the idea was to gather rich 'thick' descriptions (Geertz, 1973) of designers' activity and see where these descriptions might lead. The outcome of this procedure was a focus on changes in design activity due to the implementation of new technology. So, along with the purposive sampling of respondents with something to say about these changes, the slant of the interview changed with a stronger focus on a history of change in design activity rather than a description of everyday design activity in the present.

4.4.3 Group interviews

Two group interviews were carried early in the study: Interview 3 and Interview 5. The first was deliberately arranged by the researcher as an experiment to try out the method, and see if the advantages claimed were evident. The second occurred spontaneously: a deal of interest had been stirred up about the study and on the researcher's arrival at the research site the intended interviewee was joined by a colleague and her boss after the rest of the staff had been put back to work.

Morgan (1997) claims that group interviewing is a halfway house between participant observation and individual interviewing. Advantages claimed for unstructured group interviewing are the bringing together of well-informed participants and Blumer (1969) claims that this is 'more valuable many times over than a representative sample.' (p.41) Group interviewing demands more from the interviewer and Fontana and Frey (1994) outline these risks:

- dominant respondents taking over the interview,
- recalcitrant respondents may not participate in the interview, and
- it may be difficult to make sure there is a full range of responses from the group.

A risk not identified by Fontana and Frey is that the group may function as a group and collectively pick up assumptions or favoured responses from the interviewer. Alternatively a power relationship may be in play and skew the responses. For example, in Interview 5 it is obvious that Kevin is Ian's and Jennifer's boss. Despite this the discussion is free; although Kevin is authoritative within his expertise he defers to Jennifer's detailed knowledge in matters of day-to-day operation of, for instance, CAD:

> "Kevin: We can do - we can do a sort of - I can't remember the word for it?
> Jennifer: IGES?
> Kevin: Yeah. IGES translation, that's right."
> Interview 5 p.10

In this instance all the respondents were from the same department but had different levels of responsibility. The interview demonstrated some of the power relationships in play and revealed different perspectives of activity such as computer work. Ideas about group and discipline identity could be explored in interview 3, for though the respondents shared the same nominal discipline they came from different departments. However, these group interviews revealed no more about the design habitus than did the individual interviews; if anything, the habitus was obscured because the group identified with the company rather than designing.

4.4.4 Post-rationalisation/ truthfulness of respondents

An often lamented disadvantage of interviewing is that first hand accounts may be coloured by hindsight - the interviewee may recall events selectively or may rationalise them in some way. Darke (1979) has carried out a study into architectural design using interview data and as a by-product of the original research she makes some more general conclusions about the design process. On the subject of recall and post-rationalisation she says:

' . . . problems include faulty recall and post-rationalisation by architects describing the process after the event. In this research it has been found necessary to treat the architects' accounts as if they were accurate summaries, bearing in mind that oversimplification may have occurred. Such oversimplification, if it has occurred, may give rise to a simplified model of the design process, but such simplification is an aid to clarity at this stage . . .' p. 178

Historical fact might be important in some contexts and interview data can be buttressed with information from secondary sources but the rationalisations and selective memories are part of the folklore and therefore of the habitus. The discovery of these influences is precisely the object of this research. The lived experience of the designer is not shaped by historical fact but by their rationalisation, interpretation and active construction and reconstruction of it. Designers and their habitus shaped the introduction of CAD technology; the history, expressed in their terms, of the implementation of CAD is part of their collective history.

The concern is not with objective truth but with the habitus as it is revealed in the respondents' sub-conscious and pre-reflexive post-rationalisations and notwithstanding their conscious attempts to obfuscate and deceive. In this study the motivation consciously to deceive is very low: the statements made by respondents were not challenged but taken at face value. Confronted by a fellow designer their freedom to obfuscate was limited by their shared knowledge of designing. It would have been impossible to cross check every fact, but where this was possible no instances of deceit were detected. If the account has been unconsciously coloured by rationalisations and simplifications then these are legitimate parts of the oral history of the designers individually and as a group.

4.4.5 Data collection

All the interviews were tape-recorded, accepting the risk that the presence of a tape recorder sometimes inhibits communication. Researchers might instead rely on their notes taken during the interview or their recollections of it. Accurate and comprehensive note taking is difficult and the action of it can impede the progress and continuity of the interview- it is difficult to lend an attentive and sympathetic ear while head down and scribbling. Recall depends too much on the quality of the researcher's memory. Communication may be enhanced if the interview is designed so that it is conversational rather than inquisitional. In a conversation the interviewer can dispel the idea that he or she is an expert and thereby reduce the temptation for the interviewee to try to say the right things or regard the interview as being a test.

A small hand held tape recorder was used with, where possible, a desktop pressure zone microphone (PZM). The PZM was less obtrusive and allowed for the tape recorder to be removed from the immediate zone of the interview reducing one possible obstruction to conversation. The recordings made using the PZM had a higher signal to noise ratio than those with the microphone built into the tape recorder. Some of the original tapes were post-processed by a sound engineer to remove tape hiss and other background noise and aid transcription.

The tape-recordings were transcribed verbatim to make the text easier to manage and to allow it to be presented to other people. Transcription is, in one sense, a translation process (Bourdieu, 1999, p.621), emphasis and gesture can be lost and punctuating speech is difficult. When Udo says:

> "Udo: So, I am engineer, I am in engineering first and a designer second."
> Interview 14 p.11

The emphasis he places on the words "engineer" and "designer" are lost from the printed page. And when Harry says:

> "Harry: It's serious now, serious now." Interview 4 p.6

His animation and earnestness are hinted at by his repetition of the word "serious" but the emphasis can only really be heard in his blunt Lancashire accent.

While inflexion and emphasis are lost in presenting the respondent's words as printed text frequent reference was made to the original tapes in discussing and analysing the interviews. The texts have had punctuation added to lend them structure and make them easier to read; no words have been changed and they are presented in the order that they were spoken.

4.5 Data analysis

Coffey and Atkinson (1996) remark upon the challenge of analysing the data in a qualitative study. The work of Glaser and Strauss (1967), who advocate the grounding of any theory within the data, is the basis for a mass of social science literature on data analysis. The argument extended is that theoretical statements must be traceable directly to data, normally statements or actions by respondents in the study. Grounded theory is conceptually difficult, and depends greatly on experience in its application and the exercise of imagination.

Strauss and Corbin (1990) provide a more practical guide to the application of grounded theory. They emphasise the use of categories and codes, and what they call 'theoretical sensitivity', which amounts to a call to a broad sociological education. Due to the broad nature of sociological data their descriptions are necessarily general but some of their recommended schemes for data analysis have been adopted here. The notion that analysis of early data may inform the subsequent selection of respondents is an example.

Categories were identified from line by line analyses of the interview transcripts, through discussion with other experienced researchers and a familiarity with sociological theory. The transcripts were treated as primary data. The respondents spoke about themselves in various ways and through the establishment of a category named 'self reference' every section of interview text including such statements was tagged using a word processor. The collection of interview fragments was analysed for the different ways in which these 'self references' occurred. Some respondents included themselves as characters in a narrative of the design process. Others described the company structure and identified themselves in a hierarchy. Codes were then introduced to structure the category to better analyse it. One of the codes was 'company structure' another was 'design process.'

Initial data analysis was less than detailed and involved the identification in transcripts of the early interviews of broad themes that might lead to useful categories in later analysis. These themes included, for example, the design process, the product, and the interaction of designers with technology. In consequence the sample was purposively adjusted to include older designers who had experienced the introduction of computer technology to design activity.

Detailed data analysis and the creation of categories and codes continued until further detailed readings of the texts failed to reveal new categories. Key pieces of text were then laid out with associated categories, codes and brief explanatory notes, forming a series of what Glaser and Strauss call memoranda. Some of these memoranda were produced in the form of mind maps (Buzan, 1993) or tables to supplement more traditional ways of writing them. These memoranda are the basis of the discursive parts of this thesis.

The word processor was a considerable aid. The data could be sorted and rearranged by careful management of the categorisations and the attachment of them to the text. The build up of the data into memoranda and into text was eased by the use of computer aids. Data management has been necessary, specifically with regard to the maintenance of master copies of files and back up copies of them.

In the category labelled 'self-reference' five different codes were identified and, in illustration, these are summarised here in table 1.

A cursory glance at this table shows that respondents were concerned with where they fitted in the structure and wanted to express what they did. Apparently they were relatively disinterested in their job title and only slightly more aware of the process that employed them. Returning to the transcript data validated these conclusions. The respondents were indeed greatly concerned about their own perceptions of place and title, though unwilling to subscribe to any title except the one that they accorded themselves. The designers saw themselves as being supra any imposed structure because of their perceived higher overview of product and process and the peculiar mechanisms and criteria that they alone applied through their authority as designers. The analysis into categories and codes is an important device in that it provides a basis for subsequent inquiry and provokes speculation. It is the synthesis of the responses that matters and is definitive.

Interview	Job Title	What I do	Where I fit in structure	Where I fit in process	'Objective' title
D		X	X		
EFG	X		X		
H				X	
IJK			X		X
L		X		X	
M		X	X	X	
N			X	X	
OP	X	X			
Q		X	X		
R		In the past			
S				X	
T	X	X	Local only		
U		X			X (tribe)
V		X	X		
W		X	X		
Y	Past		In the past		

Table 1: showing the data analysis in the category of 'self reference'

The second example is more complex and further illustrates the shuttling to and fro between data and theory that is essential to inductive data analysis. More importantly it shows how the method provokes challenges to seemingly obvious categorisations.

The designers spoke not only about the design of products for consumption but also about designing the means for their manufacture. Two categories named 'product' and 'manufacture' were established to accommodate this duality based loosely on Marx's formulation of Departments I and II (Marx, 1976b). Designers are centrally involved in determining and designing methods of manufacture as well as specifying product geometry and configuration. The reality for some of the respondents was that their primary contribution was realised in the design of the manufacturing process. The two activities could be easily separated and accounted for in the terms of Marx's scheme but analysis of the data shows that the boundary with manufacturing is barely perceptible from a designer's point of view. One example from the data will serve to illustrate.

Steve was designing a large component of a product called a fascia that was to be manufactured by injection moulding. This involves injecting very low-cost liquefied (usually by heating) plastic into a cavity formed by two or more pieces of hard metal – the tool. Injection moulding will repeatedly produce finely detailed parts very accurately. The temperatures and pressures involved are high; this means that the mould tool can wear very quickly and usually must be made from hard material using costly and high precision manufacturing techniques. This makes the tooling expensive and great pressure is placed on the designer to ensure that the tool will function correctly.

From this extract it is apparent that Steve is concerned with the tool for producing the fascia. The product geometry - the outside surface of the product - is the same as the geometry of the tool cavity - the inside surface of the tool. Steve is preoccupied entirely with the design of the tool. He would rather seek to change the geometry of the product than risk compromising the performance of the tool. Notice how he refers to the tool:

> "Steve: . . . getting the production part working - the tool."
> Interview 12 p.1

> "Steve: All of this time you are trying to refine and finalise your design until you can tell the guys to go ahead and cutting the metal work for the hard tool part. And that is really when you start worrying because that - I mean, that is the turning point - going to the tooling for the part."
> Interview 12 p.5

Steve is designing the product as well as the machinery of manufacture; but his primary concern is with the tool. He may well modify the product geometry in order to accommodate the constraints of the manufacturing process. Categorising this extract in the original terms of the data analysis scheme, which distinguished between product and manufacturing, seems to be quite simple, a further, third, category could be created to contain utterances where the distinction between product and manufacture, consumption and production, is not made. The potential pitfall is to apply a theoretical category, as a kind of shorthand, without recourse to the original theory.

Marx's separation of production into two departments was, in part, a device to allow him to demonstrate the circulation of capital. He proposed an accounting scheme where the value of an artefact, be it for consumption or production, is made up of three components: the value of the means of production consumed in creating it, labour power (wages), and profit (1976b, p.444). In Marx's strict division of accounting sense, it is difficult to apportion the content of Steve's labour in the product and in the tool. Half of Steve's labour could be attached to the tool and thereby to the total value of the means of production and the other half to the fascia, or the means of consumption, but there is no way to justify this 50-50 split, or any other ratio for that matter. A re-examination of Marx's original theory is necessary.

Marx wanted to explain how the surplus value and variable capital are exchanged by both capitalist and worker in Department II (consumption) and then returned by the capitalist into Department I. When a designer's work encompasses products and their means of manufacture at once, the circulation of capital is accelerated and the turnover time of it is reduced. This tendency in late capitalism has been a concern of both Mandel (1975) and Harvey (1990). Mandel attributes it solely to advances in technology:

'The reduction of the turnover time of fixed capital is closely related to the acceleration of technological innovation. The first is often merely the value expression of the second.' p.248

He attempts to put a figure on the rate of acceleration of capital turnover, through analyses of French, German and US industrial production. Harvey attributes it to a general tendency of capitalism, which 'has been characterised by continuous efforts to shorten turnover times.' p.229.

Neither gives a detailed example preferring to use macroeconomic data to support their arguments. The use of injection moulding provides just such an example.

Categories and codes initially applied are challenged and modified by returning to the data and subsequent interviews. In this instance a seemingly obvious category was formulated and pieces of data were associated with it. Instances were identified where the data did not fit neatly into either category and so the categorisations were examined in the light of existing theory. Then, through a shuttling back and forth from the data to the original theory, the theory has been extended in line with more recent thinking consistently with empirical evidence from the study.

4.6 Method in this study

The methods used in this study have been discovered in much the same way as the findings of it. Not being initially sure of the precise nature of the object of the study, which is not a bad starting point for any scientific endeavour, the path to identifying it has been cleared along the way. Respondents were selected through their own and others' perception of their position within the field with an emphasis on understanding a variety of engineering milieux and settings. They were interviewed in a formal setting but in a way that allowed them to bring forward their own concerns and preoccupations. The emphasis in the interviews was on the preoccupations of the respondent and they were allowed free rein to voice their concerns. Routine and secondary data was collected subsequently to the main site visit. Their words were transcribed into a body of text that has been carefully analysed using ideas and methods from social theory and methodology. The inductive analysis provoked detailed debate about the formulation of categories and their validity and thereby made them more robust.

Having a pre-established agenda makes a researcher guilty of 'symbolic violence' and Bourdieu is very clear about the methods he has used to overcome this (1999, pp. 607-626). Imposing an agenda, especially in an industrial environment, requires the respondent to take a risk, that the researcher will act as a confidant, keep appropriate secrets and protect the respondent's position. So, an industrial sociologist perennially concerned with finding conflict in the workplace faces the possibility that respondents may not be willing to trust them and will conceal things from them. If they do find a respondent willing to talk openly about conflicts with bosses, colleagues, rivals, clients and customers the researcher, having set the agenda of conflict, must be prepared to take measures to protect the respondent and thereby keep their part of the bargain.

The researcher being part of the design habitus fulfils Bourdieu's criteria of 'social proximity' and 'familiarity' and promotes 'non-violent communication'(1999, p.609). Having access to the technical vocabulary and understanding that goes along with it eliminates the need for lengthy digressions and definitions of technical terms that a pure sociologist might need. When a respondent mentions specific fuel consumption the researcher, already knowing what it is, does not need to divert the interview into a definition but can get on with the business of understanding why it is important to the respondent. This proximity and familiarity should ease communication and help the respondent to express their concerns rather than those of the researcher.

However, some shared and concealed assumptions may not be exposed by an insider to the group that might be by an outsider or naïve observer. A good example of this is Becker's examination of medical students' definitions of certain patients as 'crocks.' (Becker et al. 1961) Becker, as a sociologist, sought a definition of this jargon term and through his investigation of it developed an understanding of the students' treatment of each individual patient as a learning experience rather than as the application of medical practice.

The respondent may make the assumption that the interview is to concentrate on technical matters and neglect discussion of the social issues that surround their work. However, this may not be a bad thing. Technical discussion can reveal much about the social environment. In this study technical discussions of CAD technology have yielded a rich social history of the introduction of the technology. Furthermore, technical language and technical procedures are themselves social constructions and their development can only be revealed through technical discussion. So although the interviewing method adopted here does not necessarily provide a comprehensive view it does expose a peculiar perspective that might otherwise be ignored or glossed. Shared technical knowledge allows the pursuit of a unique and fruitful line of discussion with respondents.

The question of number and identification of respondents bears on general issues of the conduct of inquiry. There are two schools of thought in social research: the first advocates 'random sampling' as the ideal but concedes that 'convenience sampling' is closer to reality; the second follows Glaser and Strauss (1967) and 'theoretical sampling.' Random sampling follows the precepts if not the mathematical laws of statistics in its expectation that a random sample will be representative of a population. The major difficulty with random sampling is that the population must be clearly defined at the outset and this is not always possible or even desirable. A further difficulty is that it may not be easy to access randomly sampled individuals and so people who are accessible are selected for convenience, giving rise to the phrase 'convenience sampling' (Robson, 1993, p.141). Researchers concerned with representative samples and undertaking large numbers of interviews tend to have a large team of interviewers. Bett et al. (2002) divided the work of 60 interviews between 3 people, whereas Psoinas and Smithson (2002) supplemented their 17 interviews with a postal questionnaire. Bryman (1988 p.35) criticises some groups of researchers for being 'preoccupied' with 'representativeness'.

'Theoretical sampling' is the term used by Glaser and Strauss (1967). Marshall and Rossman (1990) modify their language somewhat in referring to 'selection' of respondents rather than 'sampling' thereby avoiding the statistical baggage associated with the term. For this study the respondents were selected in order to follow particular lines of inquiry that arose as it progressed in line with Glaser and Strauss' strictures. In that sense they represent a group of people participating in design at particular times and places. A larger number of respondents, or different respondents might have produced different findings and led to different parameters for the selection of subsequent respondents.

The number of interviews undertaken might be small by some yardsticks and therefore its status as statistically representative is reduced. When the primary, interview, data is combined with secondary data representative conclusions can be made. The importance of secondary data cannot be emphasised too much; although the central concerns are those of the respondent they can only be properly understood or explained with recourse to background data. The description of the introduction of CAD into design in chapter 6 is a true reflection of what actually happened with an emphasis on the designers' perspective and it was only arrived at by supplementing their words with detailed study of their circumstances, environment, hardware, software and political situation. However, other findings will not be so easily generalised without further more formalised statistical analysis. For example, the postulation about differing career trajectories in different places could be examined though a comparison of the number of jobs held sequentially by designers and the turnover rates in, say, Manchester and Dundee. This could only be done by examining the careers of a much larger number of designers, where quantitative data is collected and statistical methods are used to numerically define the probability that any number of designers does represent the population as a whole. The variety of influences on the choice of design as a career could be explored through a more quantitative approach with a larger number of respondents but non-standard entry routes could only be explored through in depth interviews.

Whether the findings are typical of designers in general is a question for further research and this is typical of qualitative and exploratory studies (Bryman 1988, p.100). Some of the findings might be illuminated by further study of a completely different nature. This study is an innovative intervention in the study of design practice and the data - interview and background - collected is sufficient to direct future research in fruitful directions.

The strictures of grounded theory as advocated by Strauss and Corbin (1990) have been followed, somewhat ingenuously, almost to the letter. The first data was roughly coded and categorised almost immediately. As data gathering went on different sets of codes and categories were attached in the search for common themes that had explanatory force. Through the volume of data a further large volume of lists of codes and categories and subsequently associated memoranda was generated.

The reason for the adoption of grounded theory was that it is well represented in the literature and is advocated by methodologists of sociology. However, the application of it here might be seen by sociologists to be naïve because as Bryman (1988) points out:

'In spite of the frequency with which Glaser and Strauss and the idea of grounded theory are cited in the literature, there are comparatively few instances of its application.' p.85

He goes on to outline further problems with the method including the difficulty of suspending awareness of relevant theories, or the impossibility of 'deferring theoretical reflection.' The main difficulty is that the method is seen to be anti-theoretical. Proponents of it are reluctant to be over analytical lest they lose touch with reality whereas detractors claim that the superficial analysis belies an absence of intellectual depth.

From the transcription of the very first interview the coding for this research was carried out according to the prescriptions of Strauss and Corbin (1990). The interviews were analysed line by line and codes and categories were assigned to sections of the data at first by hand and then using a word processor. Initially many different coding schemes were used and most were discarded on the grounds of being too literal, or too naïve. Eventually a set of codes and categories that linked relationships and interactions was found to be fruitful in uncovering common themes. Each interview was analysed individually before returning to site to conduct a further one. Large volumes of lists of codes and categories were generated and attached to the transcripts in various ways to allow for indexing and sorting. Although the sorting was greatly helped by the computer the interpretation of the disparate lists of chunks of data was considerably more challenging and several iterations and repetitions were required before the coding exercise could be said to be comprehensive or informative. So, when examining the relationship of the respondents to the products they designed every single instance in every transcript was tagged as relating to product and then these chunks of data were collected and coded. After this memoranda were developed to link the instances in the category under the same code (e.g. positive or negative attitudes) or combined with codes that occurred in common (e.g. references to manufacture and product at the same time). And from these memoranda that substantive parts of the thesis were developed. A considerable amount of time and effort went into discovering and producing the themes that structure the study.

5 Products

'A commodity appears at first sight an extremely obvious, trivial thing. But its analysis brings out that it is a very strange thing abounding in metaphysical subtleties and theological niceties.' (Marx, 1976a, p.163)

First of all it is necessary to reiterate the empirical origins of this analysis and the theoretical background to it. Respondents spoke about the products they design, and in the analysis these utterances were grouped into a category called 'products.' On closer analysis of the instances in this category it is evident that the designers were, in fact, talking about themselves though their relationship with the product. The relationship with the product defines them as designers and so is connected to their sense of self. The product discourse in the design field defines the relationship of subject and object; the product is the object of the designer's world.

In philosophy the twin concepts of subject and object present the challenge of explaining how each is constituted and how the subject – the person, self or mind – can come to know the object – the thing, or other. The works of Hegel and Marx deal with the treatment of people as objects in power relationships with other people. More recently and especially with regard to postmodernism the relationships of people to the inanimate - the environment, the things with which they surround themselves and the spaces through which they move - has become a subject of discussion.

The products and designers are a special case of object and subject in production. The way that designers form their relationships with and intimate knowledge of the products of their labour is partly to do with their socialisation as designers and partly to do with the intrinsic nature of the products.

Almost all products are commodities and are produced for the purpose of exchange. In other words, engineering is almost always carried on in the expanded field, what Bourdieu has also called the field of large scale production (Bourdieu, 1993, p.115), the products being for exchange. Evidence for a restricted field, where engineering is done for its own sake, is limited although the space race and various land speed endeavours might qualify. In the artistic field some symbolic goods such as books of poetry start off as non-commodities in the restricted field. These are works of literature purely for its own sake but later they become commodities.

Marx's concept of fetishism – the reduction of the product to simple exchange and the masking of the relations of production and the means of production - is a useful one to bear in mind. One result of this study is a view of design production that unmasks the social relations of production in design and the central relationship of the product to the designer. In his examination of postmodernism Harvey (1990) points out that the postmodern fascination is often with masks and the triumphing of 'the signifier over the signified, the medium rather than the message.' (p.102) For him, this is the ultimate manifestation of fetishism:

'The conditions of labour and life, the sense of joy, anger, or frustration that lie behind the production of commodities, the states of mind of the producers, are all hidden to us as we exchange one object (money) for another (the commodity)' Harvey, 1990, p.101

The designer has a particular relationship with the product that is identified with their position as the arbiter of what is good design or, to use Cross' (1990) word, what is 'appropriate'. Designers have criteria of distinction, some of which are internal to themselves, and some external, for exposure to others. The criteria in themselves, if they can be identified, are of intrinsic interest, but the over-riding concern is with how they are developed and passed on. Designers, like all professions or social groups, have a way of talking - a discourse, the structure of which is interesting itself. The discourse has been developed and passed by the very mechanism of cultural transmission that constructs and disseminates the criteria that they apply. Discourse and criteria for distinction are socially constructed but products have intrinsic objective properties that the designers recognise. Unlike in the field of art, where the artist is subjected to external endorsement of their work by critics and dealers, the designers recognise that their work is validated by the fact that aircraft fly, telephones ring and the mail arrives on time.

5.1 Design discourse

The analysis of design discourse exposed a three level scheme. At the lowest level designers talk about product features, next they explain the technical reasons for those features and, at the highest level, they include the social background to these technical reasons. To relate these levels to design theory the social background could be linked to Moggridge's (1993) idea of a 'scenario'. The technical reasoning is similar to Pugh's (1991) 'product design specification' that has subsequently been developed by Ulrich and

Eppinger (1995). The low-level product features appear in Pahl and Beitz's (1984) notions of embodiment and detail design.

Harry was, at the time of the interview, involved in the design of a cooled drum for a process machine and this passage shows the product feature discourse in operation:

> "Harry: Right, we needed a very large process drum. And our process drum is like a double shell drum and the 50-50 mix of water and anti-freeze circulate through this annular gap which is probably about between 8 and 10 mm near the surface of the drum. And it's pressure obviously; it's under pressure to get it to go through. And normally we are down to about 2 bar pressure going through the drum. Now the actual circulation system is in close proximity to the drum, so you've got your chiller/ heater unit with short lines to the rotary union to the drum.
>
> Now then, suddenly we get a job where the chiller refrigeration unit is 30 metres away, so you think, oh dear me, like, we've got to pump this fluid down a 2 inch line 30 metres away, get it through the rotary union, through the drum and back again. So you've got an amazing pressure drop due to the route of the pipework and the length of the pipework. So then you say, you then work out that you will need say you had, just let's say for argument's sake, you had 2 bar pressure drop over the drum from entering the rotary union to coming out again, 2 bar. Then you needed 1 bar for the fluid to get from the cooling unit up to the rotary union, going through its 2 bar and you need 1 bar going back, so you've got 4 bar pressure. So you can say to yourself I could have 4 bar pressure inside that drum. Now then, things are going to start getting more interesting, because the pressure inside the jacket's going to expand both sides of the jacket, going to try and make the inner jacket collapse and the outer jacket swell out. And you know, you consider the implications of that, so we talk then to the so-called specialists at making the drum and he comes along and says, oh yeah, you're going to get some expansion, we're very familiar with that. So we say, okay, what do we do about it? So he says, well we can actually make the shell thick enough to withstand a sensible amount of expansion, only a few microns, but that's a disadvantage because you're increasing the metal mass. In our process we're going say, typically, from plus 30°C to minus 30°C on the temperature of the drum, the temperature of the steel. And we want a quick changeover from a production aspect. So, we don't want a massive great mass of steel that you

have to change from plus 30 to minus 30, it's a lot of work. So the lighter the construction of the drum the better, the thinner the shell the better. So we have to compromise.

So then we talked to them and we found out that 4 bar pressure is going to expand the surface of the drum and it's not going to be a completely cambered shape. So it comes up something like, say we had about a 1 m face width and it comes up about 250 mm up - sloping up each side and it's fairly flat across the middle then. These are the characteristics that they've measured out on the drums; they've made hundreds of drums like. And then, then they come and tell us, oh yes, but if you're sat there at plus 30, you blow it up and it expands say 50 or 60 microns, then you change over to minus 30, it shrinks back several microns. So you kind of hope to end up that it goes parallel when it's at minus 30. So that's the predicament, but we rely on them obviously, we rely on their expertise. But it's quite interesting, you know, I didn't realise, the end effects on the drum holding the shell. We're not bothered about the inside as long as it doesn't collapse, you know, the inner jacket. But the other aspect is as well, that you're exercising the steel up and down through the temperature range and the pressure range, you don't want to generate stress fractures in your welds and things like that, so the less expansion and contraction you have the less fatigue on the welds and things like that.

And it all gets interesting, you know, we're putting this inside a vacuum chamber so we can't even experience any really minute leaks where they might crack a weld and there's water leaking out and you can't see it under pressure, there's nothing wet, it's kind of vapourising out this minute leak. But when you put it in the vacuum system you're in trouble aren't you cause you know it's the old theory of one cubic centimetre of water at atmosphere expands to 1 cubic metre at 1 torr And so you get down 5 times 10 to the minus 4 you've got like 10,000 cubic metres of bloody water from 1 cubic centimetre which is a lot. People have a hard time realising that and I think the way you think about it is that the atoms of water then are about 3 or 4 inches apart, at 5 times 10 to the minus 4 so it's a bigger volume, less density I should say. So that's quite an interesting problem, you know, and you don't realise it, you think to yourself, oh we'll just order a drum from the suppliers and they'll work out how thick the shell wants to be, and all the rest of it. When they start telling you a bit more about it, it gets quite interesting."

Interview 4 pp. 17-18

One of the points to note from this story is Harry's close contact with the supplier of the drum who is a partner in the distributed enterprise. Here, the concern is with the way Harry refers to the drum, the language he uses and his use of the engineering habitus when he is talking about it. In this intensive passage Harry mentions several components and parts of the product: process drum, drum, water, anti-freeze, circulation system, chiller/heater unit, lines, rotary union, chiller/refrigeration unit, pump, pipework, cooling unit, vacuum chamber. He also mentions part features: annular gap, surface, double shell, jacket, inner jacket, and outer jacket. He hints at the complexity of the problem he is grappling with but also shows more clearly his familiarity with the concepts involved and his mastery of the language. His deftness is displayed when the number of measurements and units are considered: between 8 and 10mm, 2 bar pressure, 30 metres, 2 inch line, 1 bar, 4 bar, a few microns, plus 30°C to minus 30°C, 1 metre face width, 250mm, 50 or 60 microns, one cubic centimetre, atmosphere, cubic metre, 1 torr, $5x10^{-4}$, 10 000 cubic metres, 3 or 4 inches apart, 10 or 15 microns, every minus 1°C, so many microns. He juggles with ten different units, four for length, three for pressure, one for temperature, and two for volume. Harry skips among them with ease.

Harry uses a number of engineering principles in describing the design of this sub-section of a product and these show another more fundamental level of the discourse; he specifically covers incompressible fluid flow, pipe circuitry and elements, displacement based cylinder stress analysis, heat mass, end effects, weld fatigue, and vapour pressure. These principles combine in the design discourse elements of a traditionally defined academic engineering discourse - fluid mechanics and the mechanics of materials - to form a snapshot of the ongoing design of this artefact, which will eventually be realised in solid steel.

This initial passage shows the beginnings of a specific design discourse; the emphasis is on a component part of the whole product and the interactions of the features of that part and their effect on the required function of the part. The function is taken as a given, the reasons for the parallelism of the drum or the requirement for such a drastic change in temperature are not discussed. What does come through is that the discourse is based on product features.

The traditional academic engineering discourse has arbitrary boundaries defining areas of study: thermodynamics, stress analysis, materials science and so on. In contrast, the design discourse is based on a far from arbitrary product; the discussion centres on the product and threading through it is a web of engineering principles.

An example of the next level of discourse, the relationship between product features and product performance is given by Tony:

> "Tony: All this device is, is basically when you get up to cruise and where SFC[4] is very important, your turbine efficiency is very important, you blow cold air onto this casing and shrink the casing down onto the tips of the blade. You've got to maintain a certain clearance so that you don't actually crash the rotor into the static - into the casing when you are going - when you are actually taking off. So you have to have a build clearance and you have to have so much clearance to ensure that you can cope with the transient thermal growths, CF[5] growths. But then once you get into a stabilised condition where, you know, you spend a long time at cruise and of course, that's the most important part of the fly cycle as far as the fuel burn goes, you want a good efficiency out of your HP turbine. So, once everything has stabilised, this device basically blows cold air onto that control ring and shrinks the casing down to the tip."
> Interview 13 p.5

Unlike Harry, Tony explains the reasons for product features and in doing so adds another dimension to the design discourse: the clearance is adjusted while the engine is in use – at different parts of the "fly cycle" - to reduce fuel consumption ("fuel burn"). The language is concise showing the discourse at work in the application of a simple engineering principle – the expansion and contraction of metals with temperature – to affect the performance of the engine based on quite different and more complicated principles – efficiency and turbine performance. The important thing is how the discourse is developed to relate product features to product performance. The way that the form of a product determines its intrinsic nature.

Quist adds the social dimension to the discourse in describing his reaction to a new product:

---

[4] SFC- specific fuel consumption

[5] CF – centrifugal force

> "Quist: Right, and they designed this pick unit for picking the money, and they had this cassette like a shoe box, that you stacked all the money in, you know, spring loaded, the money was picked up. And, ah, made of aluminium. Right (laughs) now the thing was when these machines got really into production Securicor people then came in, you know, and Americans like Wells Fargo and that. They employed Securicor people to carry these cassettes, put them in, you know, and replenish the units when the bank was closed. And what they were doing is they were throwing these cassettes into the back of a truck, of course (claps), it used to just (claps) hit the first thing it came across and just collapsed; and soon as anything went that was it, rendered unfunctional. The breakdown rate of these things was phenomenal. The banks were really up in arms about it. They were only lasting about a month and then they would get taken away and get repaired, it was costing MVT a fortune. Apart from that the actual box itself cost a fortune, you know, because there was many parts in it. To the outside it just looked like a shoe box but at the end of the day it had to be secure, not from the point of view of vandals, you know, people trying to get in. It had to be tamper indicated. So that if anybody tried to maybe slip a tenner out of it, you couldn't do that. But if somebody wanted to get into it you could take a tin opener, virtually and open it, but it had to be tamper indicated. So, we got the project to do it in plastic. Could it be done in plastic, right? When you first looked at it, phew, there was no way because you had this door thing that had to open, like a Venetian roller, you know, like a venetian blind. You were saying, I mean, once you opened it there was nothing there, where do you get the strength in that?"
>
> Interview11 p.10

This description is full of information; a picture of the product (shoebox, venetian blind) and a description of the product in use (complete with sound effects) are provided. Quist introduces another dimension of the discourse in speaking of the users of the product and their interaction with it. He indicates that the tamper indicator is a primary consideration in the redesign and he details his reaction to the particular design problem of redesign using a new material with regard to the specific product geometry. Quist adds the crucial social context to the discourse and uses it to explain why the technical requirements are there and how the product fulfils them.

The analysis of the discourse brings up an interesting point of method. The researcher in this study is an engineering designer and so possesses the discourse. After an initial period in the interview the respondents recognised this and explained things in a way that they might not to an outsider. The advantage of having a researcher from the society under study, provided they are vigilant and reflexive enough, is that discourse such as this can be captured.

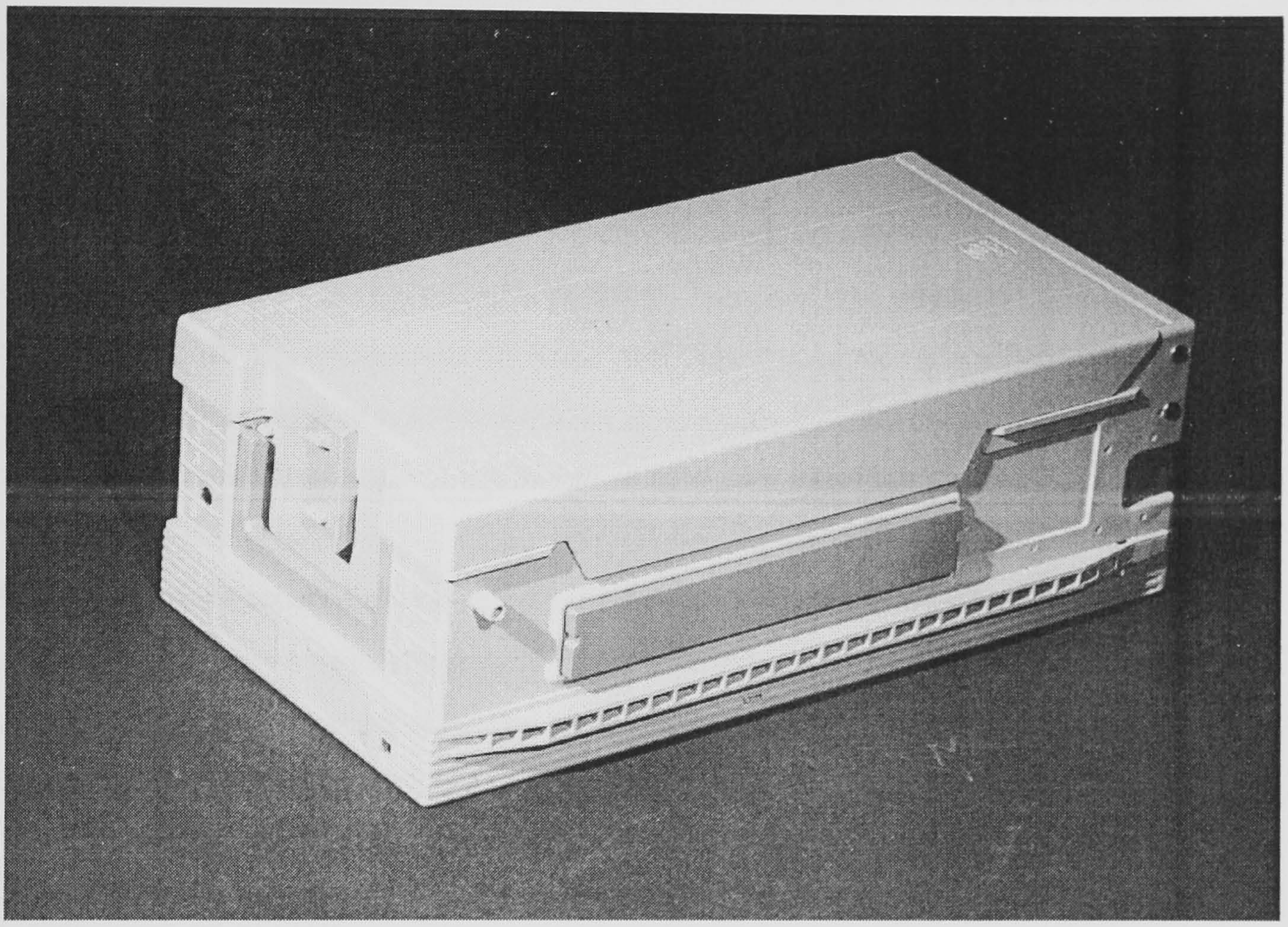

Figure 1: The money cassette

Design discourse can be considered at three levels. The first is at the level of product features, where the content of the text consists of references to product features with little context, as in the story of Harry's drum. In the next level context is added in technical terms, specifically in engineering language, as Tony explained how product features affect product performance. The third level is the addition of a social context as Quist does in his description of the security guards and the money cassette. Interpretation of the social context, in the way that Quist does, provides performance requirements that can be translated into product features. This three-level scheme is so doxic to the designers that they do not justify it in itself. It has its own internal logic that does not seem to be evident to them as they go about their business. Ultimately, this scheme can be used to give a structure for discussion about design discourse and how designers employ it.

5.2 Design consultancies and products

A sub-set of the respondents worked in design-only consultancies designing products for separate manufacturing organisations to make. This consultant role gives them a peculiar position in the structure of the division of labour and the postmodern flexible accumulation capitalism described by Harvey (1990). They are firmly placed in the periphery in Edwards' (1979) scheme, due to the risk they carry compared to the core and also in their size and capitalisation.

The consultants' engagement with the product is necessarily limited by their not being manufacturers; unlike the experiences of Harry, Tony or Quist whose designs are realised by the same firm and often under the same roof. The consultants place limits on themselves either explicitly, in the terms of agreements they have with their clients, or implicitly in tacit recognition of the extent of their own expertise.

Besides this structural relationship with the product individual consultant designers have a different subjective relationship with it; for a start they interact with a large range of products. This is a list of products that were referred to in the course of only three interviews (Interviews 5, 6, and7):

> Go Gas nozzle, Smoke detector, Manhole cover, Kitchen appliances, Welders, Fireplaces, Door knobs, Locks, Dishwashers, Black and Decker, Baby Capsule, Plastic urn, Mobile phones, ETPOS machines, TV monitors, Heaters, VHF radios, Plastic products, Condom applicator

The involvement of consultancies in the design process is variable, but always stops short of manufacture. Their contribution may be the incorporation of a client's technology into a product or it may involve the development of technology along with a product. Where the limits are placed is a result of negotiation among the collaborators in the distributed enterprise centred on the product. Kevin has a particular way of explaining this:

> "Kevin: Firstly, we need to establish what the core technology is, it maybe given or it maybe something that we have to develop, and may mean to avoid existing patents or it maybe to embrace some technology that we would then point it in the direction of. So some projects are highly development oriented, some are simply more about gathering what the market requires and interpreting

that into an aesthetic or a functional design and that's more the design group products."
Interview 5 p.13

He illustrates how the design involvement for the consultancies varies in scope. The extent to which they develop products depends on their perception of the extent of their own expertise.

"PK: Yeah, so how far do you go with the product development, do you work it up into a full tooling if it's plastic - do you? Do you go all the way?

Nick: Well, we would take it through to a point where we could pass over very accurate dimension drawings for tooling and they would be either a preferred tooling supplier or an internal tooling production division inside the organisation, they might be an outside consultant who's coming in looking at mould flow and you know plastics technology for argument's sake."
Interview 8 p.8

Design consultancies operate within the distributed enterprise and at specific points in it. The level of flexibility required by the distributed enterprise is accommodated by self-perceptions and self-imposed boundaries and the negotiations that surround them. The connection with other consultants having different expertise serves to spread the level of risk around the periphery as well as to provide an almost evanescent flexibility of configuration of organisation in the product development process.

Consultants exchange the cultural capital that they hold in the form of expertise and competence for money. Hidden from this exchange are the work-arounds, tricks of the trade and how-tos that present themselves in the course of the project. These aspects of design activity also become cultural capital - part of the habitus through the physical engagement with the design of the product, and can also, eventually in the form of expertise, be exchanged for money. Of course, the augmentation of cultural capital through time as more and more projects are undertaken and completed is not limited to the consultancies but the negotiation and exchange of it for money is more apparent to them than it would be in a core company with a design and manufacture operation.

The limits of involvement of the various parties are settled by negotiation through their own perceptions of their expertise. These perceptions are also part of the habitus, a practical sense of who does what in an enterprise. The division of labour then, is also defined by the habitus and is maintained and transmitted through it.

It is possible that a small consultancy with very specific expertise in a limited global market might find itself in two distributed enterprises that are in competition. The question about design responsibility arises. Boundaries are placed around the designers' involvement and ownership of their contribution to the design; it is across these boundaries that the capital exchanges to take place. The designers' involvement is limited by the structure of the project and their own cultural capital in the form of their competence to engage in aspects of the design process, and their own perceptions of this competence. Temporal limits as well as the structural limits surround their involvement that must eventually come to an end.

5.3 Endings and closure

There comes a point when the designer's work is done and the responsibility for the product must be handed on to someone else in the enterprise. This is part of the structural organisation of design and objectively shows the detail division of labour at work. It introduces the essential element of time to the objective and subjective limits of the designer's involvement.

Besides the objective limits of design activity it is possible to see the designers' individual subjective reactions to and interpretations of the ending of their involvement. Some of the language Dave uses is strikingly metaphorical:

> "Dave: At the moment I'm involved in working on existing machines to prototype.
>
> PK: Yeah
>
> Dave: Ironing out problems. Which have been identified by field tests, by field engineers.
>
> PK: Right

> Dave: So I'm working to get those sorted out . . . What happens here is: a prototype is made erm and then once its up and running its released into production - in other words all the drawings are made and its frozen if you like.
>
> PK: Yeah.
>
> Dave: Of course because it's a volume machine you can't easily change things once it's gone."
> Interview 2 p. 4

The language is of finishing, ending, and closure. His activity at the moment is "ironing out" – a finishing process. When the product is released to manufacture it becomes "frozen" – the fluid, dynamic design process that Dave has been involved in is at an end and the product is petrified into manufacture. This is not to say that the process of manufacture has no dynamism or that Dave is not aware of this; rather Dave accepts implicitly his role in the organisation and the accompanying limits of his involvement: it's hard to interact with the product (change things) "once its gone."

Steve's experience is similar to Dave's:

> "Steve: It's heart breaking getting to the actual finished component, but once it is done . . . Because the thing with aluminium is actually we were having a bit of a problem, we couldn't get it - the component to settle down. They were kind of still getting warped and all sorts of things going wrong with them. But these when you've sorted the problem out they tend to shoot out; bake them and never have to worry about them again."
> Interview 12 p. 5

The designer's perspective is the only one presented; no view is given of wider business pressure towards closure although these must be part of the system of constraints surrounding design activity. Sociologists of technology have adapted the notion from natural sciences that closure occurs when a consensus view emerges from a competing set of interpretations:

'Closure is achieved when debate and controversy about an artefact is effectively terminated.' (Law, 1987)

Studies of closure, in the sociology of technology are mostly historical studies, but here we see it in action. Steve refers to sorting out problems, which is also a form of negotiation within the social structure in which the product is constructed. The sense of closure is provided by the end of "worry" and "heart break." This language emphasises the designers' close, personal and subjective relationship with the product.

5.4 Distinction – 'good' design

Closure occurs when the design becomes frozen. By implication it is considered a 'good' design and central to the field of design is the distinction of good design. The power relations in the field are set up by the ability and the responsibility for distinction. Distinction must be based on more or less explicit criteria and some of these criteria have been identified in this study; but of fundamental interest is the way these criteria are socially constructed, reproduced and passed on. Furthermore, the social constructions are related to intrinsic properties of the products and by examining this relationship a phenomenological theory of design can be developed.

Being socially situated, design quality has different meanings for different people in the social space. Bucciarelli (1994) suggests that distinction in design can be situated in two dimensions: one axis represents the 'interested parties', the other the set of criteria that they apply in making their judgements (p.197). His arguments have two weaknesses. Firstly he excludes the idea that artefacts have any intrinsic quality – their properties are purely socially constructed. Secondly he does not say how these sets of interested parties form themselves into groups or how, through social reproduction, their sets of distinction criteria are developed and reproduced. He projects sets of hypothetical criteria onto groups but fails to develop any empirical examples.

Pinch and Bijker (1987) have a similar argument and use the example of the acceptance of low wheeled 'safety' bicycles over the penny farthing type. The safety bicycle, all other things being equal and even when they were not, was significantly faster than the penny farthing configuration. Bijker and Pinch argue that the social construction of speed into a requirement by relevant groups of the bicycle buying public was the deciding factor. They underplay the fact that the safety bicycle was intrinsically faster regardless of how speed might be socially constructed. Applying the criterion of symmetry, a world could be imagined where fast bicycles were seen as a social danger and the safety bicycle would have been abandoned because it was too fast for a socially responsible public. It makes no difference whether speed is constructed as a good or bad thing: the safety is faster.

Designers form an elite group in legitimating constructions of distinction in design. They have access to information about the practice of design production that is denied to other groups and their constructions of what constitutes good design are necessarily different from those of other groups. Their true power lies in their ability to predict the intrinsic properties of the things they design.

Bourdieu has a supplementary approach: rather than being simply socially situated distinction is active communication: 'an act of deciphering, decoding, which presupposes practical or explicit mastery of a cipher or code.' (1984, p.2). Designers are not like artists; they do not have the same structural relationship with critics to which Bourdieu refers. Designers are their own critics within the field and they learn to be critics of their own and other peoples' work by those acts of communication that result from a 'slow familiarisation' (p.66) with the codes and practices.

In design the habitus operates in two ways involving external and internal judgements, which may be linked to Bourdieu's ideas about the restricted and expanded fields in artistic production. Parallels with the restricted field in art are weak: designers are not in general tortured souls who, in Wendy Cope's (1986) words, 'scrape by in cheerless garrets' and, to paraphrase Baudelaire, 'design for design's sake' could only be found in the most misplaced idealism of an Art School common room. The quality of products is attributed by designers in a number of ways, both internally among themselves and externally for public consumption. The sophistication of their routine interaction with the product has already been shown in the way that they talk about them.

Vernon gives a brief interjected definition of quality for a designer:

> "Vernon: . . . what we are trying to do at our level is do a good technical job, end of story really, good technical job, in the time frame, you know, and if you meet all your targets then you get a pat on the back, that's great."
> Interview 15 p.12

Without being too semantically obtuse, Vernon recognises the work he does as a technical job; he mentions constraints of time and targets, and rewards related to quality. His "good technical job", with emphasis on the word technical, can be interpreted as an interaction with technology measured qualitatively against some obscured and internal criteria of distinction. These criteria are socially constructed partly within the society of designers and partly through experience of the product in use. The constraints of time and targets influence the technical job that he does but they are external to his relationship with the product. The words he uses to describe the reward for recognising constraints and accommodating them imply this exposure of his work to outside agents.

Mike's criteria for distinction are revealed in his emotional response to products:

> "Mike: I have a passion personally for consumer products so Power Books, ahm, Newtons, ah, mobile phones, things like that, ahm, I get really excited about, and its, I mean it's ridiculous. I can pick up a product like that and I don't want to put it down, and I really admire the design that's coming out. It sets a precedent, it's a benchmark of stuff that you put out, if you see things that excite you then you think either I wanted to design that, or I want an opportunity to be able to design something better than that. So that's the sort of exciting aspect of it."
> Interview 7 p.11

He uses words like "admire" and "excite" but his real judgement of quality is shown by his personal engagement with the product: "I want." This passage shows a level of interaction with products that goes beyond Marx's fetishism to the extent that the designer can recognise Harvey's 'labour and life' (1990, p.101) in a consumer product. Mike is selective; he names certain products but implies that there are other products that he does not admire. He makes distinctions that are based on his detailed design habitus and are not available to the external field.

5.4.1 Criteria for distinction

It is possible to identify the explicit criteria attached to designers' distinctions and examine them in themselves to possibly trace their origins. One of those apparent from this study is simplicity:

> "Dave: Yeah that's when you get satisfaction, I guess, when you can simplify a design - get rid of a whole load of crap."
> Interview 2 p.6

So Dave has a feeling of satisfaction and he also makes what could be interpreted as a more sinister qualification: he is implicitly comparing himself with another designer whose 'crap' he has 'got rid of.' An unspoken and internal competition seems to be at play among designers, which is almost encouraged by the organisation of design production to redesign and improve existing products.

Going back to Quist's money cassette:

> "Quist: Yeah. And - and as I say we reduced the parts from 158 down to about 49 or something."
> Interview 11 p.11

Quist's evaluation is quantitative lending an absolute measure of the improvements he has made that is easier for people who do not share his judgement to endorse. The detailed improvements are internal but the exposure of the improvement by the attachment of a number allows for comparison by those without Quist's level of engagement, so it serves as a veil, over the detail of his contribution.

The converse of simplicity is complexity and it is not difficult to imagine a world where designers celebrate the complex over the simple. In some fields, such as music, the complex and the simple are celebrated with equal measure, with practitioners being expected to perform complex passages as well as produce single clear tones.

The championing of simplicity by engineers is not difficult to trace and can be put down to the economics of production. As Boothroyd and Dewhurst (1983) point out each additional part of a product brings with it not only a manufacturing operation but also one of assembly. Their strictly cost-based analysis shows how cost increases with complexity. Advancing their argument further into the realms of logistics the cost of storing and transporting rises as the number of parts increases, so it is not difficult to see how this criterion has entered into the designer's toolkit for distinction. What is more remarkable is how this criteria has entered into the habitus, possibly through years of engagement with manufacturing functions within the enterprise and this assimilation also shows the designers' centrality to the entire production process and their eclectic concern for all aspects of it.

Another set of qualifying principles is to do with perception of the invention of something as new:

> "Luke: There have been some. Lots - down to David our head designer, you sort of become blasé about it. Cambrook, we did a lot of work, Cambrook is an appliance manufacturer. Their products are not spectacular but in the early days I think we prided ourselves, we quite literally invented something which we knew no one had done before, which is fairly new in industrial design. Things like, you know, plastic urns which are - everybody says yeah, wow, a plastic urn, but when you've done the first one, you sort of thought of it in the first place, you tend to be more proud of it."
> Interview 6 p. 18

Luke seems to contradict himself, qualifying that the products "are not spectacular", but then he pulls himself up for being "blasé" and recognises the achievement of invention: of thinking "of it in the first place."

Invention has a special place in the pantheon of engineering. There is a wider and more popular perception of the inventor as a Caractacus Potts character, an eccentric individual engaging creative genius in a ramshackle environment. This view is now more widely promoted by successful inventors such as Trevor Bayliss and James Dyson and in myths about their early endeavours in, respectively, a shed and a garage, equivalent to Potts' windmill. But the reality of invention is in the mainstream of engineering and is recognised by the designers in this study:

> "Dave: There was quite a bit new on that em ribbon in-feed[6] we did for the HS folder. That was the last big job we did: the ribbon in-feed.
>
> PK: Oh yeah
>
> Dave: Where it was slitting it. I had to take a lot on. A lot of what I did on there was brand new - hadn't been done before.
>
> PK: Was that these cantilevered path rollers and . . ..

---

[6] In a machine for folding printed magazine sections the 32 page printed web is split into two 'ribbons' of 16 pages and these are laid on top of each other with a system of rollers prior to entering the folding mechanism.

Dave: Yeah that was part of it and also I designed the slitting arrangement, which was able to move between frames automatically. And you've got like an anvil on one side and a slitting knife on the other.

PK: Yeah

Dave: And you got to move it about. Cutting with the paper in place.

PK: Oh right

Dave: So yeah that was quite a challenge."
Interview 2 p. 6/7

Dave talks about the product parts making up the slitting arrangement in the past tense but at the time they were "brand new." It is difficult to picture his intellectual involvement apart from his self-deprecating "quite a challenge."

The contexts for invention are hidden. Luke does not mention any reasons for using plastic in the manufacture of urns; the configuration of Dave's ribbon in-feed and its relation to the rest of the folding mechanism are not disclosed. These external exposures of design distinctions are for presentation outside the design field in terms that non-designers may have some romantic notion of and can recognise.

An extension of the idea of invention is that of reinvention. Kevin describes one case:

"Kevin: I was just thinking of that manhole cover job that we did. I haven't got the brochures with me but . . . A cast-iron manhole, you know, what could be more - more utilitarian? But we actually put some styling in to it and made it a differentiated product and at the same time we applied some technology to it in the form of finite element analysis. And to extract the client up . . . into from where he - they previously weren't in that sector of the market, they were competing and winning over products that had been on the market for 50 years. You know, so you sort of, so there's a whole lot of history that we have had to come to understand and been able to leap frog it and actually create a product that is better on a number of fronts, meets the standards for strength, and leak

> tightness and anti-rock and bolt down and a whole range of things like that, as well as it looks good."
> Interview 5 p. 18

This description of the reinvention of what seems like the simplest of products illustrates some of the complexity of the design content. Kevin lists a range of criteria for the quantitative measurement of the quality of the reinvention using external standards but finishes with the real basis for his internal judgement: "as well as it looks good." This aesthetic distinction is one of the most complex codes of the design habitus. Kevin is using his internal judgements and authority as a designer to project aesthetic value onto the object, which, as he says, is "utilitarian."

Kevin's concern for standards introduces a third benchmark for design quality: externally imposed technical standards. These may be arbitrary and folklorish as Quist illustrates:

> "Quist: The thing was, the other criteria was that this thing had to be thrown over the shoulder full of money, not break, right, not be visibly broken but not only that to go into a machine and start, right. Now, the reason I say, "thrown over your shoulder" that was the guy at the time was - he's now retired, Don Meriam, right. It was Don that said, "I want to see that cassette go over my shoulder, right, not break and on top of that stick it in a machine and I want to see it dispense the money." And that was it there was nothing . . .
>
> PK: That was the test?
>
> Quist: Yeah. There was nothing sort of three foot, four foot just phew, over his shoulder, you know, like that."
> Interview 11 p.10/11

Quist recognises the arbitrary nature of this test but he also identifies its importance as a measure of the performance of the product especially with reference to his earlier story of the security guards' treatment of the cassettes. He cleverly turns the background to the test into a story, with characters and mock indignation, which only goes to support his own judgement that the design of the cassette (and, by association, himself as a designer) is 'good.'

Products not only have to satisfy functional criteria but for insurance and other purposes they must withstand tests that represent the rigours of modern transport technology. Steve described the final shipping test, more prescriptive than Quist's test, involving measured drops and impacts, on a particularly difficult prototype:

> "Steve: I came back in here to see how the shipping test was, went into the shipping lab and there was nobody there and the unit was just sitting on the floor and I didn't know if it had been or it was waiting to go, so I was frantic. So I set off down the corridor and I passed the QA guy walking up the corridor, and he's probably about 50 yards away down the bottom of the corridor and he just goes like that . . .
>
> (Steve gives a thumbs up)"
> Interview 12 p. 7/8

This situation is more formal and the test is defined and administered by someone external to the design function ("the QA guy"). Steve's response betrays his emotional attachment and close involvement with the product at a personal internalised level.

Harry adds a time dimension in his personal test regime:

> "Harry: Now, just going back to the Design, when we design a new feature on the machine, we put it on and everybody's sort of saying at the end of the day, well that's great, a really good piece of design that. Now I always speak from experience, I always say well it seems to resolve the problem but speaking from experience let's see how it goes in production. When it's been in production for two or three months, and it's not fell off or anything, then you can say it's a good piece of design."
> Interview 4 p.10

Harry will not expose his internal judgements without the necessary dimension of time: he wants to see the product mature. He contrasts his own standards of distinction with those of other people in the enterprise.

A fourth criterion of design distinction used by the designers is the ultimate measure of success in capitalist production: success in the market:

"PK: So do you measure success - in commercial success? or is there . .?

Kevin: I have to say that is the most satisfying.

PK: (laughs)

Kevin: It's both satisfaction that we think we've done a good job but it's also the fact that the product actually made it to the market place that I think that is probably the greatest buzz."
Interview 5 p. 18

"Luke: I mean I could tell you lots of things we've done, this - we've probably done about three thousand projects or so, over the last three years or so. There are lots of good ones, there's lots which you're not happy with, or I'm not happy with, but they're still out on the market, so anything that makes the market place I think is a positive step, because the client thinks it's good enough and the customer who buys it thinks it's good enough."
Interview 6 p.18

Commercial success is an externally impressed criterion of design quality and is regarded as the ultimate criterion. In Bourdieu's scheme it represents the ultimate abandonment to the expanded field. All the internal judgements about the design seem to be thrown away and left up to the external, invisible market to sort out. The designers are celebrating the fetishism of capitalist production. The success of design labour, or design production is ultimately measured by the product's success in the system of exchange. Accompanying the success of the designer is the creation of a benign mask over their endeavours that leaves no trace of Mike's passion, Dave's challenge, Quist's shoulder, Kevin's buzz, or Steve's thumb. This is the fundamental of the relation of design to capitalist production.

Finally, Tony begins to reveal the relationship between internal and external distinctions and the pecking order he assigns to them:

"Tony: That was quite a big break through for the design because it now meant that there was a lot more scope for optimisation because you could, I mean, the stress man would tell you where he'd got high stresses but he wouldn't necessarily tell you where there were low stresses.

PK: Right (laughs)

Tony: So, you know, you'd have a safe component but it certainly might not be the lightest. Whereas, of course, as a designer would obviously be aware of the pressures from the aero-dynamicist. The pressures on the, why we needed a light engine. So, you know, he would obviously tailor his geometry to make sure he satisfied, you know, he could now optimise the geometry rather than just a stress man who would look at whether he would actually meet the life. You've got someone there who is aware of the considerations from other quarters of the design process and could optimise his geometry."
Interview 13 p.9

The stress analyst in this story is only concerned with the possible failure of the component being designed. He can determine the stress at any point in the component but does no more than advise Tony where the stresses are so high that he should consider adding material to cope with them. Tony must also consider the weight of the component to meet aerodynamic constraints and would like the stress analyst to tell him where the stresses are low so that he can consider removing material from those areas to reduce the weight.

An image emerges of the designer as the pivot around which the various distinctions rotate and this emphasises the centrality of the designer's relationship with the product: they alone know the product intimately enough to be authoritative about it. The word "optimisation" shows Tony's sophisticated view of the designer who must consider all the distinctions being made in the specialist worlds of stress analysis and aerodynamics that surround him. And, for him, the demonstration of the superiority of the designers' distinctions is the level of compromise that can be achieved.

Distinction in the design field comprises an internalised logic by which the designers construct their own judgements and also the strategies and techniques they use for partially exposing this logic to other interested parties. This internalised logic is not fully apparent in the data but it can be seen, reflected in the exposed logic of certain criteria. The notion of simplicity, in particular, exposes the internal competition among designers in the organisation of design object afresh.

5.5 Reproduction

Although the criteria that designers use are interesting in themselves, it is in how they are developed and passed on that is more fundamental. The criteria are so doxic that the designers do more than tacitly take them for granted; they actively enforce them. This exchange between the interviewer and Udo demonstrates this:

> "PK: The thing that interests me the most is: people do, more often than they would otherwise do the only thing to do and you talk to somebody and you go, 'Why did you do that then?' 'What else can you do?' And designers are the worst. 'Why did you put that bearing there?' 'What do you mean?'. It's a sort of - it's like you say, expose your logic and the logic is there, but as soon as you expose it, you . . .
>
> Udo: You see, that's right, you don't normally expose it to other non-consenting adults, I mean, you expose it to the people that are in your arena because there is a reason why it's there. But everybody knows there is a reason why its - I mean, I know why it's there. I didn't put it there but there is a good reason why that's where it is, but that's because we've grown up with these sorts of products and we understand why things are the way they are."
> Interview 14 p.14

In his last sentence Udo once more shows his thoughtfulness and his fundamental understanding of design in its social sense. The internal criteria are reproduced through socialisation that makes for an understanding of the logic. That the socialisation happens in a group is shown by his use of the second person plural. The designers' special relationship with the product is completely exposed by his use of the words "grown up" implying a maturing process that is entirely the mechanism of acquisition and reproduction of the product based habitus of the designer. Evident here are not only the criteria but the social processes by which the criteria are developed and passed on. This is a feel for the game characteristic of the successful player, who demonstrates the logic of design practice.

What has been shown in this chapter is the centrality of the products they design to the habitus of the designer. The discourse is product based and a three level scheme has been developed to structure the discourse and aid discussion of it. The structural nature of the relationship of the designer to the product is especially evident for those designers who work as consultants. The most contentious question facing researchers of design is that of design quality and how people construct judgements of artefacts phenomenologically, though constrained by their intrinsic properties. Designers have explicit criteria that they use for distinction and some of these have also been identified. These criteria are part of the habitus and are developed and passed on through individual designers' immersion in a social world of other designers, manufacturers and most importantly, the products that they design.

6 Transformation

The day to day activities of design practice have changed so much in the last 40 years that little trace of the 1960s drawing office can be found in its contemporary. That the changes have been caused by new technology is an overly simplistic and determinist view. New technology has been introduced to drawing offices, but the manner of its introduction and its consequences are the result of the social relationships surrounding it.

When computerised drafting systems were first introduced to the drawing office several stakeholders: vendors of the systems, managers, sociologists and designers' unions had a view that it would rationalise the design process, make it predictable and controllable. The intended consequences, viewed from various perspectives, were to include an increase in management control, a diminishing of designer autonomy and a reduction in skill required to undertake design.

None of these predictions have been realised. Designers are and always were, a highly skilled cadre; their judgements about good design - what will work - guarantee their significant place in the industrial pecking order. The argument that will be advanced here is that the means of design production are arbitrary, in the sense of Bourdieu's (Bourdieu and Passeron, 1990, p.31) 'cultural arbitrary'. Correspondingly their authority is their 'cultural universal', irrespective of the tools they use. Furthermore and peculiarly, that the introduction of computer aided design (CAD) technology has been mediated in fundamental ways by the design habitus. The transformation of the field of design through the use of CAD has been carried out on designers' terms. It is the designer who has the final say about what will work and what will not.

6.1 Schon's theory of design process

Donald Schon's (1987) theory of design process is useful in beginning to examine the relationship between designers and their means of production. He first coined the phrase 'materials of the design' in his description of design activity as a process of 'reflection-in-action.' He portrays the process as a series of moves, as in a game, where the outcomes of the moves are not apparent before the moves are made.

Imagine a designer sketching at a piece of paper. The marks that are made in turn tell the designer something about the designing going on. The designer may draw a line and in the act of doing so may realise something new about the form of whatever is being designed; based on this realisation the next line can be drawn or the first one altered to bring forth fresh realisations. This may continue for a while, the designer making marks and navigating a web of possibilities in an apparently continuous process. At some stage the sketching may be set aside to refer to a text or make a calculation. Each activity represents a move in Schon's schema of action. Schon calls this process of realisation that accompanies each move a reflection. In his terms the continuous conversation going on between the designer and the materials of the design is 'reflection-in-action' In this case the materials of the design are the paper, the pencil and the marks, the text, and the calculator. These are not the only possibilities: everything the designer chooses to use in the design process is a material of design.

Schon's process places the individual at the centre acting as an archetypal isolated artist might, interacting only with the materials of the design. Schon talks of a 'reflective conversation with the materials of the situation' (p.31). In doing so he ignores the indispensable social context of designers' activity. However, Schon's terminology has proven useful in sorting through the data and one of the largest groups of utterances collected during data analysis was placed in a category called 'the materials of design.' The narrative history resulting from this analysis is laid out chronologically in what follows with the intention of providing a detailed social history of CAD technology and showing how the design habitus has intervened in this history. The quotations taken from the data are by no means exhaustive and have been selected to best illustrate the narrative by using the words of the most insightful or eloquent respondents.

6.2 The drawing board

The change in the materials of design can be seen when considering the endurance of the drawing board as the nexus of design production prior to the introduction of CAD. From pre-capitalism until less than 25 years ago design has been carried out on drawing boards. The associated method of orthographic drawing and construction using Euclidean geometry has developed little since its widespread adoption following the work of Gaspard Monge (see Booker, 1979, Chapter 9). Design information was stored and communicated in the form of drawings on paper. A simplistic labour process theory perspective would view these drawings as the physical products of design labour but their true value is in the design intent that they embody. The drawing boards were arranged in drawing offices (D.O.s) that formed both a physical place and a social space for design to happen.

In a hundred years the drawing board went through three upgrades. The original board was wooden with a T square and set squares. Melamine boards were introduced in the 1950s and were fitted with a horizontal Perspex rule kept parallel by a wire and pulley system at the side.

> "Harry: You go in the Drawing Office and in those days they were just getting rid of the old fixed wooden boards that were on a slope with a T square on. And when I went in it was all new and shiny and they've got basic desks and they've got these drawing boards screwed on the desks which would pivot from horizontal to vertical and you had the Perspex square on the wires at the side. You still had to use the old triangular set square, the plastic set square, but it was a lot better than the fixed drawing board."
> Interview 4 p.1

This in turn changed to the large board standing on an adjustable pedestal and fitted with a pantograph movement carrying two scale rules fixed at right angles.

The people - designers, draughtsmen, tracers - who physically prepared drawings had personalised equipment that, unlike the drawing board, was not supplied by their employer. The symbol of these various pieces of equipment – pencils, compasses and other paraphernalia for the measurement or construction of complex or awkward shapes – was a black leather bound case.

> "Yan: You had ordinary pencils, which you sharpened, you had little bits of emery cloth. Is this before your time? Yeah, but you sort of scratched them, created chisel points and so on and that was all part of it."
> Interview 17 p.4

These instruments were personal and the designers could adapt them as they wished. The drawing board remained the property of the company and was the symbol of the place that was the drawing office.

The drawing board was iconic, almost totemistic, in defining individuals as engaged in design production.

> "PK: Yeah. So everybody had their board?

Udo: Everybody had a drawing board, yeah."
Interview 14 p.3

The actual business of mark making, producing representations of geometry to be translated through manufacture into products was carried on within the boundaries of the drawing board.

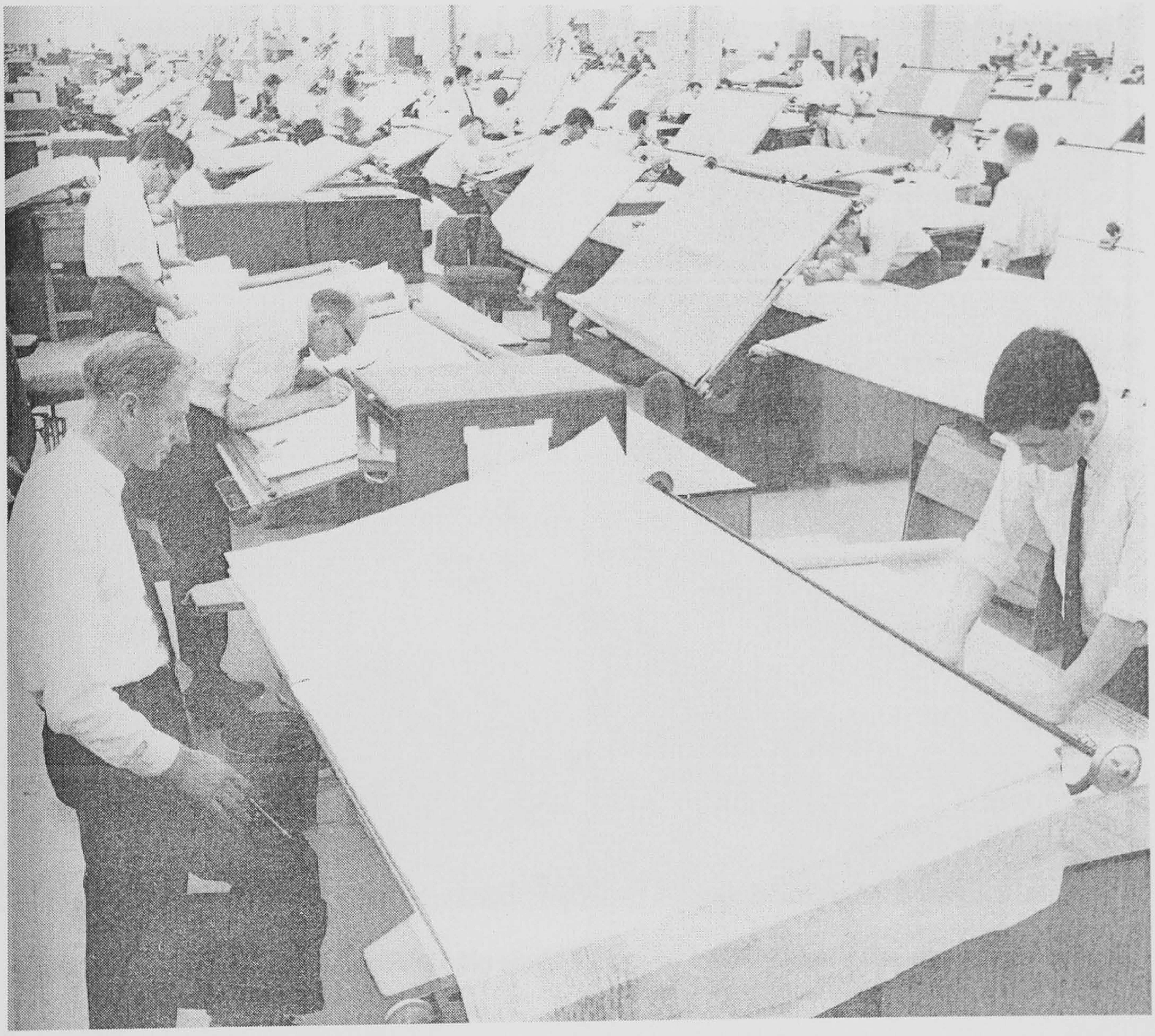

Figure 2: Drawing office at Ford Dunton 1970s

The structural anthropologist Radcliffe-Brown, in discussing totemism, posed himself this problem:

'. . . how social groups come to be identified by connection with some emblem, symbol, or object having symbolic or emblematic reference.' 1977a, p. 57

He later answered this question by saying that culture organises the relations of people to each other, but it also organises the relations of people to the environment and part of this organisation is totemism (1977b, see p.116).

This is not to say that the drawing board or any other piece of D.O. equipment is a totem in a strictly anthropological sense but rather that the equipment is part of the culture. The question under consideration is what it might take to make people give up their totems.

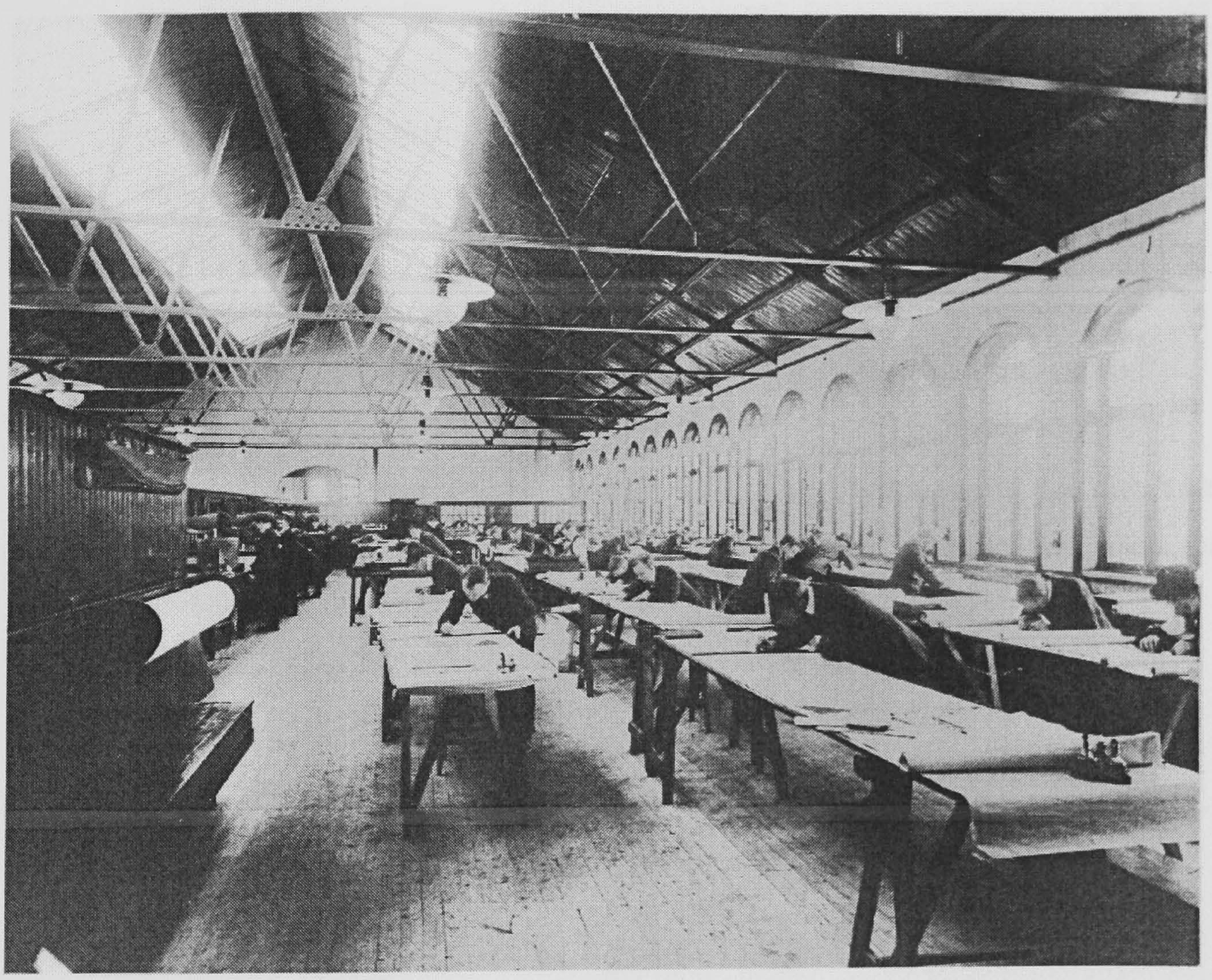

Figure 3: Drawing office at Beardmore's Glasgow c.1909 (note the double breasted jackets!)

In considering the environment of the drawing office as the means of production it is important to recognise that the designers themselves do not own it and it might then be said that they therefore have little control over it. A social structure is imposed where agency has little part to play; the social structure translates into the physical structure of the drawing office. But this formulation is overly deterministic, for the physical structure derives from the history of the office. It is the product of the collective history of designers; it has been physically constructed through the activities of designers, their negotiations, co-operations and, on occasion, conflicts with the people who employ them.

6.3 The drawing office

The respondents described the physical arrangement of the drawing office in rows of boards:

> "Yan: In those days, no, I think my earliest, they all had parallel motion so you - like we did at RJ, the earlier, well you perhaps didn't even see them, but they were parallel motion, a board, sort of a guide that went up and down and you had your set square, your T-square, sorry your set-square, and you manipulated that, that was it, and you had a desk behind you and you were in rows. You know, you turned round and you saw the back of the board behind."
> Interview 17 p.4

> "PK: What was the office environment like, how was it structured?
>
> Robert: Rows of boards, wooden seats, high wooden stools, you didn't sit properly, you know. You just like rested. And you maybe had a desk and a seat as well."
> Interview 10 p. 3

The drawing office was not just a room with boards; the physical arrangement reflected the organisational structure:

> "PK: And what was the organise - I mean, rows of boards in a room?
>
> Quist: Oh yeah.
>
> PK: And what was the? How was it organised?
>
> Quist: You had a manager that used to sit at the top in the glass office.
>
> PK: The DO manager.
>
> Quist: Yeah."
> Interview 11 p.3

The glass office for the manager might be interpreted as allowing his surveillance of the DO staff, but the same could be said of the visibility of the manager to the workers, as a benign guardian. Harry's description of the hierarchy in the drawing office introduces the idea of it as a social milieu:

> "Harry: Well, basically, the Drawing Offices probably had - the Drawing Office I worked in had about 100 guys in, and they were split into probably about 9 or 10 sections and erm the Section Leader was a very important guy. He's almost . . . he was almost equivalent to sort of say, what a Project Engineer is now. And er you had like the Section Leader, who me, as the apprentice in the Section, never bloody spoke to, he was well above me, like. And I spoke to the Assistant Section Leader and I called him Mister. And then you get on with the guys in the Section. The Chief Draughtsman, he was like God; he never spoke to anybody, I don't think, but he walked down the office and they all stood to attention, virtually; and it was very, very Victorian, you know, and just bloody ridiculous."
> Interview 4 p.2

Social interactions occur within an organisational structure according to culturally transmitted rules. Harry's imagery is of hierarchy and authority, including approved lines of communication, and forms of address. Harry learned the social rules of his particular office by being there and being inculcated and indoctrinated with them.

Udo's firm was organised slightly differently. He describes how different aspects of design were dealt with on different floors - the physical arrangement of the office reflecting the structure of the product:

> "Udo: Well, it was all, we designed everything in one huge department we weren't projectised, we are now completely project orientated, in fact we are changing; we went from everybody designing things on floors, so your compressors, and turbines and installations and combustion were all on various floors, irrespective of the engine project. You designed for all projects by core competences, if you like, by floor almost, in fact it was by floor."
> Interview 14 p.3

Again the physical layout of the office was in rows of boards. He goes on to detail the relationship between the physical layout and the structural organisation of design:

"Udo: You had group leaders, or section leaders in those days, that were responsible for various parts of the engine, so the compressor was split down into various bits of the compressor and you had section leaders who were, you know, the experts at the time. And fortunately for me my education was helped considerably by half the section leaders being taken out and put into a staff design functional role. So you had experts: manufacturing type experts, aerodynamic type experts, oil system experts, heat management experts, those sorts of experts. And they were then put here in a box so this was a staff design function, and they came round and looked at you depending on what job you had got on your board, and we had a very simple colour code. So they could look round 200 boards on each floor and just look at the colours and they could find you."
Interview 14 p.3/4

It is possible to see how the social organisation of, not just the office with its rows of boards, but of design activity - involving interactions of various kinds with the experts he lists - contributed to the development of the design habitus - Udo calls it "an education." In the system he describes the designers are stationary - each attached to one of "200 boards" - having a social solidarity through being shoulder to shoulder. The experts are fluid, moving from one designer to another to engage in aspects of design activity, and in doing so reinforcing the design habitus by having the designers as pivots, unmoving, as the information and intent flow through and around them. Notice how Udo, like Harry in the previous chapter, distances himself from the experts who are not designers, reinforcing his position through maintaining his sense of otherness to those who are not designers.

Harry tells a wonderful story showing the rituals, symbolism and iconography of the drawing office as a social milieu:

"Harry: I mean, erm, in those days my father was a chief draughtsman and he said they used to go to work in a double-breasted suit. And er, well, in the early days, perhaps going back to when he was about 18 or 20, they went in a double-breasted suit. And when they got to work they weren't allowed to take their jacket off and they undid their double-breasted suit and they buttoned it the other way cause they leaned on the flat board shining up the suit you see; so

when they went home they went the other way then so they had a shiny side which was inside and this is what actually happened."
Interview 4 p.1

This story illustrates a whole range of social phenomena. The dress code is evidently imposed by the employer, but may have been more subtly enforced by the peer group in the office attempting to mark their social distance from manual workers. It also shows the thrift of the middle class between the wars indicating a certain economic position. The image of the designer leaning on the board provides an example of the hexis - the physical attitude that is part of the habitus. Most importantly a snapshot is taken of a certain aspect of the social organisation of design at a certain time.

The traditional drawing office with its social and physical organisation and associated paraphernalia endured for so long that it seemed eternal. Design is not organised like that now, and many of the social and physical changes have been accompanied by the gradual introduction of CAD technology into the drawing office.

6.4 The introduction of CAD

The biggest revolution in the way design production is organised since the introduction of the factory system has been through the introduction of CAD technology. From the perspective of the designers in this study CAD was initiated by the introduction of numerical control (NC) of machine tools and, eventually, went hand-in-hand with the adoption of computer aided manufacture (CAM).

6.4.1 Numerical Control

The development of machine tools as far as numerical control can be examined in terms of Marx's definition of machinery:

'All fully developed machinery consists of three essentially different parts, the motor mechanism, the transmitting mechanism and finally the tool or working machine.' 1976a, p.494

In metal-cutting machine tools it is the middle part - the transmitting mechanism - that has undergone the most development, the motor mechanism has been stabilised by the universal adoption of the electric motor and the primary changes in tool technology have been in the introduction of ceramic tipped tools.

The driving force behind the automatic control of machine tools was the need to make the tool move in a predetermined path with minimal manual intervention. This was achieved, as Marx says, by employing ‘fly-wheels, shafting, toothed wheels, pulleys, straps, ropes, bands, pinions and gearing of the most varied kind.’ (1976a, p.494) The problem with such machinery was that it could only be used to produce one kind of product and had to do so in volume. The pressure, therefore, was to design automatic machinery that could be used to produce different products with slight changes to the transmitting mechanism. One example of this is the gear hobbing machine, where gears of different pitches can be made on the same machine by altering the gear ratio between the table and the hob.

The culmination of the development of the automatic machine was the profile machine where each axis of movement of the tool was controlled by a cam. The cams could be easily changed and they could be stored and re-used.

The next step was to remove the cam and electrically control the axes of movement; the steps in the sequence of operation were stored as sets of numbers representing co-ordinates in space. This is numerical control. The numerical steps were stored as binary numbers on pieces of punched paper tape (ppt) and each sequence was a program.

Noble (1979) gives a detailed history of the emergence of NC technology from a range of competing technologies. He argues that NC was adopted because it was intended to remove any control over the manufacturing process from the machine operator, echoing Braverman’s (1974) arguments about de-skilling.

In the organisation of production the production planner, who would previously have been responsible for ordering the manufacture of new cams for the profile machine, for instance, had to learn a new skill: NC programming. This involved the translation of the information on a drawing from the drawing office into an NC programme on a ppt. A simple computer was used to do this.

As Noble points out this re-skilling was a part of the introduction of the new technology. He makes the further point that the skill level of the machine operators was not reduced; skilled labour had to be retained to look after automatic machinery for it was not completely reliable and was expensive. The aim attributed to management was an increase in control over the production process but this was not entirely achieved. The power of the machine operators lay in their skill with the machine, management was perceived as trying to reduce this power by reducing the operators control over the machine. However, the machines did not always work as planned and needed skilled labour to keep them working correctly. The actual advantage to management, according to Noble, which was initially unforeseen, was the elimination of pacing and rate setting. The time for a job became dependent on the 'tape time' to run the programme and not on the skill and application of the operators. The advantage manifested itself in an improved ability to plan, knowing, absolutely and objectively, the times taken to make different parts. But the point Noble misses is that these times were not minima, a skilled worker, suitably motivated, could produce more quickly where a machine could not. The introduction of NC machine tools had effectively placed an upper limit on the pace of production.[7]

6.4.2 CAD and NC

The next step was to have the drawing office supply the part geometry information in computerised format. These were the beginnings of CAD. From the designers' point of view the first equipment was not intended to aid them but to allow the generation, transmission and storage of geometric information in electronic form for the use of other departments in the business.

In manufacturing the introduction of NC machinery and its link to CAD led to the displacement of labour and the replacement of old skills with new. NC machinery brought with it the capability to produce complex geometry that previously could only be produced with intensive application of manual skill. Yan tells the story:

> "Yan: One of the things that struck me and it struck everybody, it turned the tide in a way was the fact that you know, you may or not have seen biscuit rolls these rolls that created biscuit shapes, they were all done by hand. We used to design the biscuit shapes, according to the manufacturers desire, but we had to design them in the round, such that whenever there was a baked biscuit it was

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[7] Machine pacing as a tool for productivity is becoming outdated. Goldratt and Cox (1984) have shown that fully utilised machinery can reduce profit rates by increasing turnover time and that turnover rates can be increased by having machines idle.

the right weight, size, it had little holes in it all the rest of it. Well, this had to be done on a drum, brass I think it was, or copper, and they were literally done by hand on the pantograph. They created a model which was twice full size and engravers used to do them. Traditionally from start to finish it took about a month to create a new one.

PK: Bloody hell

Yan: It was a replacement, if the other one was worn out. With their little docker pins all drilled by hand. Little pins that created little holes in the dough and so on and also push the dough out. Quite a sophisticated thing and quite a skilled, very much a skilled operation, quite mature guys, like a little tool room.

PK: Yeah

Yan: Guys, you know, with their little hats on, lights on. Wonderful things and - they used to polish them all up and they were spot on. Well, doing it on CAD and the fact that two of the terminals were used for doing programming, you know NC programming, they could actually turnaround from design, designing it, programming it, to machining it, because they'd bought in a new machine, a multi-spindled five axis milling machine I suppose you would call it, engraver and it had three heads or four heads, high speed it used to run around 30,000 revs and you may have seen it there, maybe you did, was it there?

PK: I don't know

Yan: Well anyway it was there, em consequently the whole thing was done automatically and spot on of course and from three to four weeks, it was down to three to four days, now that was magic really I mean you could take the order in and despatch it by the end of week.

PK: Yes

Yan: And of course having done - if it was a repeat then you didn't have to even draw it, you just hooked it out, of course that went, you know went DNC[8] in the end so you didn't have to actually punch tapes."
Interview 17 p. 10

The "guys with hats" were displaced by two terminals "for doing programming" and a new machine tool with electronically controlled axes. Yan did not mention what happened to the guys, nor is there any trace of sentimentality in him. His response is revealed in his introduction to the story where he explains how everybody was "struck" by this new technology. His habitus allowed him to recognise the power of the technology and the consequent transformations in labour organisation that it made possible.

This story illustrates Braverman's (1974) thesis about skill displacement by machinery and automation. His argument is that skill is simply replaced; he either ignores any new skills, which might be brought about by new technology, or he downplays these skills, such as computer programming. He also attributes the introduction of new technology to the requirement for management to control the pace of working but he fails to foresee such large reductions in the time needed to do a job as have been possible. Braverman sees the skill as resting in the division of labour; Yan sees the new technology as part of a system of production from "designing it, programming it, to machining it" and "take the order in and despatch it." The skills of the men with hats have been displaced and the designers have been made to learn new skills. Furthermore, programming represents a new skill not previously found in the division of labour. Yan's habitus allows him to engage with the new technology. He does not have a sentimental attachment to old ways - being a designer his attitude is towards the new. He also has a designer's doxic overview of the process. He seems to share the management view, but management might measure the process (of design, program, machine) in economic terms, whereas Yan's is a technical standpoint - he see it as a better solution to a problem.

Harvey's (1990) observations on 'time compression' in the circulation of capital are also supported here. Radical shifts in production technology that produce shorter turnaround times in production also alter people's perception of and relationship to time. Yan is

[8] Direct Numerical Control where the CAD machine has an electronic link to the machine tool eliminating the need for tapes.

struck by this radical reduction in turnover time; he describes it as "magic." More importantly the phenomenological experience of time by all those involved in the process has been completely altered. The increasing pace of production brings with it a sense of acceleration that is accommodated by the habitus. The new production process for the biscuit rolls was taken for granted almost as soon as it was introduced.

Tony's story differs significantly; his preoccupation was with the technology as a design tool rather than as an aid to manufacture. He takes umbrage that it is not being used first and foremost for design :

> "PK: No, that's great. Do you want to talk a bit about CAD, because you have obviously got quite a lot of experience about how that was introduced into the company?
>
> Tony: Erm
>
> PK: So it - was it like 97 - 81 was the first?
>
> Tony: Well, we did have some old CADDS 3, but it was so slow, it was ridiculous really, I think you could almost say it was unusable. And there were one or two older guys who used that and I don't think, to be honest with you, they . . . I think they used to draw the designs and then input them into this CADDS 3. So it wasn't very impressive at all. It was unbelievably slow, and very limited. CDS 4000 was probably the first useable CAD software that you could, you know - that a designer could use. And I think really it was driven by the perceived downstream benefits. You know, the idea is that we could produce - we produced a profile in which you could create an IGES file which could then, basically I don't know all the systems involved but you more or less produce a tape because these are basically turnings.
>
> PK: Yeah
>
> Tony: And you would load up your NC machine and more or less straight from the geometry onto . . .
>
> PK: This is these rings, is it?

Tony: Yeah, that's right. That's right.

PK: So you just turn it on an NC lathe

Tony: That's right, that's right."
Interview 13 p.6

He knows that the reason for the introduction of the technology was ultimately to produce the tape for the NC machine. His suspicion that "they used to draw the designs" (i.e. manually) and then input the geometry indicates how the early technology was geared to manufacturing. But Tony really wanted computer drawing to live up to the computer aided design label – and be a design tool. He was actually affronted that it was not being used for design immediately it was introduced. His design habitus disposes him to take this position and begin to push for the new equipment to be used as he would like.

6.4.3 CAD and communication

He goes on to illustrate how the existence of data in electronic format began to influence the way that designers communicated with other departments beyond manufacturing:

> "Tony: I mean that was - that was back in - I mean, basically we have gone along with the improvements in the software and the speed of the computers really. I think, the first, the next break through, and I say, this was all in one room where you had about, I think we went up to a dozen heads, all in a room, separate from the main line design areas, which I never thought was that good. The XJ600 was the first engine which did have extensive scheming done on the CADDS. And the idea is as well that you could actually transfer geometry around through IGES. But at that time we didn't have - the designers did not have the access to sort of finite element programs like they do now. And basically, we would pass the geometry around between the draftsmen and the stress man."
> Interview 13 p. 6

The detail division of labour at Cooper Clarke includes a department where the main activity is stress analysis. This department analyses the geometry produced by the designers along with information about the material to predict the strength of the components. The stress analysis department already used computers to perform the numerical arithmetic associated with a specific stress analysis technique called finite element analysis (FEA or, simply FE). A secondary result of the data exchange with manufacture was the ability to exchange data with the stress department.

Robert used to work in the stress department at Cooper Clarke:

> "Robert: '79 or something like that. Then they were getting a computer system - finite element. Associated with that was a drawing package, and you had to - you could use the computer, not from a drawing point of view but from a modelling point of view, so you could lay the mesh on for finite elements. So that was my first introduction to computer drawing."
> Interview 10 p.5/6

Robert's first use of the computer drafting technology was not to do design as Tony would have liked, but to do stress analysis on components that had already been designed by manual methods and not using the new computers. The data transfer that Tony mentioned would have removed this requirement for the stress people to effectively re-draw the geometry. The perennial situation of the designer as the pivot around which the rest of industrial production rotates was being reinforced. Instead of communicating design intent in the traditional manner using drawings on paper the mode has shifted to communication through electronic representations of geometry. Concomitant to Tony's interest in using the technology as a design tool is his concern to keep the flow of information, and its form, under the control of the designers.

6.4.4 Implementation

Computer technology was advancing in the late1970s and early 1980s because of a number of strategic alliances among producers – most notably between Microsoft, IBM and Intel. The key players in the development of computer technology were emerging coincidentally with a political transition in the West: the election in 1979 of both Reagan and Thatcher heralded a long period of dogmatic monetarist economic policy, following a decade of political turmoil. Harvey associates this period with a transition 'from Fordism to flexible accumulation' (1990, Chapter 9). Fundamental assumptions about economic life, such as working for the same company for life, the belief in the structural stability of the firm, faith in the system of exchange and the value of money were being challenged and replaced by altogether different expectations. Previously employees had loyally worked for the same firm and were valued for doing so; the new career path comprised a portfolio of jobs. Firms changed by valuing the 'flexibility' of employees over loyalty. Monolithic conglomerates were restructuring into a core and periphery format as described by Edwards (1979). The collapse of the Bretton Woods agreement fundamentally altered the system of exchange along with a series of recessions altered peoples' appreciation of the value of money. These external influences also had a profound effect on the practice of design as the mode of production changed to cope with the changing economic circumstances. The designers had to adapt to a changing sense of space and time and coincidentally to a changing economic and political situation.

Yan illustrates the industrial relations situation when the new technology was being introduced:

> "PK: Tell me about CAD
>
> Yan: CAD started, for me, and actually for the country as regards UniGraphics we were the - RJ were the first UniGraphics users there. 1977, early part of 1977. And yes, oh, that was quite something from a union point of view. People knew about CAD; they knew that this thing was marching on and they knew what the management was saying that we had to get involved, we had to have a faster turnaround, from taking orders or whatever it was that needed to be done. The turnaround time had to be improved from a printing press, from the time of taking orders to when it was, when we could actually say yes get it out and running which was traditionally sort of 18 months, and they had to get better, you know turnaround much quicker. And in their opinion the only way to do it was either take on a lot more people or invest in this new technology. Of course the papers at those times, in those days were full of marching technology, redundancy, mass redundancies, Labour governments, Labour - the movements were very strong, our union was very strong."
> Interview 17 p.7

The scene is one of political turmoil, accompanied by management pressure to improve 'turnaround time.' The driver for the new technology was not any perceived improvement in quality or leap in the technology of the product, but simply a push to reduce the turnover time of capital. Harvey (1990) attributes this to a general strategy in the 1970s to escape the effects of high inflation. From 1975, he says, corporations turned to:

'Technological change, automation, the search for new product lines and market niches, geographical dispersal to zones of easier labour control, mergers, and steps to accelerate the turnover time of capital.' p.145

This formulation is more sophisticated and explicit than some of the rationalistic drivers for the new technology that were being bandied about at the time. Löwstedt (1989, p.30) mentions, 'rationalisation', cost efficiency, 'higher quality' through 'better designs' and better outputs, 'efficiency', 'integration', 'flexibility', adaptability and tucked away in the list, reduction in 'throughput time.' A narrow focus on the drawing office and the CAD implementation caused some analysts to miss the wider picture that Yan saw at the time, which is that the entire business cycle had been compressed and not merely the time to put a drawing through the D.O.

Yan went on to describe the material situation of the pressure to change as the Technical Director addresses the design staff:

> "Yan: But nevertheless I remember him speaking to all of the engineers, some three or four hundred, quite a large number in all the disciplines, bakery, biscuit and so on, in the works canteen and he was pleading with us, he was really pleading not to throw this away because he needed co-operation, he needed people to train on it and the hands were going up, "Well, at least half of us are going to be made redundant." You know, they were talking about productivity of 3 to 1, wow 3 to 1, all right a third of you, two thirds of you are going to go. "Oh, it's not going to be like that." You know, and there was a lot of pressure on him and everybody a bit - very concerned, certainly because all the publicity was that way round. As we know the benefits which is what he was saying were for those who grafted quickly could leap ahead of the competition - do it quickly and do it well and of course choose the right product for you. So there was a lot going on and although the union said OK, you know, we'll go along with it, you know, our jobs depend on it really that is the outcome if you don't take it then you're going to lose out."
>
> Interview 17 p.7/8

This whole process is a classic example of the transformation of labour processes in the pursuit of capital accumulation. But it also shows how the Technical Director's rhetoric as well as the designers reception of it made a 'virtue out of a necessity' (Bourdieu, 1984, pp. 175-179) by talking up the new technology to the designers advantage. Implicit in this exchange is the recognition on the part of management of the designers' power. By buttering them up and allowing them to take charge of the new technology the Technical Manager is also gaining their acceptance of it. Management is willing to concede ground to the designers in order to reduce turnover time contradicting claims (summarised in McLoughlin, 1989, p. 27) that the technology tends to increase management control.

The confusion and turmoil surrounding the introduction of the technology is illustrated by management's attempts to control designers' working patterns while accepting that designers had taken control of the technology itself. Listen to Yan once more:

> "Yan: So rather than ask draughtsmen, they thought they would go up - engineers, these are more responsible people, you know, this was the thing that was how it was put to us by our technical manager. The thing was of course we weren't, that's right I'll tell you a bit later, we weren't actually paid overtime, it was one of those moves, the first move up in the strata so we were the responsible people, we would like you to train on it, and then shown how, you know, that it is a wonderful tool."
> Interview 17 p.9

> "Yan: . . . but the thing that encouraged draftsmen back was that they wanted to use, effectively use the time available. They had got these computers, you know, these terminals, and they were only used lets say from eight till four or seven till five at that sort of time. So they wanted us to work overtime, well we didn't get paid for it and all being with strong unions you know, they said you'll have to start changing it, you know, put us back on the overtime. And plus the fact if you want people to train you've got to pay them. This is a new skill so it really became a money-spinner for about 3 or 4 years, it did really. This is what encouraged people to join, to get on, on the band wagon, they could see that not only were there people learning something which you ultimately were going to learn anyway, in the long term even though there were some there that said it would never last. It was something that people wanted to do eventually and the fact that they were getting, you know they were losing out. And there were some payments to learn for the first, for training on it, which was a fortnight and at the end of I think it was the end of the month you got another payment and after 6 months you got another payment because you were then up and running you see. And then of course the designers they were now getting paid over-time and these were the ones that they were encouraging

> to work lots of over-time to get the most out of it, in theory they wanted people to work night shift but nobody would do it. I think it was down to money in the end, they wouldn't just pay them double shifts and so on, but nevertheless that encouraged a lot of people more and more."
> Interview 17 p.11

In labour process studies of the implementation of CAD (e.g. Schmidt 1992) several responses to shift working were considered but in each case the researchers assumed that shift working was a scheme for increasing management control. Even McLoughlin's (1989, 1990) otherwise well-balanced analysis includes this assumption without properly testing it. In Yan's firm shift-working was one mechanism by which management could make supplementary payments to those who accepted and engaged with CAD.

Two management tactics were used to encourage the implementation of new procedures and new technology. The first was the nominal upgrading of the technology to a higher level of skill. Designers rather than draughtsmen were the first to use the technology; they were members of a different union to the draughtsmen, they had slightly different educational backgrounds and they were salaried staff. Management was not only prepared to give control of the technology to the designers but also allowed them increased prestige.

The second tactic of making supplementary payments to those who enthusiastically engage with the new technology brings to mind Schmidt, Taylor's (1917) 'man of the type of an ox' (p.62). Schmidt agreed to be the first person subjected to Taylor's methods for an extra 70c a day only to have his wages reduced back down to $1.15 a day (to Taylor's annoyance) when the method became widely accepted. Yan says that the over-time, shift-working and training bonuses were "a money spinner for 3 or 4 years"; it can be assumed that after 3 or 4 years the technology had penetrated the business to such an extent that it had become the norm; it was not unnecessary to make extra payments for 'normal' activity.

Harvey makes a link between turnover time and reskilling:

'It is in this context that the adaptability and flexibility of workers become vital to capitalist development. Workers, instead of acquiring a skill for life, can now look forward to at least one if not multiple bouts of de-skilling and re-skilling in a lifetime.'
1990, p.229/230

The pressure to re-skill results in a new skill of adaptability, of an ability to take on new contexts and methods and apply them on an individual basis. This contrasts sharply with labour market theorists discussions of flexibility in working patterns, which Hakim (1990) and Pollert (1988) have found little evidence to support. A further divergence is with the economically driven rhetoric of flexibility that Bourdieu has criticised in his political writing (1998b, pp. 45-51). The challenge for business is to make this skill of adaptability available, and allow people to engage it on their own terms.

The designers had this disposition. The transition was not revolutionary but neither was it seamless. The position of designers in the vanguard of the new and the possible makes them engage with new technology when it arrives. The designers made internal judgements about the advantages of CAD as a design tool which were not apparent to management, or to themselves initially; their disposition to innovate enabled them to appropriate the new technology as a designer's tool. Designers are also disposed to deal with uncertainty in the face of conflicting and contradictory demands. The wider economic confusion and the changing modes of production allowed the designers to flourish while embracing the new and technical change specifically.

The aims behind the introduction of CAD were initially quite well defined, despite what some labour process theorists claimed - to reduce turnover time through faster data transfer and easier data management. In doing so designers were able to appropriate control of the technology and increase their prestige. The adoption of the technology has had many effects that could not have been foreseen at its introduction. Management structures have changed fundamentally and interactions in the firm are now very different from the time of the drawing board. As McLoughlin (1990) says:

'A common research finding is that when new computing technologies are adopted organisational structures are made more complex rather than simplified, and new conflicts and rivalries emerge.' p.229

All this did not happen overnight but took several years for the acceptance of CAD to become widespread; in Yan's firm it took "three or four years." The arrival of the technology in the D.O. was not wholesale; many designers carried on at their boards while the CAD equipment was being used by other people. The start of this gradual infiltration of the technology into the structures of design production is signified by the first interaction of the respondents with the technology in production.

6.5 First job on CAD

Without being prompted, the respondents who were around when CAD was introduced spoke about their first time using the technology. They attached special significance to having been on the spot when the changes were happening and emphasise their role in implementing them. Personal presence at the time of a momentous change is important in reinforcing the folklore of the profession and the telling of history from the designers' point of view.

> "Vernon: So I had always been interested in computers but I never had a great deal to do with them. But, erm, as soon as that kit came in I was able to sort of wheedle my way into this new department using this CADDS stuff. And erm, so although the first few years I was using a drawing board as soon as we got the first CADDS screens in design I was one the first users, I think I was on the first training course in fact. And I have sort of stuck with it ever since."
> Interview 15 p.3

The year was 1982, and Vernon was motivated by his interest in computers. Tony's first involvement was because of those "rings":

> "Tony: And it was decided the policy was that the discs - I don't know how familiar you are with gas turbine engines - but the discs are the rotating parts of the engine that basically hold the blades. And it was decided that, they basically had the CDS 4000 equipment installed, and that these discs were to be done on the CDS 4000 CAD equipment, because you - the tape definition from that would then feed down to manufacture. They could create a tape from that geometry. So, I was actually one of the, I was probably one of the first to ever do a CADDS - get a proper CADDS scheme."
> Interview 13 p.3

The first design that Tony generated using CAD was for a turbine ring and that was because of company policy ("it was decided") to use NC technology for manufacture. Tony downplays the decision to use NC machinery for manufacture and emphasises his own involvement. Designers have appropriated the technology to their own ends and they have adapted the social history of it to make their own role central to the story.

Quist remembers his first job on CAD as a transition; some components were drawn on the board and some using the new CAD:

"Quist: You can see a fair bit of detail, and as I say, the whole of that, that you can see really, the main body bits were all done on, you know.

PK: On the board?

Quist: Drawing board.

PK: Yeah

Quist: The wee bits and pieces here we started to do, I started to do, these were some of my first CAD bits, that little peg in there and that. These were the first bits I struggled with on CAD. And you have this nice little bracket designed as well, first class."
Interview 11 p. 12

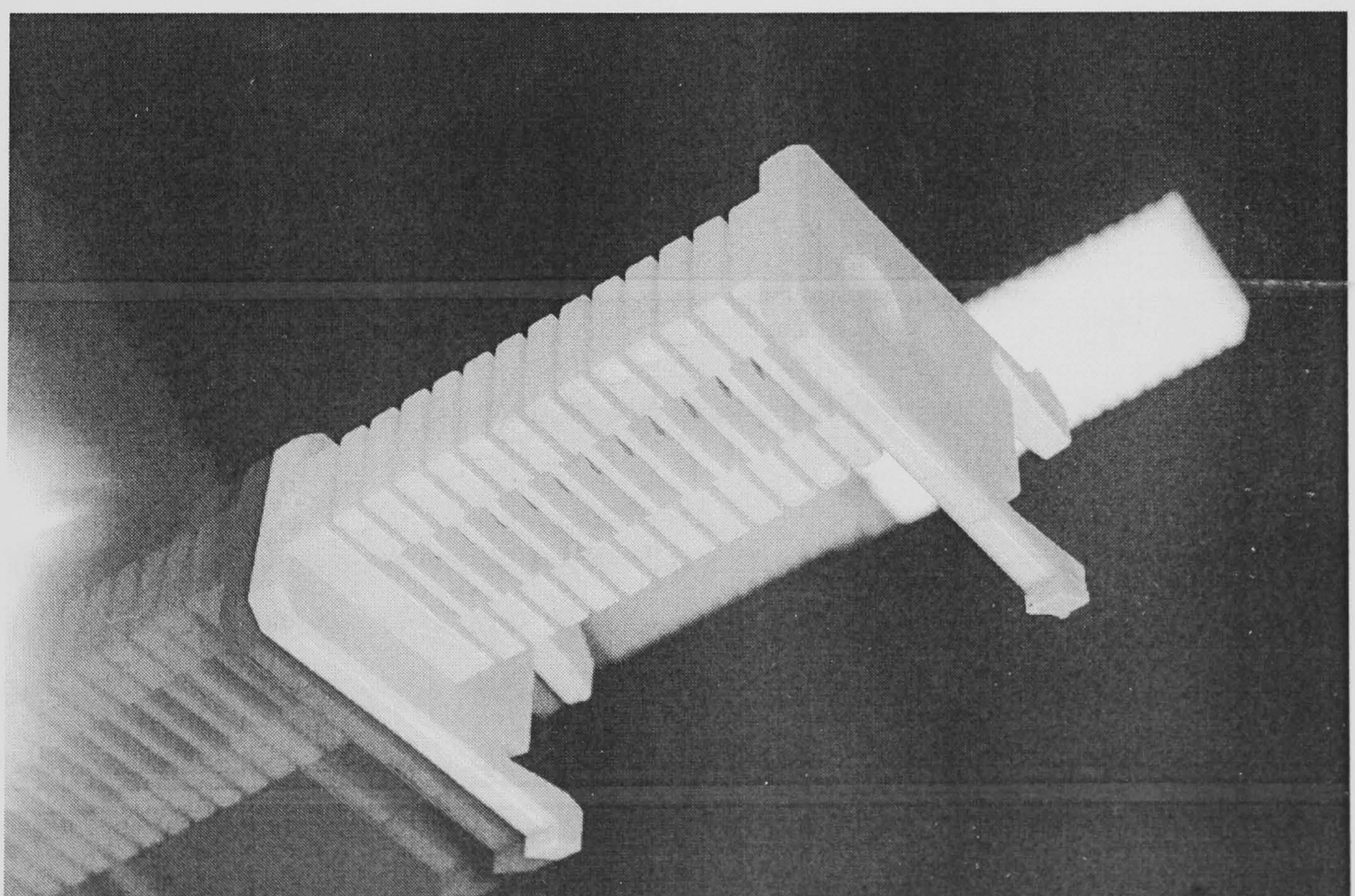


Figure 4: The "nice little bracket . . . first class"

He mentions specific parts – the "little peg" and the "nice little bracket" – that have a special meaning for him. They are parts of the money cassette, which for Quist is also a significant job. But this story matters to him personally because it describes his first use of CAD on such a job. He expresses ideas of quality and distinction: the design was "first class." Examination of the little peg and the drawing of it demonstrate a greater sophistication in Quist's recognition of what the new technology can do for him.

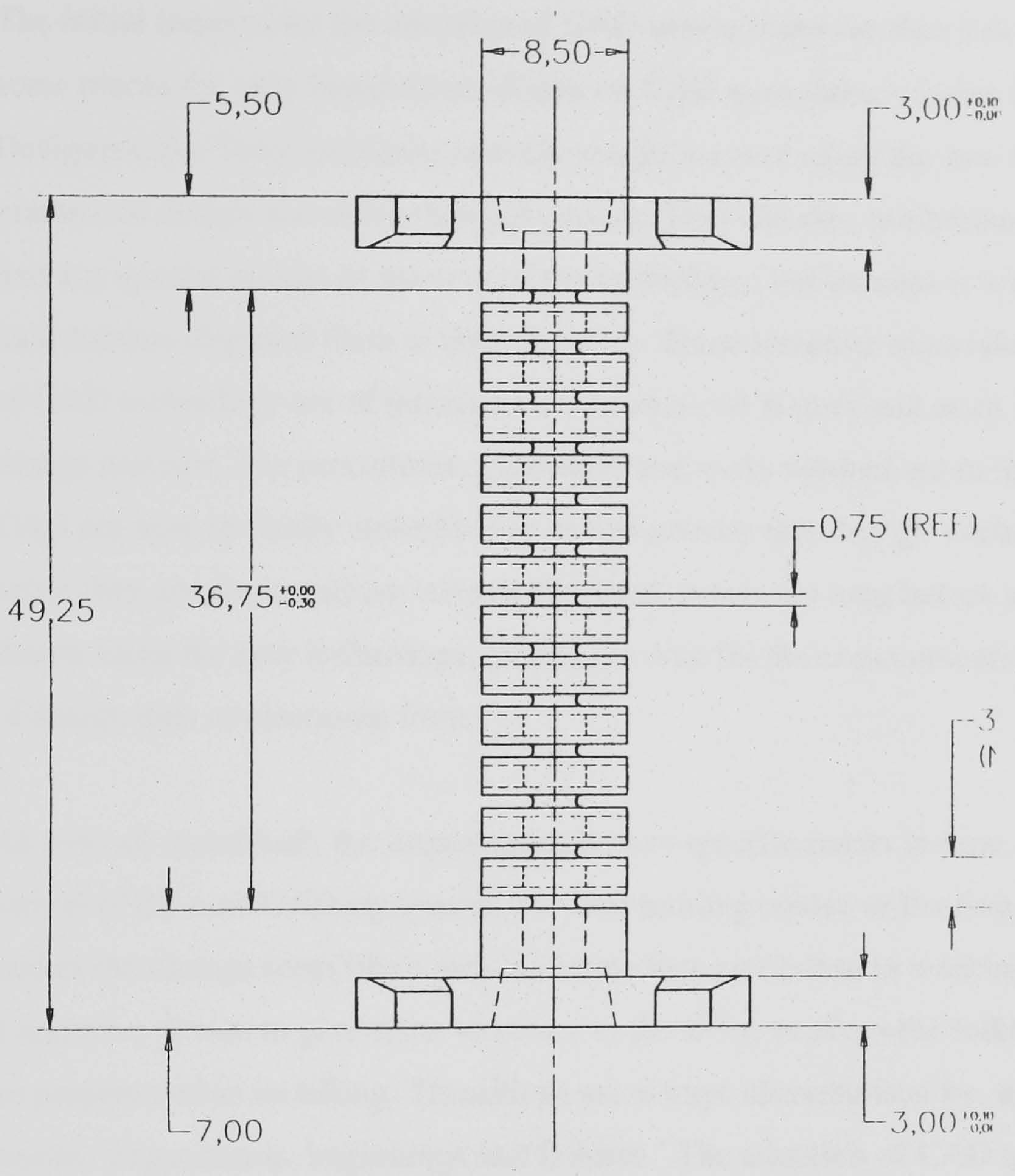


Figure 5: Part of the computer generated drawing of the "nice little bracket"

The peg has repeated features that would take a long time to draw using traditional manual methods. Quist realised that the copy and pattern tools in the CAD software could be used to draw the geometry more quickly. He had an immediate engagement with the new technology and he used it selectively in a situation where he recognised it could reduce the tedium of the manual task. His knowledge of and ability to deal with geometry conceptually allowed him to make this realisation. What psychologists might call spatial reasoning or spatial ability that is an unarticulated (and possibly not able to be articulated) part of Quist's habitus is shown in action.

Because he knew the properties of the computer system and understood the geometry of the part he was designing (a part that did not exist at the time) he could use the CAD equipment to his own ends and make the conceptual leap that this required.

The initial impetus for the adoption of CAD was to make the data link to manufacture; in some places the only components drawn on CAD were those suitable for NC production. Designers like Tony and Quist actively sought ways of using the new technology in their practice of design and make their jobs easier. They did this, not because they individually had any special insight or mastery of the technology, but because it was normal for them, their habitus disposed them to do it that way. These tentative steps taken by the first users of CAD technology are of intrinsic interest as social history and as an illustration of the design practice. The procedures, guidelines and tricks worked out in the early days of CAD are now so firmly embedded in design activity that they go unchallenged, in that sense they are doxic and are left unarticulated. It was not long before all products were drawn using the new technology, paving the way for the communication and management of design data in electronic form.

As with all transitions, the importance given to specific points in time, such as the day of arrival of the new CAD equipment, the first training course or the first components, makes the change seem like a step, an immediate revolution in working practices. This is a narrative device to give some structure to the story, to allow the folklore of the group to be perpetuated in its telling. Transitions are always characterised by, in Edwards' (1979) words, 'experiments, beginnings and failures.' The adoption of CAD technology has been a long gradual process and it still continues today.

6.6 CAD transitions

New technology brings with it unforeseen consequences which are difficult to reconcile with a determinist viewpoint. The aims attributed to management in the introduction of technology were frequently frustrated by the technology itself. Some respondents spoke of the equipment in an almost nostalgic way.

> "Yan: Oh, I'll tell you something about the CAD; the processor for the CAD system, it was a Data General Eclipse, 200 I think they called it, do you know how much core it had?
>
> PK: Go on?

Yan: OK I've got more in my watch now.

PK: laughs

Yan: No, 128k, 128k there was one disc drive I think a zeta drive they called it and it had a multi series of platters, you know like big LP's and em I think that was the 90 megabytes. Major problem really, major problem because when we first got it if two or three people filed at the same time the plotter stopped.

(laughter)

Yan: And the other thing, in fact if you were trying to plot and people had got big jobs on and they kept re-painting and doing you know number crunching work, you never got your plot done, the pen used to dry out you know "Oh, for gods sake. Stop it." You know. Anyway they changed the priorities such that the plotter got more priority than the other equipment. It was quite amazing, when you think of how much power is available now.

PK: Yes.

Yan: But you know 128 I remember that"
Interview 17 p.11

Yan's comparison of the first CAD computer with his watch is telling in three ways; firstly it illustrates how far technology has advanced in less than 20 years. Secondly it shows the level of interaction with the new technology at the time - its novelty, and how the users of it invented new ways of working to accommodate it. Finally, it shows Yan's familiarity with the technology now, whereas at the time it must have been quite daunting. His present attitude is to take for granted the properties of the technology, and the discourse surrounding it, again as part of his habitus. The tone is much different to when he was talking about chisel point pencils.

The story about the level of performance of the plotter system is an example of the unforeseen limitations of the technology. Rather than speeding up the work of producing drawings, a fixed upper limit was imposed by the maximum speed of the plotter. Also exposed is the importance of the close co-operation of the users in the detailed operation of the technology. They could do this because of what they shared, an investment in design as an activity, and in their application of the new technology and the maintenance and advancement of their position within the firm.

The terminology Yan uses to measure the performance the computer indicates the way in which he has taken on the discourse of the technology. He uses two measures of performance in two ways – the size of its core memory and the size of storage memory. In his case the core was 128k. The computer being used to process this thesis has 250 times that and the file containing the thesis would fill it eight times. Nick uses similar language:

> "Nick: Yes, I have come right through the computer, we bought a Macintosh off the first boatload that came to Australia, the first 512K Macintosh bought literally the first shipment, or one of the first shipments." Interview 8 p.9

The reference to the memory capacity of the computer signifies how this has become a standard way for people to talk about computer performance. Moore's Law (Moore, 1975, cited by Ceruzzi, 1996) dictates that the number of components on a chip doubles every year (every two years since 1980) indicating that technological change is more or less linear. MacKenzie (1996) has a special insight into this supposed law:

'Moore's Law is not merely an after-the-fact empirical description of processes of change in microelectronics; it is a belief that has become self-fulfilling by guiding the technological and investment decisions of those involved.' p.8

It is not just the people involved in developing microelectronic technology that make Moore's law self-fulfilling, it is also the constant expectation of those who depend upon it that the technology will advance. People who use microprocessor technology have had their sense of time altered in two ways. The first is that they can subjectively measure time by their experience of technological advance and in doing so have a sense of the pace of time. The second shift is through their subjective sense of the future as being mapped out before them, predetermined, in the French sense of *le futur*. Technology will advance, they expect it to do so, and this expectation conditions their attitude to it.

This is not to say that technology determines the environment or the mode of working or even the arrangement of the office. The direction taken was strongly influenced by the users and their dissatisfaction with early implementations of CAD. Vernon talks nostalgically of the "old days":

> "Vernon: In the old days you see we used to have - used to have Techtronix type terminals that linked directly into mainframe and a lot of analysis was done on those. You know, sort of the erm cooling analysis and sort of aerodynamic performance type analysis and that sort of thing. So that preceded CADDS type terminals obviously by several years, by many years I would say, so the old green screens, you know, with the built in keyboard all metal cases, em, a lot of the early analysis was all on those basically."
> Interview 15 p.11

In the first implementations the architecture of the system also reflected the arrangement of the work. A system where all the terminals were individually connected to a mainframe computer allowed for and encouraged the communal working already mentioned by Yan because the people were using exactly the same resource. As well as the system, the actual equipment is described - the 'green screen' with the metal case. Yan goes on to describe his unhappiness with a similar system:

> "Yan: In the old days when we were let's say mainframe driven and we had the green goddesses in there and there, they had some raster screen ones that thought they were re-fresh screens, I can't remember D90's or something they were called, they were black and white. But they really were a raster but they hadn't got the wherewithal.
>
> PK: They were McDonnell Douglas, weren't they?
>
> Yan: Yes they were, yes they were, ergonomically designed rubbish."
> Interview 17 p.13

Yan describes a significant technical development but he places little emphasis on it. The green goddess he mentions is a Techtronix 4014 terminal that used a vector system to control the electron beam in the same way that a radar screen did. Raster screens which pixellate the image representing it as a sequence of tiny dots rather than continuous line vectors superseded these radar screens. This leap in technology is unimportant for Yan;

although he is aware of it he does not sense that it affects him personally. He is more concerned with what he sees as a fundamental design problem – the ergonomics.

Yan's dissatisfaction comes from his disposition as a designer. He criticises the design of the equipment because, as a designer, he is qualified to make those judgements. Baldry and Connolly (1986) identify the 'fragmentation of the social cohesion of the drawing office' (p.64) as a result of the physical organisation of CAD equipment. No evidence has been found in the current study to substantiate their findings. To the contrary, Yan's description indicates that the social organisation was strengthened because the use of CAD equipment required closer co-operation than in the manual drawing office. The new technology brought with it closer involvement with management:

> Quist: In the early days I was sitting doing nothing, some days I couldn't get on. Maybe somebody would come up and say 'how's your shattin's?' 'I haven't done anything with it, I can't get on to the CAD'. That was just pressure from my manager on to the CAD manager, supply and demand at the end of the day."
>
> Interview 11 p. 9

It is difficult to imagine this type of interaction happening in the strict drawing office of Harry's apprenticeship.

Initially the technology was imposed and the humans had to adapt to it, sometimes by altering their physical attitude. Yan's indignation at that stage of the introduction of CAD marks the beginning of designers wanting to control the technology for their ends rather than it controlling and making impositions on them.

The working environment changed as well:

> "Yan: Oh that's right, well all those rooms were rooms for the old main frame, as it was. Big Hitachi thing yeah, that's where it was before when they built the new building on the front in '74 - '75 then they transferred it to that new bit, it was much easier to get to - more purpose built. But that particular modern building was fully air-conditioned and it was cold wasn't it?
>
> PK: Yeah

Yan: With the cold air. The air conditioning was blowing through the sides, through the top in fact it - probably . . . There was an underground place for cables which again traditionally was the way that computers were fed. Because they were very temperature sensitive in those days, you know, if the temperature wasn't kept just right then they just used to fall over, well not true any more, but it was then and of course it was deemed suitable for putting computer terminals in."

Interview 17 p.13

The physical environment was built to suit the machine and not the people; temperature and humidity had to be closely controlled to support the machinery and the architecture of the buildings reflected that need. People using the computers had to alter their dress, their working patterns and their physical attitude because of the low temperature in the computer areas.

All users were challenged by the task of selecting a system that would suit their needs and those of the wider business. This choice was made difficult by of the variety of systems available and uncertainty in evaluating competing claims for their effectiveness. Many companies were obliged, early on, to replace systems that quickly became obsolete or did not yield the promised performance.

"Quist: That's a DDM over there, which is clapped out, you know.

PK: (looking) The old tablet?

Quist: We are now on Pro, this is our second system, ProEngineer - surface modelling."

Interview 11 p. 8

The early CAD market was competitive and fragmented. The geometry produced using the CAD equipment had to be compatible with the CAM machinery. This required a high level of integration between the machine tool manufacturers and the computer systems suppliers or, as in many cases, a move by a large conglomerate to develop hardware and software for use in house and, eventually, for sale to third parties. McDonnell Douglas started Mac Auto, which became UniGraphics; Hewlett Packard had ME10 and ME30, IBM developed CADAM, Dassault Systèmes developed CATIA. As is the way with large conglomerates UniGraphics is now owned by EDS, IBM had a bad year and sold

CADAM to CATIA and these two have now merged. Over time many CAD/CAM systems fell by the wayside, such as Quist's company's DDM, and it was difficult initially to decide which one to go for.

The systems that have survived are those developed by companies with large manufacturing and design commitments especially in the aerospace industry. Software houses and computer suppliers had little more than mathematics and computing science to contribute. As the market matured users could appreciate the benefits of those systems developed with hard design and manufacturing in mind rather than clever geometry manipulation alone. The systems selected as the technology matured are those that are more in tune with designers' thinking and through this experience of selection designers learned what a system should provide and were better able to specify their needs. Design practice has moved on from a blind acceptance of the enduring traditional drawing office with its boards and pencils to an active engagement with the development and specification of design materials.

6.6.1 Interpretations

The physical separation of different departments led to different interpretations being made of the technology and its use. Tony outlines the situation between the design office and the drawing office, an artificial separation that was still in place from the days of manual drafting and taken for granted by those involved:

> "Tony: Right. I think probably the very first time we started to use CADDS. I mean, it was all quite exciting, and we produced these shapes, but the one thing that we did find was that when we were passing things through translators you don't get perfect translations. And we would put things in, you know, the cob would be 2" wide and the radius would be 13" diameter. You know, nice round numbers and by the time they have been passed around the group, if you'd passed models - the idea is that you would produce your basic geometry, you would then pass it through to the stress man, who would use his old fashioned finite element programme which was called GSS. And then he would pass it back to me, and then I would get some idea of where the stresses are, I could talk to the manufacturing side, where the machining cusps are going to be, where it would be acceptable and where it wouldn't. And then I would pass that onto the drawing office. Because every time we had these, we were all using different systems, so everything had to go through IGES. And by the

time they had been passed around, you'd find that a lot of these dimensions had actually changed quite significantly. It was now 12.9846, you know. And we didn't realise until we actually started passing these things to the EDO[9]. And of course the EDO are very disciplined."
Interview 13 p.10

"Tony: Its - the designer basically specifies the technical requirement but the EDO actually define the component. And because we - they were getting all these models through and when we first saw their drawings with all the dimensions, they dimension everything, we would put key dimensions, but they would dimension everything so that you could give it to a man at the lathe and he would make it. And we saw all these odd dimensions, you know, and then they started saying, "Oh, this is, you know, they've actually put down 4.9863, you know, plus or minus whatever." We started to query this and they said, "well, that's what's coming through." You know, and it was obviously, the thing that - we went into this a bit naively without thinking about the working practices and it was from that, that we really - we, you know, they were taking what we were giving them as read, you know, it had to be this, you know, we had carefully calculated this 4.9365. And, you know, they were dimensioning them up accordingly, you know. I mean, the one thing that emerged from there, was the need for working practices, and understanding what was happening. I mean, I think they had thought that we had gone mad, you know thought we'd gone all Mr Spocks and working things out to such high decimal places. But yeah, I mean, certainly that was an example even at the very beginning where people had got a certain technology and there were surprises that emerged. You know, they can see, you know, they have a vision of how they're going to use it, and they think they know everything about how its going to be used and then you get these things creeping up. And we see that all the way through, we see that even now. And I do think the working practices do tend to lag. There - I don't know - it's probably the only way you can do it but it seems to me you can only write the working practice once you have had a go with this sort of technology. But of course that doesn't go hand in hand with, you know, what we are supposed to be as a total quality organisation, covered by all the procedures and the working practices. You know, it's really, it's a struggle to keep up with technology." Interview 13 p. 11

[9] Engineering Drawing Office

Tony is describing a kind of computer Chinese whispers. The translation process required to communicate the geometry information to the various computer systems employed by the people in the design process would lose tiny (quite literally) bits of data and the original dimension of 5 would end up being 4.9635. The EDO made the assumption that the adoption of computer technology meant that the designers along with the stress department had found a new level of precision that transcended previous efforts and ran to four decimal places. The two departments made different interpretations based on the habitus at work in each and reflecting the detailed division of labour at Tony's firm. The Drawing Office had traditionally been concerned with the detailed communication to manufacture of precision information and they carried this concern through the introduction of the CAD system. The designers' concern was that their intent was correctly communicated. This clash is an example of what Bucciarelli (1994) would call an 'object world' and Darr (2000) would call an 'interpretive framework.'

These limits and interpretations were challenged and modified through the very human interaction that uncovered the errors. The slight difference between the transmitted and received numerical values would not have affected the performance of the product significantly, it would have made the cognitive and communications processes more difficult because it is easier to think in terms of 5 than in terms of 4.9635. The error was not due to incompatibility of the technology; the social organisation of the link between the design office and the drawing office was at fault. The error was discovered through the organisational link between design and manufacture and, in this instance, could be corrected by a change in procedure.

6.6.2 Computer Aided Design in the Drawing Office

At first the CAD equipment was in the computer room and this encouraged, as in Yan's case, close social contact among the people using it. The geometry error that Tony refers to came about partly because the designers' computer room was physically separate from the EDO's computer room. The D.O. with rows of boards was maintained separately from the computer room and designers had to move between their boards and the CAD screens. It was the penetration of CAD equipment into the mainstream drawing office that sealed the acceptance of the new technology and completely ended any of what Baldry and Connolly (1986) perceived as 'fragmentation.'

"Tony: . . . the next breakthrough was really the stand-alone workstations. Because then that enabled, rather than having a separate room with a load of terminals linked into a mini computer, you know, you now can basically put computers onto the desks of the designers - where they are at the moment."
Interview 13 p.7

From having to deal with what they perceived as badly designed equipment in hostile and cold environments the technology has been received into the designers' own environment and on their terms. Ideas about the imposition of management control and Taylorisation of design work were unfounded because in the end the designers were robust in their defence of their design authority and by extension their right to appropriate whatever technology they were confronted with to maintain their position.

By the time designers had computers on their desks beside their old drawing boards the novelty of CAD had worn off and it was fit for mainstream design activity:

"Tony: And then, you know, we just saw more and more coming in. And I suppose the speed improved, the capability of the machines improved."
Interview 13 p.7

There is a sense of the acceptance that the infiltration of the technology will continue to gradually increase and that the performance will also follow an almost pre-determined trajectory. At the centre is a feeling that designers are getting on with what they always have done, the technology becoming merely contingent to their routine activity. Yan sums up:

"Yan: we got more systems, instead of one we had two, we had three, it grew, it gradually grew - bigger processors, more terminals, of course as soon as they put a new processor, they put more terminals on, and you realise you're back to square one, and "Oh its going slow." The usual thing you know. You are always chasing, you are always chasing and it developed in that vein, such that more and more people were on it and less on the drawing boards. You always had a drawing board as your base but you went to do your work and came back again. Of course towards the end of our career in Peterborough when we transferred from Westfield Road that's where the drawing boards never went with us, and we just had terminals."
Interview 17 p. 12

The limitations of the technology became "the usual thing." The routine interaction with the technology was within these limitations. The drawing board (totem of design production) had its final end when it failed to follow the terminals during the office transfer.

Herein lies the main challenge to pessimistic technological determinism. The designers are still in the drawing office but they have moved the CAD technology in with them. They have maintained their authority over design and strengthened it by appropriating technology for their own ends and not for the ends ascribed to their employers. Technological change has also become routine, as routine as the technological changes designers invoke through their own normal work. Change, to use an older term, is the norm. The design habitus has mediated in the changes in technology and the working methods and procedures developed by designers are now part of it and are passed on and reproduced through it. New designers coming into the office are immediately confronted with a technical configuration now so taken for granted that it is unremarkable. It remains though, a product of the history of the changes in design production demonstrated here. At a fundamental level it is the human involvement in production that makes it productive.

6.7 CAD and management

Designers' interactions with their management were changed by the widespread adoption of CAD. From vague statements by managers about 'productivity' and 'remaining competitive' Baldry and Connolly (1986, p.63) concluded that CAD was introduced with the express intention of increasing management control over design work. Subsequent work by Senker and Simmonds (1992) recognised that Baldry and Connolly were working in the very early days of CAD and that such predictions have proven to be unfounded. They identified a widespread ignorance of technology on the part of management that was complemented by McLoughlin's (1990) finding that CAD designers 'enjoyed a new found 'skill superiority` over their supervisors' (p.229). The relationship with management has changed, based on designers' immediate engagement with CAD technology that their supervisors do not share. The design habitus has contributed to and mediated in the development of this new relationship.

The physical environment has also changed considerably, from a large room with rows of boards which was quite definitely a drawing office to a room with computer workstations which, apart from some minor details, might be an office anywhere in the industrial world. Baldry and Connolly's 'fragmentation' of design work caused by the separation of CAD equipment from the main office has not been realised. The equipment is now firmly where designers want it - in the D.O.

6.7.1 Walking the boards

The layout of the traditional drawing office with drawing boards lent itself to a high degree of surveillance. The senior member of the design team, section leader or chief engineer, would 'walk the boards' when everyone else had gone home. Drawings were left taped to boards overnight and the manager could see what had been accomplished during the day. Designers were managed by a designer who was extremely skilled at reading drawings quickly and critically. This management interaction with the designers was interrupted by the introduction of computer technology:

> "PK: One of the things that seems not to happen now with CAD is, the chief draftsmen used to walk the boards at night, and you would come back to your board and find a sketch on. Did that kind of thing happen?
>
> Robert: Well you had something there. I mean, they, well, they could progress a job, and see what - what activity was done that day in your - that, you know. I mean, you tended not to - you can see that it doesn't happen now, because they don't know what we are doing. And it was even worse when - with the software engineers, you know, nobody knows what they are doing. But, yeah we just took that and that was just the accepted way, you know."
> Interview 10 p.4

The designer in front of a computer presents a barrier to detailed interaction between the designer and management. A different level of interaction between the designer and the CAD technology has replaced this interaction with the management.

> "Luke: Computers, I find computers are difficult to supervise. It's a one to one relationship with the operator and the computer, and doing product design on the computers, well, you have no feel for the size, for the complexity. You cannot see the full product. It's impossible to walk around at night and have a look what's been done by the operators."
> Interview 6 p.10

Luke finds it impossible to walk the boards and recognises a new, "one to one relationship" between the designer and the technology. Eric's comment exposes this:

> "Eric: When they found the CAD system it got rid of all the tediousness of dimensioning and a lot of hours slogging over a three paper layouts of general assemblies and things so that's all gone now. We don't do that because, you know, working on the actual physical model of it."
> Interview 3 p.12

This seemingly throwaway comment exposes some of the designer's prejudices. The interaction with the traditional materials of the design was tedious and time consuming. The interaction with the new technology is with the "actual, physical model" of the product. Of course the model is neither actual nor physical but Eric's use of those words betrays his transcendental[10] interaction with the product design through the new technology.

Eric really means that the "actual, physical" product can be passed around those with access to the technology. He continues:

> "Eric: So when you're actually working on it somebody else can re-use that as it is without having to transfer all the information on paper."
> Interview 3 p.12

As explained earlier, the drawing board underwent three upgrades in 2000 years. CAD technology is upgraded every two or three years, so the operational familiarity essential to designing cannot be sustained except through constant interaction use of it. But it is not just access to the technology that is required. The codes and ciphers of design practice have been extended and require a new level of mastery. The people doing the designing interact with ease with the technology and their practices are reproduced on a day-to-day basis by their almost constant engagement with each other through the technology. Changes in the technology such as software upgrades are taken on individually and informal structures ensure that the detailed practices that may arise are passed along within the workplace. Different design establishments using exactly the same software

[10] This word carries a lot of baggage; it is used here in the sense: 'beyond the limits of ordinary experience' (OED)

may have entirely different working practices based on the way they have interpreted and use the technology.

6.7.2 Management limitations

The people charged with supervising or managing the design process have limited access to the technology and no access to the new extended and rapidly changing habitus and can be excluded by those who do. Previously they would have had a fundamental and skilled understanding of the materials of the design, which were relatively stable. Now, their understanding is diminished because they do not have access to the channels of reproduction of the habitus. Udo has an insight into this:

> "Udo: In the good old days like that (points at engine section on wall), forget that's on CAD/CAM, on a drawing board my bosses could actually scan it, I'm into how your brain works this week, they can scan it in one pass and can pick up everything because what you see is what you get. With all our CAD systems now, with all our analytical systems you can't see anything; it's all hidden in the bowels of the machine. So as a result we are getting more and more people getting further and further out of touch with what's actually happening because our design chiefs; new design chiefs, don't hit the keys, you know, they've not come up to that sort of schooling, so as a result, the boys, and I was one of them, can snow 'em, you know it'll be alright, it's on the machine."
>
> Interview 14 p.7

This thoughtful comment implies a necessary division of labour between the "chiefs" and "the boys", also that the chiefs have a level of expertise which is born of experience. There is an implicit acceptance that design requires a high degree of social co-operation; this in turn depends upon there being a high level of socialisation. The obverse – people getting "out of touch" - is perceived as a problem. The final comment reveals a possible element of conflict. Previously when everything was out in the open and nothing could be hidden from the experts, people's personal efforts, in which they had large personal stakes, were permanently on show, the level of criticism from experts, management and colleagues was applied in a special social milieu. Now, though, with everything "hidden in the bowels" it is the possible to hide one's personal interactions with the design from all but a few colleagues who have the same level of knowledge of the materials of the design but a lower level of knowledge of the design itself. Both the managers and the designers have an encompassing view, which was reproduced through the variety of social interactions in design production. But only the designers have a materials of the design habitus which is applied and reproduced through a more limited and secretive social milieu and excludes their managers.

It may be that the managers in the traditional drawing office did not have access to the full range of judgements made by the designers; the managers' judgements were necessarily different. A contradiction is evident in the ease with which data has to be accessed to keep the distributed enterprise going. Never before has everything been so out in the open. A parallel may be drawn with Bourdieu's restricted and expanded fields in art. The restricted field in design is the one that designers share among themselves an their judgements are applied within the field. The expanded field is where those judgements are ready to be exposed to a wider audience, which includes their managers. Designers in traditional offices may have also had a set of judgements restricted to themselves but with the CAD technology they are more apparent. The way that designers show their work to management may only have changed superficially but their perception of the relationship with management has changed because of management's evident exclusion from the materials of design.

6.7.3 Uniformity of output

The things that are on show and exposed to external people are the outputs of CAD technology and share a uniformly high quality of physical output. The output might be photorealistic images on a computer screen or perfectly laid out engineering drawings. Nick explains why this quality is important for him:

> "Nick: The other thing that I should put in there is that 9 times out of 10 these days what we're showing at the first stage - first presentation stage, will be CAD produced material, whether it's an elevational views or renderings or you know graphic design layouts or whatever, we will discourage it us going with anything but CAD output, simply because we find now that we can get from the concept to a very high quality of preliminary presentation in CAD. It streamlines and shortcuts any mechanical processes of sketching, and I think the market place probably expects it. I hope they expect it of Concert Design anyway."
>
> Interview 8 p.7/8

The important thing for Nick is the level of client expectation and although he wants to present the design in the best possible way he is tacitly championing the medium over the message. This, in turn poses the question of what is the best medium for him.

Yan described the transition from pencil drawing to computer output:

> "Yan: And you had a flair; it gave you quite an experience of drawing something, which obviously CAD doesn't do. Everybody's is the same now, you can't tell one from another. Em, you developed a style which was part of it really, that was you know, something you got pleasure from seeing this thing generated. But of course the most important thing you drew something that was accurate, designed well."
> Interview 17 p.4

The primary concern in the traditional environment was design quality and after that there was an opportunity to show off a flair or drawing style. Taking part in that activity gave a level of emotional satisfaction. But as he says: "everybody's is the same now." Generating traditional design output such as engineering drawings requires little personal involvement as Frank says:

> "Frank: Yeah. There's this wonderful, em, menu which is called Layout. Basically you've sort of got this thing all worked out, you've got the part there and you hit this thing and it more or less just sort of draws it in 2D for you. Brilliant. Love it, I love it."
> Interview 3 p. 12

The original technique of drafting has been replaced wholesale by a new technique of interacting in 3D with the product design through a computer and with the geometry in the digital form all manner of automatic manipulations can be performed. The most visual of which is the automatic generation of traditional output in the form of an engineering drawing. This is possibly what Cooley (1971) was worried about when he predicted the 'automation of the drawing office.' However the output technologies, whether they are used for presentation, as Nick does, or to save tedious drafting operations, as in Frank's case, are part of the communication of the most important aspect of design activity: design authority. Udo, with his usual insight, makes this point:

> "Udo: If you can't design, sitting at a CADDS terminal isn't going to help you at all, it's going to confuse every other bugger because your output looks so authoritative that they think that you know what you're doing. Same as producing drawings; if the drawing looks neat and presentable and it looks typographically correct, that can be a disaster, because it can still be a load of crap."
> Interview 14 p.7

He is concerned, as Yan's is, with design intent. This is a return to the fetishism argument because what Udo is talking about is the separation of the outputs from the relations of design production. Nick does not want to present the activity of design production to his clients but only the outputs from it; his quality of presentation serves as a mask over the activity and the judgements embodied in it. Udo makes the distinction between the appearance of the object and the underlying intent. His understanding of the design process is shown by his concern for the web of confusion that may be generated by a lack of differentiation between the accidental output qualities and the substance of design practice that are the judgements embodied in it.

6.8 Cultural arbitrary

CAD was introduced to design production to reduce the turnover time of capital. A strict labour process approach misrecognises both this and the 'object on which work is performed' (Marx, 1976a, p.283), in taking drawings as the 'products' of design. A neo-classical economic view (and one held by Marx) is that capitalism works to increase the rate of profit. In most cases the rate of profit is not increased by overbearing management control. The evidence presented here shows that management has conceded control to designers in order to reduce turnover time.

Predictions that CAD technology would lead to the de-skilling and downgrading of design work have also not been vindicated. If anything the designers now see themselves as more skilled than their supervisors, in a reversal of the traditional drawing office where managers could exercise their design authority through their familiarity with the materials of design production.

The traditional drawing office with its regimented rows of boards was a social milieu where the design habitus was reproduced and transmitted. The imposition of CAD can be seen as a step change disrupting the traditional order of things. In reality the transition to

CAD was gradual, the early forms of installation did not endure and the technology was forced into a form that reinforced the designers' place in the enterprise.

The transformation of the habitus has incorporated changes in production technology and reductions in turnover time. The phenomenology of time, for designers, has been altered by these changes. But the habitus has also had an impact on the way things have changed; the contemporary form of CAD organisation has been realised on designers terms.

The power of designers lies in the authority vested in them to make judgements about what will work. This is their cultural universal and the surrounding organisational form, the technology they use - their materials of design and so on are cultural arbitraries for them.

7 Postmodernity and design production

In Harvey's (1990) analysis of postmodernity, based on various macroeconomic data and an examination of postmodern cinema and architecture, he identifies time-space compression as a key feature of the postmodern age. He speaks generally about the emergence and adoption of new production technologies, and new technologies for the representation of space and time but he does not give any detailed examples. Stereolithography, a rapid prototyping technology, provides time compression in design production. Data transmission technology supplies space compression. The case study developed here illustrates Harvey's arguments.

7.1.1 Time compression: Stereolithography

Stereolithography (SLA for Stereolithography Apparatus) is a relatively new tool in the designer's kit – the technology appeared in early 1988 (3D Systems, 1995). It was the first of the several rapid prototyping technologies (RP). RP is a product development tool with which a 3D model of a part can be manufactured quickly and directly from a CAD representation of it constructed by a designer in the ordinary course of designing. The SLA technique forms solid shapes by selectively curing a light sensitive, liquid resin using a scanned laser beam. The comparison is with largely handcrafted models constructed by traditional means from engineering drawings of the part or assembly at great expense and with a considerable time penalty. SLA is very expensive to buy and to run - the resin costs £200/litre at 1999 prices. It depends upon specialist operational expertise and must be employed to its full capacity. Therefore, it is rare for even a large company to maintain an in-house capability. Specialist bureaux have been set up in strategic locations to serve industries needs for RP facilities, many of them being traditional model making concerns. Customers can instruct bureaux entirely via the internet and be sure that 3D CAD data they provide can be pre-processed to drive the RP technology most appropriate to their needs.

Part data is sent to the bureau; the bureau's technicians then manipulate the data for four reasons. The first is reasonably obvious, the diversity of the software originating the data leads to compatibility problems. SL technicians have a range of software tools available to help them interpret data for use with their systems. The second is that the SL process converts the 3D solid geometry into a series of slices so that when the model is built the surface appears as a series of steps; if necessary the model is hand finished by a craftsperson to smooth out the surface. The model must be built so that the steps are easy for the hand finisher to remove. Third, the build process takes a certain amount of time and a skilled SL operator can minimise this by orienting the geometry appropriately. Finally the models are not self-supporting within the bath of resin and features like bridges must be supported so that they do not collapse. These supports are added by the SL technicians (see 3D Systems, 1997). So the job of a SL technician is a skilled one and is a case of skill displacement from the hand building of models to their computer generation.

The organisation of the RP market is along the lines of Edwards' (1979) core and periphery. Some customers for the products are product development operations of core corporations, others are product design consultancies contracted to develop products for core companies. The RP bureaux are in the periphery along with other sub-contractors providing services to the core.

> "Steve: Years ago we used to get model makers to do like plastic glued together things. But now we tend to use SLA's or CNC machines to try and generate a prototype."
> Interview12 p.5

Quist compares the development of his money cassette against the new model:

> "Quist: Now again, we didn't have any, well, we didn't have CAD, there was no SLA models, you know the Stereolithography modelling. Which, we were just talking about that the other week it would've been dead simple. Well, not dead simple but it would have been a hell of a lot easier if we had had all these tools when we were doing this cassette."
> Interview 11 p.10

> "PK: So, like you said if you were doing that now, what sort of technology do you use now?
>
> Quist: On that, what we would use?
>
> PK: If you were do something that big?

Quist: Yeah, well that would be Pro. On here? In fact there is a new one, there's a wider one, they've widened it another inch, something like that, plus there's a few other things, electronic bits on it. In fact there's a PCB on it now. And it was done on Pro. And it was SLA'd as well.

PK: So the full thing is SLA'd, is it?

Quist: Well, the one that, yeah, I wasn't involved in that. The other one, that one wasn't, that one was done by the old fork and knife."
Interview 11 p.13

The SL model itself is brittle and only suitable for visualisation, limited physical testing and to make mould patterns for moulding limited numbers of production components for more rigorous physical testing.

"Peter: These start off as being test racks where we don't have any mouldings. It's just a big PCB laid out with a big keyboard and a big screen- all the hardware fundamentals. As we get closer and closer we might start providing them with maybe the first or the second SLA type model after we've finished using it

Odette: The castings from the SLA models."
Interview 9 p.3

Quist's use of the term "fork and knife" is a reference to the leap the technology has made since the original cassette design, which itself represented quite a leap in technology with the reduction in the number of parts and the application of new materials.

The development of rapid prototyping technology illustrates general theories of technological development such as that proposed by MacKenzie (1996). The geometry being available as 3D computer data seems to generate a need to reproduce it physically in 3D by some computerised means. Applying the principle of symmetry, other methods must have been available for development but were discarded in favour of a fully automated system. As has been shown the process is not completely automatic and requires considerable human intervention, but the SL technician does not intervene between the geometry and the model.

The generation of part geometry as 3D data has become so orthodox that it is an expectation of design practice. It seems that this has led designers to expect automatic physical generation of their geometry and hence the development of rapid prototyping technology in its current form.

Rapid prototyping allows designers to have more rapid 'conversations' with the materials of the design than model making did. It remains to explain how RP relates to Harvey's (1990) thesis about postmodernity and its relation to Marx's theory of machinery:

'On a closer examination of the working machine proper we rediscover in it as a general rule, though in highly modified forms, the very apparatus and tools used by the handicraftsman or the manufacturing worker' Marx, 1976a, p.494

With stereolithography this is untrue – almost nothing can be recognised in a stereolithography machine, even in a 'highly modified' form, any 'apparatus or tool' which could be wielded by a manufacturing worker. Marx's physical theory of machinery is lacking but his analysis of the transformative power of capital, as used by Harvey, can explain the technological development of rapid prototyping.

One of Harvey's main points is the tendency towards a reduction in turnover time for capital. The main tactic for this, he maintains, is in the fictitious money market, but there is also a drive towards new production techniques, and forms of control (e.g. the so-called 'Japanese' just-in-time inventory control system). Stereolithography gives just this reduction in turnover time compared with manual modelling methods.

Harvey also introduces the idea of 'flexible accumulation', a characteristic of which, he says is 'the emergence of entirely new sectors of production' and Stereolithography is surely one of those. He goes on:

'The economies of scale sought under Fordist mass production have, it seems, been countered by an increasing capacity to manufacture a variety of goods cheaply in small batches. Economies of scope have beaten out economies of scale.' 1990, p.155

and further:

'Such flexible production schemes have permitted and to some degree depended upon, an acceleration in the pace in product innovation together with the exploration of highly specialised and small-scale market niches.' p.156

Harvey does not give detailed examples of 'flexible production schemes' but stereolithography is certainly one of them. Rapid technology in general fulfils his first criterion of economy of scope, and the second, of accelerating the pace of product development and each rapid technology individually fulfils its own specialised niche. (See e.g. Ryder et al. 1998)

But it is more than just that. The stereolithography process is a reversal of Marx and Engels' (1998) famous phrase 'all that is solid melts into air'. All rapid technologies take the ethereal, the unreal (or in the common parlance, the virtual), and convert it into solid material. Stereolithography performs this magical transformation with light and liquid, it represents the harnessing of the formless into a form. At the same time the SL model itself is only a stage on the way to a product, it has no function other than to act as a form, itself for conversion.

As a final point on rapid technology in Harvey's scheme: the trade journal is called Time Compression Technologies (Rapid News Publications), using one of Harvey's own phrases. Beyond the field of social science, Harvey's concepts are part of the linguistic battle over innovation. They owe this appearance to the theory's close correspondence to the lived experience of the fast changing world of technology production.

7.1.2 Space compression: Data management

Time compression achieved in production depended greatly upon the introduction of computer-controlled machines and the capacity to transfer design data to the control system. Data management is the set of strategies and techniques developed for the storage, retrieval and transmission of the data. Tony's story about the computerised Chinese whispers has illustrated an instance of the development of such a technique. The way in which electronically held data enhances the designer's already complex web of social interaction is noteworthy:

> "Eric: But I suppose with CAD and things its main advantage is being able to share your work with other people and then extend, you know,

teamwork and being able to work in conjunction with people that are remote, well, that aren't close to you like remote in other divisions.

Frank: Yeah, yeah, ah, um. You know, you hear about a product in some other division, you get on, send an email message to the designer, get a name there, and within 24 hours you've got the whole product in your directory and you can just have a look at it, look round it."
Interview 3 p.13

The technology has progressed from allowing data sharing between operations which are more or less in the same room to operations in the same building, such as in the early days of NC programming. The ability of the global telecommunications network to deal with electronic data has allowed data sharing between extremely remote centres. Just as rapid technology represents Harvey's time compression so this global information network represents his notion of space compression.

Nick has no problems sharing data with his clients and it seems to be an important part of the relationship:

"Nick: How do we share data with clients? Well we find that very comfortable. We'll pick up - we'll pick up any sort of data from our clients."
Interview 8 p. 9

Vernon gives an example of how interactions are organised through the data management system:

"Vernon: EDM vault. V A U L T.

PK: Oh right.

Vernon: It is another Computervision product EDM it is our electronic data management system.

PK: Right OK.

Vernon: It stores both CADDS files and finite element stuff as well, you know, so all sorts of stuff. It's just a repository really it's not particularly

intelligent, except it knows - you have to book - you have to book tasks out of it. So if you follow the naming convention, this particular file of mine, the vault knows that I am working on it and it won't let anybody else create a file of that name, well create it locally but they couldn't store it on the vault. The vault sort of parcels it out basically."
Interview 15 p.14/15

The Vault software mimics the traditional D.O. where only one person could work on a drawing and make changes, people wishing to reference a drawing had to make a paper copy. The Vault organises this process, but the master and the copies are geographically indeterminate and indiscriminate, they can and do go everywhere.

7.1.3 Time-space compression

The combination of RP and data communication provides an example of Harvey's phenomenon of time-space compression. Mike gives a perfect illustration:

"PK: So, d'you find that would work with people in other time zones?

Mike: Oh it's great. Probably the best example of working in other time zones is with Pro Engineer, where we can do a model, we can drop the files onto a bulletin board at the clients, the company in California picks up those files in that night and does part drawings for those components and they're finished by the next morning when we get up. So that works really well, and that's because the client requested it, again the timeframe that is done is so short that we have to sort it out, people who do that all the prototypes we do are really done in Western Australia and Los Angeles, and the files are modemed over, and then five and a half days later we get a federal express package with prototypes sitting there. So I mean it is - the timing is more important in this industry now than anything - than it ever used to be."
Interview 7 p.11

While many postmodernist theorists lend awe-inspiring importance to what is possible with new technology - heralding a new age, of information, of ephemera, and even as Fowler (2000) suggests, phantasmagoria - people like Mike are just getting on with it. Indeed the story of the introduction of this new technology is just one of people getting on with it.

This is a counter to some of Braverman's (1974) nostalgic arguments about skill. The respondents suggest that re-skilling is something which people take on as individuals with some enthusiasm and that new skills such as computer programming, about which Braverman is especially disparaging (see p. 444), bring with them another skill of adaptability - a willingness to engage with the new and in many cases to push it forward. Transformations of labour processes under capitalism are more complicated than a simple impetus to de-skill. New technology never has the consequences intended at its introduction. In the case of design, the materials used by designers in production have been engaged in creative ways by them. The transformations of design production are social in nature and are engaged, sometimes enthusiastically, by the people doing the work. The injustice is not the 'creative destruction' (Schumpeter, 1943) of old skills and their replacement with new ones but the limitations on access to the new for so many people.

8 Objective Structure

When designers act they seem to do so freely, but they are bound by cognitive and material structures which precede them. Cognitive structures are part of the habitus, products of the collective history of the group, transmitted and transformed through its members. Material, or objective, structures might seem to determine human action where the individual is seen as passive, but the reality is a continuous engagement between individuals and their material environment that results in the development of both.

Notions of the imposition of material structures identified by the respondents serve as a starting point to explore some traditional sociological concepts. Ideas of bureaucracy, labelling theory, anthropological conceptions of tribalism, the structure of the family, and the school system, have been developed to show how they affect the actions of designers individually and collectively, and the development and reproduction of the habitus.

Returning to phenomenology, and the theme of experience of space and time, ideas about place are discussed to show how the geographical organisation of design is related to subjective experiences of location that accentuate the pre-existing spatial structures of design production.

8.1 Organisation

The reality of life in today's productive system is characterised, as Harvey (1990) says, by eclecticism:

'Eclecticism in labour practices seem almost as marked in these times as the eclecticism of postmodern philosophies and tastes.' p. 187

In late modernity a variety of structures or organisational types is possible and the respondents have their own subjective responses to the forms that organisations take. The prevalent organisational form in operation today is that of the distributed enterprise. Harvey has described the labour market surrounding this succinctly:

'The current trend in labour markets is to reduce the number of 'core' workers and to rely increasingly upon a workforce that can quickly be taken on board and equally quickly and costlessly laid off when times get bad.' Harvey, 1990, p. 152

The internal labour market has subsequently developed into an even more complex web of connections. The 'core' is increasingly hard to locate and in the course of an economic cycle functions such as finance, design, test, manufacture, distribute and sell may be provided by companies having different organisational forms. These specialist companies will service several core organisations simultaneously as they move between temporary structures created by core organisations.

Examples of this mode of production have already been given, from Mike's position in the chain between his client and tool designers in California and toolmakers in Singapore and the transfer of his data to them, to Quist's colleagues designing the new money cassette for use by security guards employed by banks to distribute money in the form of cash to people some of whom may operate the stereolithography machine used to make the prototype.

The distributed enterprise can be seen as a large scale team organisation where the people with the peculiar skills and knowledge required for a specific project are brought together and the primary link between them for that time is the ephemeral and short-lived project. The configuration will never again occur, the speed of technological change ensuring that the next project and the technology brought to bear on it will be different.

However, the distributed enterprise is not so fluid as it might first appear. Small-scale but enduring alliances are formed among contributors to it and some operations require organisations with large enough inertia to exhibit more or less bureaucratic forms of control. Working in these, often temporary, structures affects the way that designers practice.

8.1.1 Bureaucracy

Sociologists have adopted Weber's (1968) ideas to study industrial bureaucracy more extensively. Among others, Gouldner (1954) proposed a typology ranging from an 'indulgent' form to a 'punishment' form. Edwards's (1979) emphasis is on the 'form of control'. This is defined as bureaucratic when people are promoted through the offices of the bureaucracy according to seniority and experience. The career ladder in the system is visible to all those on it and social relations are based on the system rather than on people, even if some individuals are dismissive of it.

All the companies in this study had some form of nominal bureaucratic structure, but it served, in the main, to demarcate positions in the reward structure of salaries and job titles. Dave came closest to describing his own position in the hierarchy. He drew an organisation chart:

"Dave: So this is me. That's Jimmy

PK: Yeah

Dave: He's my immediate - He's my line manager

PK: Yeah

Dave: He in turn reports to Brian Chappell who's the Engineering Director and he's under the MD - Dieter."
Interview 2 p.1

The chart puts him fourth in the chain of command below Jimmy, Brian and Dieter. He positions himself relatively to others in the company and his perception influences his relationships with them. However, to position himself he talks primarily about what he does:

"Dave: At the moment I'm involved in working on existing machines to prototype

PK: Yeah

Dave: Ironing out problems. Which have been identified by field tests, by field engineers."
Interview 2 p.2

"Dave: So really it's design work, development work, cost in mind, ease of assembly."
Interview 2 p.3

"Dave: As I said the responsibility was really the same as it is here . . . looking after contractors and designers. Designing up things. Making sure

things could be made. And talking to the technical manager seeing that briefs could be met."
Interview 2 p.4

Dave's activity is typical of the other respondents; it is varied, it brings him into contact with a number of different people and is technically demanding. His contact with other people does not necessarily follow bureaucratic lines but, unlike all the other respondents, he does not form narratives but tends to refer to areas of his own responsibility with which he is familiar. Though he seems unwilling to speak for other people, he does have a tacit understanding of the bureaucratic structure and the labels employed in it.

8.1.2 Labels

Dave referred to several people by title rather than name. The offices in Weber's (1968) scheme have titles or labels and part of the power of bureaucracy is in the way incumbents are dissociated from the office as individuals by means of these labels.

All the instances where respondents spoke of people, including themselves, were gathered together and the ones where they used a label were divided into two categories: job label and occupational label. The labels used for offices in a bureaucratic structure are job labels; labels that respondents associate with an occupational group are occupational or disciplinary labels.

Occupational titles are not specific to individual companies but emerge from the habitus, or Becker and Carper's (1956) 'acquired ideology' which is assimilated early in the career during education. Industrial designer is one such occupational label carried over from Art School departments of Industrial Design where some of the respondents got their education. Job labels, on the other hand, are imposed by management and have more meaning for management than the people being labelled. It might be expected that the respondents would refer to themselves in terms of a job title or some occupational title. This happened rarely and the use of any such title was heavily qualified.

Take Jennifer's use of an occupational title:

"Jennifer: Oh, I'm a UG draughtsman. I'm a discipline industrial designer, too, but I am trained in UG, I love it."
Interview 5 p.9

Jennifer calls herself an "industrial designer" to distinguish herself from people whose role is purely as a "UG draughtsman" and nothing else. Jennifer was the only person to refer to herself directly with an occupational title. Other people in the study referred to themselves as design engineers, mechanical engineers, or industrial designers or whatever, but were more circumspect. Eric, Frank and Gordon share the same job title, which could be said to be both a company job title and an occupational title:

> "Eric: So. Well, I suppose as product designers we are all employed in the research and development department; em, which is usually er split down into sections, and which then again are split down into individual project teams. And so we are - the product designers are a member of the project teams."
> Interview 3 p.1

The title "product designer" is used to position the three of them in the company structure at a local level, but it is problematic:

> "Frank: Don't you think there's this problem with . . . here being unique in that product design is both industrial design and mechanical engineering."
> Interview 3 p.15

There is a lack of distinction between "industrial design", which might be well defined to the respondents linked to a particular educational trajectory, and "mechanical engineering", whose self-assigned members had a different educational career. The activity associated with both labels is substantially the same, but this group of respondents make a demarcation between the two disciplines that is not evidently based on activity but on another differentiation based in the habitus acquired during early assimilation into the profession.

Peter eventually let slip his job title:

> "Peter: And there'll be Product Engineers, maybe, this is what me and Odette are actually called."
> Interview 9 p.8

But his use of the passive voice implies that he sees the title as externally imposed by someone else.

Tony was the only respondent who gave an obviously formal job title:

> "Tony: Yeah, well I am actually the team leader of the advanced projects design group."
> Interview 13 p.3

He realises that the title doesn't have any meaning in itself, and, in any case, it isn't even accurate:

> "PK: That would be APD, I guess?
>
> Tony: We are called APSD, that's Advanced Proportional Systems Design, is the full title but that is a bit of a mouthful, preliminary design or advanced projects, people seem to know who we are."
> Interview 13 p.3

In the wider scheme of the company three or four ways of referring to Tony's group are acceptable and whichever one is used Tony is the team leader. Even then the titles may reveal a little about the activity of the group, the word "preliminary", which is not in Tony's job title, gives a large clue:

> "PK: So, what does that involve?
>
> Tony: That's more concerned with, I suppose, conceptual designs of the whole engine. It's basically, we look at new concepts, or the likely development of gas turbine technology into the next 10-15-20 years; that's one aspect of the job. The other is actually acting as almost a pre-launch design group before the company agrees to a launch, and then it gets to a launch into a full project."
> Interview 13 p.3

Tony eventually has to explain more fully what he and his team actually do and where they fit in the company structure and in the design process.

In symbolic interactionist terms the job titles are symbols and can be used as signifiers for the self. But this does not seem to be a frequent strategy; designers do not use externally imposed job titles to refer to themselves. The wider terms of an occupational title are also weak criteria for self- identification but designers have more of an attachment to an occupational identity even if their job label does not reinforce this. What does happen is that the respondents label groups to which they belong and this reinforces their self identity.

8.1.3 Labels for other people

Although the respondents preferred to situate themselves according to their occupational activity and not their job label, they nevertheless spoke about other people in terms or job, or office, label and not by name. The respondents frequently observed the dissociation of the incumbent from the office, as in Weber's (1968) scheme, when speaking about other people. The job title is a mechanism to emphasise the distance between themselves and other people. In Harry's story of the design process he refers to the Sales Engineer, the Project Engineer, and the Chief Design Engineer but not by name. Harry is the Chief Design Engineer; the two colleagues he identifies have badges of office but only Harry has a title that makes a hierarchical distinction by using the word "Chief".

In Dave's interview (Interview 2) he refers to these people by job title: Managing Director, Engineering Director, line manager, Sales Director, Manufacturing Director, Personnel Director, Field Engineer, and Technical Manager. He refers to only two of them by name: Dieter is the Managing Director, and Brian Chappell is the Engineering Director. The sense of hierarchy is clear with Dieter at the top and the other Directors filling a layer below him. Below that is a layer of middle management including Jimmy, Dave's line manager, and lower still is a layer of peripheral workers: subcontractors and draughtsmen.

At Lambert Cawthorne (LC) they refer variously to 'management', as a general group distinct from themselves as designers, and also to 'software', and 'double E' (electronic engineering) as disciplinary groups based on an occupational split. Other people are referred to by department: marketing, finance, procurement, and production. The LC designers are a special case; their work is more visible than that of their colleagues in software or electronics and is therefore more open to scrutiny. Also the mechanical designers are in a minority. Frank uses his disciplinary label to separate himself from another group.

> "Frank: They're not mechanical and that's the other thing: and you know the core competence in this place is double E not mechanical."

Interview 3 p. 15

In referring to other departments the respondents impart a sense of geographical separation:

> "Frank: We tend to get the mechanical people from production turning up occasionally to this meeting."
> Interview 3 p.3

This kind of reference is echoed by Mike:

> "Mike: So there'd be someone from engineering, someone from tooling and someone from industrial design areas."
> Interview 7 p. 2

Frank talks as if "production" is a place (or even a foreign country) and Mike's language supports this geographical allusion with his use of the word "areas." The travelling distance for these people may be across the office or down the corridor. The emphasis is on ideological rather than geographical distancing.

The various references made by the respondents to other people indicate the extent to which they have become socialised to ideas of hierarchy and bureaucracy in work organisation. The primary meaning for the respondents is the idea of a hierarchy as in Weber's (1968) ideal scheme. Dave's responses indicate this very explicitly, whereas the "management" at Lambert Cawthorne and Udo's "admirals and generals" lend a more vague sense of a level above. A second feature of Weber's scheme can be identified in the idea of offices dissociated from their incumbents at all levels of the organisation but this is used by the respondents to emphasise their occupational distance from other groups in the firm.

The designers use labels for other people but not for themselves. They refer to themselves in terms of an occupational group, to which their allegiance is strong, and not by using their job title. The respondents accept and are even complicit with hierarchical and bureaucratic structures and these are elements of a general work habitus rather than a specifically engineering one. Equally, their strong identification with a profession is part of a professional habitus that is not exclusive to engineering designers.

8.2 Project teams

Some of the companies organise themselves with a formal bureaucracy based on discipline but then select members of project teams from different disciplines to work together. This form of organisation can lead to conflicts of loyalty between the discipline and the team. Each firm had a different approach to project team organisation; Vernon explains the arrangement at Cooper Clarke:

> "Vernon: Now, the project groups themselves have got, it is a bit like a matrix, the project groups themselves have got some design capability but not enough to do the total job. It is a bit complicated. In a way you've got the projects coming down like this, I need one of Udo's diagrams, you have got the project coming down and us running across so we potentially can contribute to the turbine bit of every project."
> Interview 15 p. 5/6

Eric, Frank and Gordon position themselves within the company structure as members of teams and also in the disciplinary group of product designers. Although Odette and Peter are known as Product Engineers within their company they are also members of teams. The companies organise their employees into teams and day to day production is done and experienced as a member of a team.

The Lambert Cawthorne group drew an organisation chart:

> "PK: So you report back to project managers?
>
> Eric: Er, yes, reporting to project managers.
>
> PK: (drawing) so you've got R and D and you've got product design.
>
> Frank: No. R and D. You've got projects."
> Interview 3 p.1

The chart has rows representing the various disciplines and columns identifying the teams. Each discipline is represented in each team; R and D is the department with the product design resource. Other members of the team are software engineers and electrical and electronic engineers. This is one example of the arbitrary but doxic division of labour in engineering. The project managers are external to the discipline based departments:

> "Eric: So we all report to one project manager.
>
> Frank: Who might report to a section manager.
>
> PK: (drawing) OK. So a project team, there'd be project team, project team, project team, and a project manager.
>
> Eric: Right.
>
> PK: And then, maybe a section manager?
>
> Eric: Yeah. That's the one."
>
> Interview 3 p.2

Odette and Peter at Genus are in the same discipline and have the same job title but their project teams are smaller and more loosely organised.

> "PK: What size of team are you looking at for a product? I mean people who -
>
> Peter: Five
>
> PK: Five?
>
> Peter: Five core people.
>
> Odette: Yeah. For that product. When we did Sparkle there was three of us."
>
> Interview 9 p. 7

Technology Design is part of a large group of companies and is responsible for product design within the group and also offers design consultancy to external companies. Their project teams can vary greatly in size from the small, like Genus, or large like Lambert Cawthorne. They also use a form of the matrix model for project teams.

"Jennifer: . . . there is a tree. We do belong to business units but we work cross business unit. We work very team - its a very team based system and for a project, a team will be gotten together from anybody in the business. You might be working with someone from Sydney. You could be working with one of the directors or you know."
Interview 5 p.6

The team structure is based around projects and the links are strong within the project team. The business units are broadly separated by disciplines:

"Jennifer: Yes the Product Development Group is two business units, one of them Technology Design and one of them is also called Product Development so that's a bit confusing but those guys are all the engineers, we are all the designers. That's the basic sort of split.

Ian: But then the designers also have engineers on staff."
Interview 5 p. 6

Jennifer tries to make a simple disciplinary split between the two business units but Ian corrects her. In any case the disciplines are subordinated to the projects.

"PK: Right. And this is just like a pool of people?

Ian: Yep.

PK: Right. And you just pull out for the teams?

Jennifer: Yeah.

PK: And you can get from . . . other . . .

Jennifer: Yes. Other. .

PK: So you can get marketing, you can get . . .

Jennifer: . . . groups as well.

PK: Right. Depending on the project.

Jennifer: Yep."
Interview 5 p.8

The project structure can create tension, which arises at Lambert Cawthorne because though theirs is the smallest group the work of the mechanical product designers' is highly visible whereas the contributions of software or electrical and electrical components of the products are virtually invisible.

> "Eric: Yeah. I suppose the problem is that with product design is that everyone thinks of themself quite properly as a mechanical engineer. You know, it's a nut and a bolt, so you know, an electronic design engineer - software say, "Oh well it's just a matter of simple common sense engineering." I think we suffer a lot from that."
> Interview 5 p. 8

Eric has internalised what he thinks is the relatively low value other people place on his work. Different groups have different perceptions of each other and they can lead to this kind of antagonism. The emphasis for the designers and others as individuals within the corporation is on their disciplinary identities and not on the project or team which are transitory in nature.

> "Eric: And then within the corporation, I think that as a group of engineers the mechanical designers globally have got their act working together. We all talk to each other on a pretty regular basis and we all use the same tools and we all co-operate in enhancing those tools which doesn't really happen with the EEs or the software design engineers. But maybe it's because we're a smaller group."
> Interview 5 p.15

Eric compares his group favourably with other groups and in doing so emphasises their separation. The product designers also organise themselves outside their teams, within their discipline:

"Gordon: Well, we have project meetings. We also have, well we have a mechanical engineering forum once . . .

Frank: (interrupts) . . . once a month, whereas we have weekly meetings of all the product designers. So out of all these projects, each product designer comes out and we sit around for an hour and a half to . . .

Eric: (interrupts) Yes that's to discuss our common issues.

Frank: Common issues.

PK: And is that, sort of, just a thing that's organised among yourselves as product designers?

Eric: Yes I think it very much is a self-motivated . . . arrangement.

Frank: The minutes sort of circulate . . .

PK: So, it's a sort of semi-formal arrangement?

Eric: Yes. That's . . . we initiated it and we minute it and the minutes are distributed around a wider distribution than the people at the meeting. . ."
Interview 3 p.3

They get together as a group to discuss their "common issues" with regard to design; they inform other disciplines of their activity by circulating the minutes of their meetings. The arrangement of the mechanical engineering forum is informal in that it was initiated from within the group of designers and not by the company. It may be seen as a reinforcement of a habitus based occupational identity within the firm, that is, an identity going beyond the boundaries of the firm.

The discipline identity is reinforced by regular communication and the use of common tools. The product designers recognise that they form a small group in a large organisation that is dominated from the management side by another discipline, in this case electronic engineering. Eric thinks the mechanical designers have "got their act together" better than other groups in the company, indicating that a little perceived persecution can be good for a group in reinforcing group identity.

Quist has a problem understanding the structure he works in.

"PK: Just to get a few things tied up. What is the company structure now?

Quist: In respect to?

PK: You know, sections leaders and . . .

Quist: It is pretty mean. I don't like it, what's there at the moment. There seems to be three structures, we have product management, we're manufacturing, we're design. So product management, sorry, manufacturing and ourselves - design. And all these three have go to flow into one. That's the bit I can't, you know.

PK: You are in design?

Quist: I am in design, but I could actually be working some day for maybe some guy here (points to organisation chart) and his manager there. And vice versa.

PK: Depending on what the project is?

Quist: Yes. At the moment I would be hard pushed to say who my immediate manager is. We started it off last month. They re-structured the thing last month and I know the guy I was meant to be under on paper but I since went onto this new project and its under another manager. You know, I don't like it, I like to know where I am sort of thing."

Interview 11 p. 14/15

For Quist the recent change in organisational structure is alien. The sense of hierarchy and bureaucracy developed early in his working life is absent; he has nowhere to position himself relative to other people apart from the notion that he is "in design." But this habitus based distinction has no structural meaning within the company, it only has a disciplinary meaning for Quist. This lack of definition leads to Quist's feeling of insecurity that is only reinforced by his perception that management is indifferent to his aspiration for a wider view of the business and his position in it.

At Cooper Clarke the structure is mixed. Project teams are organised along matrix lines as Vernon has pointed out. Detailed specialists are organised into what they call "core groups."

> "Vernon: When I first joined the company there were no project teams, all the resource was in core groups, so if you wanted a turbine designed you came to turbine engineering and we would design it."
> Interview 15 p. 6

Vernon then explains the transition from this structure to the present structure:

> "Vernon: And we moved away from that because some of the project managers - say we make you project manager for the next engine, CBR 900. We give you a job to do and we say you have got to get it out by then, and you look round, 'Who am I going to get to do it?' You have got no staff of your own to do it with. So all you can do is go cap in hand to various departments saying, 'Please can you give me this resource?' But you are fighting with other project managers who are doing exactly the same. And I think, the way I heard it was the project managers felt that they couldn't deliver and couldn't commit to deliver unless they'd got some sort of resource of their own."
> Interview 15 p.7

The transition to the project based structure involved negotiations about the allocation, control, and use of design labour. The end result was a mixed organisation involving core groups and project teams. Other considerations about resource are raised by the new scheme. Vernon goes on:

> "Vernon: But the old days every turbine was done in the same area by the same people; you had this tremendous experience base built up. It's phenomenal some of the blokes that were working here when I first came to this company were just phenomenal. They'd worked all their lives in one group and what they didn't know about turbines wasn't worth knowing"
> Interview 15 p.6

Vernon is talking about engineering tacit knowledge of the kind described by MacKenzie and Spinardi (1995). They researched a group of engineers involved in the design of nuclear weapons during the current test ban. These engineers were frustrated by their inability to test their designs and at the same time were concerned about losing their touch as a group of successful designers who were getting older. The pool of experts with practical knowledge of nuclear explosions is dwindling and their accumulated knowledge is being lost.

Vernon recognises that design work involves a build up of experience that is embodied in people, and in groups of people. This knowledge created through experience is a company resource and is held in the form of cultural capital by the people in the group. It is embodied in individuals in their knowledge about the product. Furthermore, it is part of a group habitus in their knowledge of each other, ways of working, and communication systems (e.g. jargon, symbols, filing systems) again as cultural capital but this time in a form that reinforces the identity of the group. Vernon recognises the need to guard this capital and to invest in it. The project system of organisation allows the experience to be built up during the course of a project and the cultural capital resulting from bodily engagement with the project - its materials and the members of the team - is embodied in the individuals and in the team as a whole. When the individuals move on to another project the team part of the knowledge is lost leading to a sense of loss or disjointedness that is the source of Vernon's unease.

> "Vernon: The problem is, you see, that if you have got project based designers you find that a mistake that was made on the CBR 1000 - made, discovered, understood and fixed is repeated exactly on the CBR 1100 because you got a new set of people. It is almost as though you throw all your experienced staff away and bring in a new lot. It's not quite as bad as that."
> Interview 15 p. 6

As he says he is overstating the case somewhat but it is evident that he thinks that the knowledge belongs to the group rather than to individuals. This 'know how' knowledge is part of the individual habitus and is one way in which the habitus also reinforces the identity of the group.

The project system is the distributed enterprise in miniature. The respondents know that the team is transitory and will be disbanded at the end of the project. Discipline identity is more fundamental and has associated knowledge that is valued by the designers. A conflict arises between the distributed enterprise organisation with its advantage of flexibility to reconfigure the exact knowledge mix needed for each project and the discipline identity of the designers. The challenge is for organisations to develop so that they maintain their flexibility of configuration but also maintain their cultural 'how-to' capital through the discipline identities of the workers.

To do this they should understand the history of the disciplines and how they interact. The individuals are engaged in a kind of prisoners' dilemma; if they all commit wholeheartedly to the project team then the likelihood of the project's success is greater and they know, or at least perceive, this. However, they must also maintain their allegiance to their disciplinary group because they have to go back there when the project is finished.

The respondents organised into project teams still keep an allegiance to their perceived discipline and reject imposed labels and structures. The various disciplines are recognised by all and are somehow constructed and reproduced by the people in them. Udo has some insights:

> "Udo: Oh tribes. We've always had tribes and if you work in mechanical technology and you are a finite element guru and a crack propagation guru and all these wonderful things, then you are a stress man basically. If you are an aerodynamics guy, you know, got long hair, sort of, you know, smart arse, with, you know, good at sums, you know, you are an aerodynamicist, thermodynamicist what have you, it doesn't matter. And if you a manufacturing guy then you are a manufacturing guy. And if you are a build person, you are a build person - you build engines and if you test engines, you test engines, you know, they have oily fingernails and pullovers. And so, we are all still tribal and although we build Integrated Product Teams, IPT's and you put people into IPT's you still have an allegiance to your tribe. So my tribe is engineering, I have always been in engineering, most of my mates happen to be in manufacturing, but that's just a quirk, that's a social quirk. So, I am an engineer, I am in engineering first and a designer second. I wouldn't thank you for welcoming me as a stress man or as an aero guy or a build man or whatever because I am not."
>
> Interview 14 p. 11

Udo uses the archaic term tribe, which was discarded because it was considered offensive to the groups of people labelled by it in favour of the equally offensive term ethnic group. In any case Udo sees the disciplinary distinctions used by the respondents in terms of primitive allegiances.

Udo's depiction of the job functions as tribes identifies group identity and a sharing of values in recognition, through his habitus of his group and of other groups. He makes further play of physical characteristics of the various tribes – "long hair", and "oily fingernails" which only the most naïve of anthropologists would make explicitly but for Udo they are part of the game of recognition of himself and others. The difference between a tribe and a profession is that tribes are based on kinship and are associated with sedentary social structures. Entry into a profession is the result of certain choices influenced by other factors than kinship.

8.3 Entry into the profession

Designers identify strongly with the design profession and all professions develop some sense of identity in their members. The commitment to a professional field such as engineering requires an investment in it; time and care taken to learn the rules of the game and to absorb the taken for granted doxa of it. Bourdieu calls this investment the illusio:

'Each field calls forth and gives life to a specific form of interest, a specific illusio, as a tacit recognition of the value of the stakes of the game and as a practical mastery of its rules.' Bourdieu and Wacquant, 1992, p.117.

'The game makes the illusio, sustaining itself through the informed player's investment in the game.' Bourdieu, 1993, p.257.

The illusio is not just an investment in economic terms, as a cursory reading of Bourdieu might infer, but a commitment to the game itself.

'the chase counts as much as the capture, if not more, and there is a profit of action that exceeds the profits explicitly pursued, wages, prizes, rewards, trophies, titles, and positions, and which consists in escaping indifference and in asserting oneself as an active agent, caught in and by the game, occupied, an inhabitant of the world inhabited by that world, projected towards ends and endowed - objectively and thus subjectively - with a social mission.', Bourdieu, 1990b, p.195.

The concern here is how people adopt the illusio of design and begin to acquire a design habitus. They must come to recognise the value of being in the profession and range of possibilities it offers them. Against this they must weigh the investment in time and energy required to master the rules of the game. In beginning to make this realisation people are influenced strongly by their educational experience, their family background and wider society.

Becker and Carper (1956) in their studies of professions identify three mechanisms for the inculcation of professional identity: the first is the 'acquisition of ideology' which includes a 'development of interest' and the 'acquisition of skill'; people develop an interest in the activity of the profession and then learn to take pride in their skill at it. The second is 'the internalisation of motives' where the range of possibilities offered by the profession is opened up to the initiate through discussion within clique groupings of fellow trainees and, in engineering, apprentices. Third is the role of 'sponsorship', which they emphasise is a two way interaction, with a senior figure recommending a junior for a particular progression, while at the same time the junior must repay this faith with satisfactory performance. This obligation reinforces commitment to the profession through individual loyalty and the outward show of professional behaviour.

Another way to theorise the acquisition of a professional identity is to see it as part of the self; people come to see themselves as members of a profession. The construction of a self-image comes from interactions with others and Mead (1964) calls this self-image the generalised other. According to Mead, through interactions with others, people take on characteristics of them that they see as desirable, for whatever reason. Specific people who are emulated are significant others. Despite the possibility of conflicts among them, significant others are internalised into the generalised other. The generalised other works at many levels – the universal level, of language, of certain aspects of social behaviour and at other levels including the occupational level. The most obvious significant others are parents and family members.

8.3.1 Family members

Some respondents volunteered their father's (never their mother's) occupation without being prompted. It may seem odd, but of those that did, only Harry followed his father's footsteps into engineering, although Mike's father is an architect, which might be seen as a related occupation. Of the other respondents that indicated their parent's job, Dave's father was an NCO in the RAF, Quist's worked on the railway, Steve's was in the forestry commission, and Yan's was a butcher. These are all skilled trades which could be said to be representative of an artisan class, so there may be a class influence on going into a skilled trade but not specifically engineering. The other respondents were contacted after they were interviewed and asked their parents' occupation. Of those that responded none had parents that were involved in engineering, but all were of generally lower middle class origin.

This study cannot provide a classically statistical analysis of parental influence in career choice but this lack of following the family profession is supported by a survey study by Lightbody, Siann and Walsh (1995) who found little evidence of children following their parent's profession and in some cases negative reinforcement. They quote these University students responding to a question asking what they would definitely not consider for a career:

'I would not like to progress into teaching, mainly because my Dad is a teacher and I can see the pros and cons'

'Medicine, my sister is a doctor and I don't wish to suffer the emotional pressures she had to deal with.' Lightbody, Siann and Walsh, 1995, p.21

The family is important in influencing decisions about profession but not through direct example. People must see possibilities even if not through the example of their parents. Tony had a favourite uncle:

> "Tony: I'd got an uncle who was a Chartered Engineer, and I suppose when we were younger he used to live quite close by and I think he was a guy who - he was - he always appeared quite well off, there was that aspect, but I mean he was also a very - he was a fun person to be with, he was a, you know, a well liked uncle. So, I think that possibly had some influence."
> Interview 13 p. 2

In Tony's case an extended family member had an influence on his career choice because Tony identified that person with affluence and more importantly for him with having "fun."

8.3.2 School – Work Transition

A more significant influence is located in the school. Several respondents had favourite subjects at school:

> "Quist: Well at school, you know, I think, technical drawing and sort of things like that. Mechanics."
> Interview 11 p. 1

> "Tony: No, I think I always quite liked - I mean, I was fairly good at Maths and Physics."
> Interview 13 p.2

> "Yan: I was always into, well certainly from the age 11 onwards, interested in engineering, mechanics that sort of stuff."
> Interview 17 p.1

Academic competence in key school subjects influences the careers that schoolchildren are directed towards. For engineering the main one of these key subjects is certainly mathematics, and others are physics, mechanics and technical drawing. Schoolteachers have a set of schemes, which map traditional school subjects onto categories of work. This begs the question of what other sets of criteria schoolteachers employ based on class, gender or other factors and also the expectations the schoolteachers have for their pupils' future. Schoolteachers must also have acquired these doxic ideas about career, from their own education, from their own experiences with professionals (doctors and lawyers, maybe) and tradespeople (motor mechanics, plumbers etc.), but without necessarily engaging in any of the activities themselves. The schoolteacher's role is of critical interest because they give a lead in the concrete form of advice but also through their unarticulated attitudes and dispositions, without direct experience of that which they are influencing their students about.

Notwithstanding the schoolteacher's role, in the normative case the initial idea of a career in engineering has its origins in high school and is accompanied by good performance in certain subjects. Becker and Carper (1956) claim that socialisation into engineering begins at a very early age, before college or university. They contrast the case of doctors who must have a good idea of what they want to do on leaving high school, with that of physiologists who gain their occupational identity later.

Some of the respondents did not take the normative route into the profession and an advantage of the interview method is that these atypical cases can be examined in more depth. Steve had no firm idea what he wanted to do when he left school:

> "Steve: At that - when I was 18, I didn't give a damn what I did, I would have done anything. It was 'get a job'. I wasn't particularly bothered about further education. And then, I think if I was being honest I think I was in the door at tech. - Hobart Street about 10 minutes and I really realised what I was going to be doing for a living, I thought this is what the thickos did at school, you know, metal work. I never - I never regarded, you know that I would ever end up doing that sort of thing for a living, but what happened after, say maybe 3 months of getting used to the job I loved doing it, absolutely loved the job. The money was terrible. And part and parcel of doing the job you had to do an ONC going on to an HNC, which I did, and I actually did very well. I started paying attention, started enjoying it and from there onwards it kind of picked up whereas before I hadn't - honestly, when I left school I hadn't a clue what I wanted to do and I didn't care."
> Interview 12 p.1/2

Steve's school experience was difficult for him and prepared him badly for career oriented work. He did not have any favourite subjects and his teachers had little influence on him. He stumbled into a job which offered him academic and career progression and managed to engage him personally. The development of a commitment to and an acceptance of the illusio of engineering is quite explicit in his story even to the extent that his previously held attitudes were reversed.

Vernon's story is even more convoluted:

> "PK: Well, how did you get into engineering, really?
>
> Vernon: All right well, that's - crikey, that could take an hour, em. Went to Aberystwyth University straight from school reading maths. Got chucked out after the first year for failing the first year exams. Due purely to laziness and immaturity basically, spent several years doing a whole range of jobs including

sort of labouring jobs, police force, clerical jobs, computer room trainee type jobs."
Interview 15 p.1

Vernon's capability at maths could indicate to some people who might seek to influence him, careers officers, or job centre staff, that he may be suitable for a career in engineering but it is more complicated than that:

"Vernon: . . . and ended up in the civil service. Did three years in the civil service in health and social security and decided I needed to get into some field that was sort of more me really. Erm, and the employment exchange as it was then were running some like career advice type sessions you know. And the chap I talked to - the only subject I'd really been interested in at school in was art. So he said that pure art itself is a difficult field, you know, but there are - there's branches like industrial design which is sort of arty but nevertheless a bit more practical and there are more job opportunities. So we sorted out a course and Preston Polytechnic was doing a - like an industrial design course or so I thought at the time. And erm so I sort of enrolled for that and went to Preston for three years. It was actually all a little bit strange in that when I got there I found out what it actually was, was an HND in mechanical engineering with an industrial design module tacked on just half a day a week. Which I was sort of pretty gob smacked when I first found out about it because I thought I had gone there - and it shows how well I had researched it doesn't it really - but I had gone there to do industrial design and all it was, was a module tacked on to an HND.

PK You went as a mature student?

Vernon: Yeah I went as a mature student, yeah, aged about 25ish something like that. After about three weeks I was actually really glad, it was that way round because the module, the industrial design module was being taught by a freelance industrial designer. And he was so infinitely above anything I could have ever hoped to be in terms of ability that I thought if I am out there in the field trying to compete with blokes like this I'm going to starve to death, you know, because he was just so good. And luckily I found I was actually enjoying the mechanical engineering side of it you know. So what I ended up with was a degree in mechanical engineering that I could then use."

Interview 15 p.1/2

The freelance industrial designer had a significant influence on Vernon, as did, indirectly, the "chap" at the employment exchange. Vernon's early career was tortuous and difficult in terms of his socialisation into a profession. Becker and Carper (1956) emphasise the importance of the 'acquisition of ideology' in entering a profession and this comes about when people question the worth of the activity they are engaged in and through interaction with significant others they acquire explanations for the value of their activity. Vernon had not done this in his previous itinerant career; he found no ideological fit with police, clerical or computer work and even after three years in the civil service he had not made a commitment to it. In his case, which is out of the ordinary, he found the time to develop his professional identity during his undergraduate studies.

8.3.3 Apprenticeship

Steve and Vernon did not have typical experiences of becoming engineers. The route followed by most engineers until the mid-1980s was through a craft or technical apprenticeship. The process of apprenticeship involves the deliberate placing of a group of initiates in a milieu of significant others from whom they can acquire their professional ideology and the elements of a professional habitus. The placement of a new apprentice with experienced workers can be formal or informal and is not entirely comfortable. Robert talks of his first day as an apprentice:

> "Robert: Like my first day I buffed the tip of my finger. I probably should've left and maybe done something else."
> Interview 10 p. 2

He goes on:

> "Robert: But still buffed the tip off and just continued working. I didn't really like the manual side of - I was an apprentice fitter and it was only until I got in the office that I started to enjoy myself."
> Interview 10 p.2

Robert's early experiences were physically unpleasant but he stuck at it because there was little other work to be had. His move to the drawing office was obviously a turning point in his career. The apprenticeship scheme is a milieu where career opportunities for engineers are made apparent to them from early in their careers through the gossip of the clique of apprentices and through their contact with others in the firm. Through his socialisation in his particular group Robert saw the move to the office as an advancement. He continues:

> "Robert: So, normally, like, its apprentices - got a chance of going in the drawing office so that's what happened to me. If you were doing your correct night classes.
>
> PK: Did you chase that? Did you chase the opportunity to go into the office?
>
> Robert: Mmm. I can't really remember but I think I might have. It depends on what night cl - what day release and how you were doing, whether -
>
> PK: Right.
>
> Robert: And they always needed people in the drawing office, I can't remember actively seeking it.
>
> PK: What was the -?
>
> Robert: The office was a better job.
>
> PK: Right. Yeah. Sure.
>
> Robert: And there was more money. But I mean it was a long time ago I can't really remember if I actually sought it out."
> Interview 10 p. 2/3

Robert does not let on the kind of social interactions within the group of apprentices, but these must have included a clear idea of the possibilities for them and the idea that "the office was a better job." In Becker and Carper's scheme this is the 'internalisation of motives' and is most strongly found in apprenticeship relations:

'As the person learns about the kinds of positions he may expect after finishing his schooling, he also learns why people want these things.' Becker and Carper, 1956, p.297

Apprenticeship is more than schooling in technique. A whole range of social nuance must also be learned, Bourdieu's 'rules of the game' as well as a commitment to them. Through the social contact provided by apprenticeship people gain an idea of what the future might hold, Bourdieu's 'space of possibilities' and what their progression in it might be.

Udo introduces another important group of people in apprenticeship: the experts and masters from whom the apprentices gain not only their craft skills but also their professional identity. Pupillage with an expert is a deliberate placing with a significant other:

> "Udo: I was trained by working with Charlie, in fact I am now Charlie, Charlie is gone, all the gurus, all the smart people, all the experts have now gone."
> Interview 14 p. 2

For Udo the significant other from whom he gained his generalised engineering other had many positive attributes: he was an "expert", a "smart" person, and a "guru". Udo's problem is how the next generation of designers will develop their individual selves through role models which he now thinks are absent; he recognises himself as a replacement for Charlie but he does not attach the same attributes to his own way of working. Nevertheless, during his apprenticeship with Charlie he must have been made aware that he too in his turn would be expected to pass on his knowledge. He details a formative interaction for himself:

> "Udo: If I wanted something in the past and I came to see you, you answered the question by saying "aha" a bit like Harry Enfield "aha". "I know that is the question you've asked me but the question you really should've asked me was this one." "Why?" "Because, because." And then bingo you're away."
> Interview 14 p.2

This kind of interaction is instrumental in the acquisition of an engineering habitus and Udo understands this. What he does not make explicit is his own role as a significant other for the younger engineers around him. In Erikson's (1980) stage theory of development Udo is being generative, as is typical of somebody in middle adulthood and is represented by an increasing concern for the future and future generations. Udo's commitment to his profession is reinforced by his enthusiasm for passing it along to the younger people around him and his desire to leave something behind as he begins the end of his career.

The respondents' strongly held allegiance to groups divided on general occupational or disciplinary lines is a central part of their habitus. They acquire this discipline identity early in their careers through apprenticeship and education. Family and school influence people in their choice of career but not always in ways that are expected or intended. The design habitus includes embodied dispositions acquired during training which is body-to-body, requiring prolonged contact with significant others including fellow trainees and established professionals. It includes occupational identity, which is constructed through design activity: the acts and social acts designers engage in. The social group of designers is internally defined by a common set of activities and attitudes that are acquired during their early careers.

8.4 Place

The phenomenological experience of time and space for designers has already been analysed in terms of Harvey's (1990) ideas about time-space compression and through the example of the introduction of new technology into design activity. It can also be analysed in terms of events, points and places in the dimensions of time and space. Engineering design happens discontinuously; it happens in a directed way in certain places and at certain times. The choice of place made by individuals and organisations affects the way that design is conducted. Organisational and design decisions also reflect the times in which they are taken.

People choose places based on the availability of work or for family or other reasons. The organisations they work for are affected by these choices and the location of a company influence its organisational structure and investments in technology. The choices in their turn influence the dispositions of the people making them, constraining and enabling them in different ways.

First of all, though, people choose a place to live.

8.4.1 Home

There is a strong link in life history between entering into a career and leaving the parental home, forming a relationship with a life partner and setting up one's own home. In Erikson's (1980) theory of stages of adult development these actions would mark the end of adolescence and the beginning of young adulthood. For engineers the choice of a place to live must be influenced by the availability of work and the location of companies providing work compatible with the educational background and aspirations of the individual. Further considerations are those to do with family and birth location; staying close to one's birth location will allow close contact with family.

Yan gives a very personal account of his choice of Peterborough:

> "Yan: I was getting to the stage where I was married and I was looking for somewhere permanent to live and then the whole melting pot came in and I came up to Peterborough and joined Rathbone Johnson.
>
> PK: What year was that?
>
> Yan: That was in 1965, in September. I, it wasn't the only place I looked at, I mean, we were looking at a lot of, being a Londoner, I did tell you I come from London didn't I?
>
> PK: Yeah, sure
>
> Yan: There were lots of expanding towns; they called it London over-spill; it was when all sorts of places in the country, lots of market towns, local market towns, Swindon, I went to Swindon and sought out a number of companies down there. Square D. They were going to offer me a job that was all electrical you know all lot of training, you know, and I didn't mind.
>
> PK: Yeah
>
> Yan: Vickers were down there. It still is down there, I think.
>
> PK: That's in Portsmouth isn't it?

> Yan: Well, they had a place in Swindon there. I know I got an interview there. But nothing gelled. And somebody said, part of the family because we'd got some family, we've still got family on Sue's side, my wife's side, em, in Peterborough, and they said why not try Peterborough? That's an expanding town and that's what happened. I wrote to Rathbone Johnson which was the first name that I knew simply because one of Sue's family had worked there and they responded immediately I mean you know with all the letters I'd been firing off; they wrote back said "Yeah, we are interested, come on up." I came up, had an interview and they offered me a job then and there. This is brilliant and there was an estate right next to the factory all going up and Sue and my Mum came up and they saw this house that was going to be ready in 3 or 4 weeks time, they put a deposit on it. I'm still in it!"
> Interview 17 p.3

Several considerations are important for Yan: he was married quite young, age 22, he wanted to move away from London, there were employment opportunities for suitably qualified people away from London and it is also worth noting that both Peterborough and Swindon are on main rail routes from London and both have strong historical railway links. The three factors that seem to be decisive in his move to Peterborough are:

- the family link
- the availability of housing and
- the implication that if nothing had 'gelled' in Swindon then it had in Peterborough at Rathbone Johnson.

This story shows a picture of the UK in the mid-60s. The feeling is of optimism: expanding towns, new housing, and a buoyant employment market for technical staff. This feeling was supported by the prevailing political climate: Harold Wilson's Labour government had been elected on the back of Wilson's progressive series of 'New Britain' speeches (Pimlott, 1992, p.304) beginning at the Labour party conference of 1963 with Wilson's 'white hot technological revolution speech' (Morgan, 1992, p.247). The economy was stable and the period of economic and political unrest in the early 70s was in the distant future, the sixties really were swinging.

Yan makes no mention in his interview of any consideration of a further move from Rathbone Johnson; as he says, he's still in that house. Throughout his career there must have been difficult times, boring work, problems in relationships with colleagues and superiors. However, these have limited mention and do not seem to have affected his contentment with his situation. There may be another more insidious reason for Yan to stay put: Peterborough has only two employers of qualified technical staff. The main business of Rathbone Johnson was the manufacture of capital plant for the bakery and printing industries. The other employer makes diesel engines – the difference in the technologies involved is large with only minor overlaps. The objective possibilities for Yan were limited; movement across town was therefore difficult to contemplate. Movement away from town was not even a consideration.

Compare Yan's situation with that of Quist in Dundee:

"PK: Can you tell me a bit about your background.

Quist: Yeah, well, I started as an apprentice in 1961.

PK: Here?

Quist: That's here.

PK: So you have been at MVT for the last what?

Quist: No I left because there was huge redundancies in the early 70's and I left in '75. I spent four years in the big wide world, well, Dundee, I never left Dundee. I got jobs with various agencies, you know. So I was never really, month maybe unemployed at a time. I picked up six-month contracts here and there. And I got the chance to come back to MVT; I got re-deployed in 1979, so I have remained here since then. 31 years, you know, all told, 15 and now actually more it's 18 - 33 years."
Interview 10 p.1

"PK: Is your family background engineering?

Quist: No. No, dad was railway and he worked in the jute trade for a while, you know. Although my dad did start his apprenticeship but two or three years I think he lasted and then went down south for the big money."
Interview 11 p.2

Quist's story is noteworthy in that he never left Dundee when he was forced to leave MVT because of his redundancy; he stayed in Dundee and was employed intermittently. A possible inference from this is that there was no alternative permanent employment available for someone of Quist's education and background; another is that the labour market was in such a state that short-term work was all that was available. It is important to note that the only engineering employer in Dundee was and still is MVT. Whatever the interpretation of the employment situation at the time it is curious that Quist did not consider moving to another place where the employment situation for design engineers at his level was better. An easy inference to make is that he has family ties to Dundee and, indeed, emotional ties as he is a Dundee native. As an aside it is also noteworthy that Quist's period of interrupted employment coincided with a period of economic instability and industrial unrest in the UK.

Both Yan and Quist were constrained by their objective situations in towns with limited opportunity for engineers to move from company to company. Their habitus allowed them to cope with this limitation but was also developed by it into company and group loyalty thereby making a 'virtue out of a necessity' of their situation. Compare the situation in Manchester at a similar period:

> "PK: Right, So what . . . between the 50's and say the early 90's, there was still a lot of changes.
>
> Harry: Yeah, there was, up until I would say 1965 . . .1965, 1970, it was easy to get a job as a draughtsman. You virtually rang up an engineering company and said, "Any vacancies?" And they'd say, "Yes." And they'd virtually fix you up. The reason being is the old engineering companies were big outfits, they employed a lot of people, they had all their own manufacturing facilities, they had very big drawing offices and offices."
> Interview 4 p. 2
>
> "PK: When you say that it was easy to migrate from company to company, were all the companies operating the same sort of structure?
>
> Harry: Yeah, they were all similar, big, big engineering companies. You used to work in the office and you'd typically get somebody in the section who'd say, blow, I've had enough of this job, I'm fed up with it, they'd pick the phone up and ring up another engineering company down the road and say,

> "Any vacancies?" "Yeah, when d'you' want to start?" "Next week," Boomf, and that was it. And that is how easy it was to change in those days."
> Interview 4 pp.3-4

Harry is, of course, a Mancunian and it seems that his options throughout his working life have been less limited than those of Yan and Quist. In the late 1960s and early 1970s if you were a designer in Manchester and you had a row with your boss or the project you were working on was going particularly badly or the remuneration was slightly less than elsewhere in town, it was relatively easy to find employment as a designer in another local firm without any domestic upheaval so they did not have to 'make a virtue out of a necessity' (Bourdieu, 1984, pp.175-179). The design employee habitus was different in that such irritations of the job, which were minor for Quist and Yan, would be enough to make somebody in Manchester look for and find work elsewhere.

Taking the case of Manchester as a large industrial city of the 1960s, similar to Birmingham or Glasgow, a number of comparisons can be made with Peterborough and Dundee as examples of smaller cities where the main industry is not engineering.

8.4.2 Changes in company organisation

In the 60s, Manchester had a number of large engineering concerns: Metropolitan Vickers, Johnson and Nephew, Mather and Platt, General Engineering and Ferranti, are just a few. They all had large design and manufacturing capabilities and employees numbered in the thousands. Of these companies none are left in their previous form. To take the special case of General Engineering, there was a receivership in 1979; the company lumbered on until the mid-1980s when it collapsed. A number of smaller companies have emerged since the failure and, supporting each other, still deal with largely the same customer base. The company had considerable expertise in building large high vacuum systems mainly for the roll coating and cathode ray tube industries. One of the smaller companies has taken over the design of roll coaters and assembles them from components which are supplied by local subcontractors, including a company formed by the people previously responsible at General Engineering for manufacturing the large vacuum vessels. The people from the vacuum service department formed a successful company that now does most of the work they used to do at General Engineering.

In both Peterborough and Dundee the major engineering employers number one or two. In both cities these employers remain substantially unchanged. Production and design are carried on in the same place, and employees number in the thousands.

8.4.3 Homogenisation

The situation that Harry describes resulted in a lot of intermingling of the staff base across Manchester companies. One result was the homogenisation of engineering in large industrial cities in the UK. The procedures and organisations tended to be broadly the same. Primary evidence for this is no longer available; the engineering organisations of the 1960s no longer exist. However, the evidence is to be found in relics of these earlier systems. The main example of this is the use of the same drawing office standards as people moved from one firm to another. Appendix C shows a sheet from a chart from the Staveley machine tool company which was found in several drawing offices in Manchester and was also used by contract draughtsmen. Designers would collect documents such as this and build them up into personalised standards manuals. The content of these manuals would be decided on a personal notion of the quality or usefulness of the information.

By the 1980s the conduct of design in certain industries and cities was broadly the same. The language and jargon crossed companies so that on arriving at a new job the designers found it easy to fit in because most of the systems and procedures were the same as at their previous employer, indeed some of their colleagues would probably be the same. Take this comment from a designer who started his career in the 1980s.

> "Dave: No really. You know I've not really bedded myself in here but there are similarities . . . there are differences. Basically design is design. As I see it."
> Interview 2 p.10

Dave does not see design as significantly different from place to place. He does not regard location as an obstacle to moving jobs and he has worked in three towns since entering the labour market. It may be that the tendency of younger engineers to have left the parental home to study at university makes them less inclined to see such upheaval as a problem. Also younger people, especially men, are marrying and having children later in life than people of Yan's generation. Dave does not, at the moment, have to consider the commotion involved in moving a family; his wife may have her own career and older children might have their school careers interrupted. Dave's outlook may change in the future.

From the responses of the older designers the pattern of migration in Peterborough and Dundee differed greatly from that in Manchester. The options for designers, especially, are limited. If the designer has a row with the boss or the project is going badly or for any of the other reasons a person might want to give up and go somewhere else, then the designer is probably best to stick it out until things get better.

The procedures, organisation and company culture are less homogeneous in Dundee and Peterborough than those in Manchester. Curious quirks in the language and design culture are developed and reinforced. An example is the introduction of acronyms, and jargon. Listening to designers in Dundee and Peterborough is different from listening to them in Manchester. Quist gives an example of jargon specific to his company in Dundee:

> "Quist: And we have a GRIT system, I think Robert and I are . . .
>
> PK: What's GRIT stand for?
>
> Quist: Get it right first time. That phrase was initiated about four year ago by my old manager, who's since retired. And he thought of this 'get it right first time'. And he put this, you use a bit of licence with it, its now GRIT. A lot of people don't know that, that work here. (laughs) Some of the young guys with GRIT. 'Oh, the GRIT, you know.' And I go up and say to them, 'Do you know what that means.' 'No. What is it? Does it means something?' 'Yeah, get it right first time.' 'Ohhh!'"
>
> Interview 11 p. 17

In Peterborough Rathbone Johnson provided a small but detailed handbook containing information specific to company operations. Reference was made to standards from other sources and, in the main, to British or other internationally recognised standards. The contrast is with the eclectic and personalised standards manuals built up by individuals in Manchester engineering companies

The opportunities for movement within the profession that were available to older engineers in cities with a large industrial base and to younger engineers without the encumbrance of a family led to homogenisation of practice. In places where designers had little mobility of employment design practice has more distinctive features and quirks.

8.4.4 Adoption of CAD

A seemingly unrelated fact is that new technology in the form of CAD was adopted earlier in Dundee and Peterborough than in Manchester.

The argument for CAD was stronger in organisations where the design and production facilities were co-located at the time when this new technology was emerging. Direct links between design and manufacturing could be made within the same company. The benefits to a company not producing component parts (like Harry at Coating Technology) were limited and would have required investment in CAD and NC machine tools on behalf of their suppliers. It was only later, when the benefits of data management became apparent within the distributed enterprise that companies like Coating Technology invested in CAD technology. In large companies with production facilities in the same place as design then the driver for the adoption of CAD was the manufacturing link and data management came later.

Developments in data communications technology now also allow the small intellectual core company to take advantage of the manufacturing link and transfer data files to suppliers with suitable technology. Rathbone Johnson invested in CAD in 1977 and enjoyed immediate benefits in manufacturing. Later, like Cooper Clarke they began to appreciate the data management capabilities of the technology. Coating Technology on the other hand invested in CAD in 1990 in order to take advantage of data management. Only recently have they been able to take advantage of manufacturing links by exchanging data with suppliers using Internet and related technology. The structural organisation of a concern influenced the decision to invest in CAD.

The willingness of respondents to move and the factors affecting this choice have an influence on the way companies are organised in different places. This sample is focused on older people with more experience but it may be that, among other things, this group has less enthusiasm for upheaval than their younger colleagues. In places where engineering has been a major local employer, employment has been reorganised in a more flexible way; this has been allowed by the maintenance of long standing activities, relationships and structures which cut across economically imposed boundaries of business units to form a distributed enterprise. On the other hand, in places where engineering has not traditionally been a major source of employment, companies are organised to maintain their niche and protect their tacit, company and product knowledge. This is not to say that companies in these two categories organise themselves entirely differently, they are organised in similar ways, in terms of bureaucracy and their internal structures. They also use much of the same technology in the form of CAD, CAM and the Internet but in different ways.

The actions of respondents in designing products and their use of equipment to do this illustrates the design habitus in action regardless of place. The contrast between the attitudes of designers in different places shows nuances of the habitus that relate to those places. Differing dispositions to mobility within the profession affect the loyalty of designers to company and product. The ways that design and production are structurally organised within the enterprise, either within the firm or on a distributed (albeit local) basis, also affect the detailed habitus and the dispositions it embodies to, for example, new technology.

8.4.5 Australia

It has been possible to compare the organisation of design in Australia with that in the UK. Australia resides on the less dominant half of many traditional geographic boundaries but aligns with the dominant: West/East, North/South, and Atlantic/Pacific. This may be due to the strong European heritage built on the influences and ethnic mix of the early colonisers. More recently the influx of people from East Asia has increased the cultural mixture. Australians are proud of their exploratory heritage and are keen to adopt new technologies as they emerge. Australia has the second highest per capita ownership of cellular telephones (after Finland) and the highest per capita ownership of home computers.

Australia has developed a credible design activity that extends beyond its immediate manufacturing ambitions. Australian designers have been forced to innovate by their need to find and collaborate with manufacturing capacity in the USA and South East Asia communities. The design and engineering communities, and therefore the methods they employed, depended greatly on their British heritage and Commonwealth business. Australian designers have moved on from their heritage and are, if small in number and quite specialised, significant players internationally.

The Australian economy is less industrial than the UK and the separation of population centres makes some analysis easier. The location of the design centre of Australia is in Melbourne which is the second city of Australia but:

> "Nick: Melbourne's the design capital of Australia." Interview 8 p.10

Nick continues:

> "Nick: . . . the majority of good design work is done in Melbourne, and it's a more mature market place for design, there's a bigger manufacturing base in Melbourne, and I think that's tended to create a bigger and more sophisticated product design fraternity."
> Interview 8 p.10

It is difficult to say why this should be so. Australia is atypical in that it has an artificially placed administrative centre in Canberra. However, Sydney is the first city and the cultural and financial centre of Australia. It is easy to draw comparisons with other second cities such as Glasgow and Chicago and point out that the while the cultural and financial leads were taken by the corresponding first cities of London and New York the manufacturing activities were taken on by the second cities.

It is safer to say that Melbourne is a primary centre for design education. It has two major centres for design education, one at Monash University and the other at the Royal Melbourne Institute of Technology and a smaller but significant activity at Swinburne University of Technology. The main provider of design education in Sydney is at The University of Technology, Sydney with smaller departments at the Universities of Sydney, New South Wales and Western Sydney. Taking a rough measure such as teaching staff, 90 people are listed as teaching design in Melbourne Universities as opposed to 47 in Sydney (Association of Commonwealth Universities, 1999). This is not to say that a strong design industry in a city is the result of a strong design education culture in that city or vice versa, but it can be said that each is supportive of the other.

The comparison of Australia with the UK is difficult at first because the history and geography of design organisation are very different. The Australian experience provides another example of changes in the phenomenological experience of time with increasing globalisation. The unique geographical location of Australia makes these changes more marked and easier to see.

8.4.6 Time

Radical geographers like David Harvey (1990) argue that geography is about time as well as place; indeed, for them, the theoretical separation of time from space is a major concern. Melbourne, where Nick works, is in the same time zone as Tokyo, three hours ahead of Singapore, seven behind California and 10 hours ahead of London.

> "Nick: There's almost a visual and audible sigh of relief that they can actually deal with someone who's in the region, and they don't have to deal with you know an American office or a German office, and they can deal with someone who's in the same time zone, who can be there in a short period of time . . . they're only a day away, we can be on a plane in the middle of the day and in Hong Kong or Singapore in time to have a 9 o'clock meeting tomorrow."
> Interview 8 p. 11

> "Mike: Probably the best example of working in other time zones is with Pro Engineer, where we can do a model, we can drop the files onto a bulletin board at the clients, the company in California picks up those files in that night and does part drawings for those components and they're finished by the next morning when we get up."
> Interview 7 p. 11

Globalisation and its implications are explored by Marx and Engels in The Communist Manifesto (1998) and, as Hobsbawm (1998) says, their emerging view of the world in 1848 rings even more true today. Increasing globalisation (in what is arguably late capitalism) allows places that were not previously in competition to compete. The spread of computer networks and the increasing division of intellectual labour (product design, tool design, tool making) make round the globe and round the clock working possible.

All of the Australian consultancies in the study had strong links with manufacturers in South East Asia.

> "Luke: Well, going back about two or three years, when we started off in Singapore."
> Interview 6 p. 8

"Ian: And we've also got the office . . . and if you go through the office in Kuala Lumpur."
Interview 5 p.4

"Nick: We've got a very strong office operating in Singapore, we've got a lot of work happening in China, stuff in Hong Kong and China, we're working with Malaysia, a bit of work in Taiwan, a bit of work in Vietnam, we've just got office projects in Cambodia, but we've done a few projects in Europe and the USA."
Interview 8 p. 12

"Mike: And I think that within, I think because Australia, because Melbourne particularly is . . . 'cause South East Asia is one of the places a lot of the companies are coming to set up head offices, it lends itself to design in a lot of ways because the decision making is done here or in Sydney, so the hardest thing is just getting to know who's in charge and who's responsible for what.

PK: So you're closest to the world manufacturing base.

Mike: Yeah.

PK: Temporally.

Mike: Yeah that's right. Yeah. I mean all, the work that - that in - again in that I was involved in London was still being manufactured in Hong Kong, a lot of it, ahm, or China, but of course it was that much more difficult to get to. That's – it's quite interesting and I think it is with a lot of other consultancies in Melbourne which have been established for longer than we have who have offices in Singapore."
Interview 7 p.14

Even though Australia is in or around the same time zone as South East Asia it is still quite a distance from Melbourne to Singapore - about 7000km; any journey in Europe can be covered in a lot less than this. The success of the Melbourne consultancies in South East Asia is based geographically on the temporal proximity of Australia, and the advances in communications of the late 20th century. The location of the Australian consultancies in the South East Asian time zone alters their subjective interpretation of space. They feel closer to the South East Asians and through their place in time their experience of space is compressed. Modern production technologies also allow for subjective experiences of time to be compressed.

This still begs the question about why the industrial design activity is not carried out in Singapore or Hong Kong. It may be that South East Asian aesthetic culture does not translate easily to the Western consumer market. Education in industrial design in Singapore started very recently and the government there has recently begun to promote education in the Fine Arts. The movement of capital, especially manufacturing capital and the movement of manufacturing activity (the labour in Harvey's terms) places the Australians as cultural and geographical (in the sense of space and time) intermediaries between Eastern production and Western consumption.

Australian designers have responded to their peculiar position on the globe and the demands and challenges that go with it in creative and imaginative ways. They have take for granted their experience of their location and used it to have a global outlook; they are globalising without even being consciously aware of it. Their phenomenological experience of time along with their attitudes to place influence their structural organisation of design in ways that contrast strongly with UK practice.

8.5 Organisation of design labour and intellectual capital

The idea of the generation and retention of tacit knowledge in the form of cultural capital has been introduced through Vernon's concerns about project team organisation at Cooper Clarke. This capital - intellectual capital - is made up of the procedural and tacit knowledge held by groups and individuals. It is organised in different ways in different companies and the form of organisation is dependent on their geographical locations.

Harry gives a good picture of the organisation of design in his own company in the 90s:

> "Harry: Now, then things changed dramatically erm when it got to say 1980 and what happened then is, as it is today, they're all small hi-tech companies now, where you just have your own nucleus team in of engineers, small team, then you take on contract guys, there's no big drawing office anymore, there's no draughtsmen anymore, you take on contract draughtsmen and they come in, they do the job, and you're not carrying this erm very big

> overhead then, and it works well now because obviously I work in this small hi-tech company. I mean we employ what, 60 people in this company . . ."
> Interview 4 p.3

The structure that Harry describes has some characteristics of core and periphery organisation. However, it is not of the classic form described by Edwards (1979) where the core is comprised of monopoly capital and the small employer is on the periphery. Harry describes a core and periphery of intellectual capital. The intellectual capital, procedural and tacit, individual and group is held in the core company. The periphery is engaged in production, an activity with lower value intellectual capital.

The business situation in such a core company are also described by Harry:

> "Harry Well, I mean, if you take us. Our company buys all the parts, they all come in, we build the job. We don't manufacture anything ourselves. There's small things we do but we rely on our suppliers. If our, you know, we do rely . . . If we order a vessel at our fabricators and he doesn't deliver the vessel on time, he let us down, we're in big trouble. Now, all we can do is say, okay, next time we'll go to another company, now but when you're building a machine with thousands of parts in it, some of them bought out items, some are manufactured items, if all those parts don't come in at the right time you're in serious trouble. I mean, at the end of the day we can have a million-pound machine held up for one small part that happens to be on a long delivery. Okay, somebody can forget to order it. It can be ordered and they can let us down, and that is where you're in trouble."
> Interview 4 p. 7

Harry gives a generic account of the interaction within his own company of the components of the system of production. Bucciarelli (1994) tells a similar, more specific story; he likens the idea of "a million pound machine held up for one small part" to a natural ecology where small events have large consequences. Bucciarelli's theory becomes more sophisticated if Edwards' theory of production is considered beside it. Harry's firm does form part of the periphery in terms of money capital. The most significant added value is bestowed by intellectual capital and their position at the core of this capital market allows them to organise production as they wish, on their own terms.

Quist and Yan, on the other hand, are not engaged in a similar mode of organisation of intellectual capital. Intellectual capital is embodied in them as individuals and within groups of people within their companies but it is organised in a different way to Harry's. This particular core and periphery theory is difficult to apply to them although Edwards' more general theory about labour market division does apply.

In places where engineering activity is historically limited to a few firms then intellectual capital is preserved in companies by the constraints on the mobility of individuals. In places where large-scale engineering activity has broken down and the substantial material capital in plants and factories has disappeared the cultural capital created by those industries continues in the form of intellectual capital. A new organisational mode based on a core and periphery of intellectual capital has emerged in response to the disappearance of large scale material production.

8.6 Structure and interaction

The material structures inhabited by the designers have been examined. Some are social structures such as the bureaucratic organisation of the company and its offices with their job labels. The designers, on the whole, reject the labels given to them, preferring their own internalised labels that they have acquired through a different set of structures - of the school, including university, and apprenticeship. When designers are organised into project teams, tension between occupational groups leads to individual conflicts of loyalty to the team or the group. At Lambert Cawthorne the team structure serves to reinforce the group identity by giving the designers there a sense of being in a persecuted minority.

Social structures arise from the community of designers themselves – their identification with a disciplinary group comes from repeated contact with their peers and colleagues. The origins of their identification with their professional group come from their early initiation into it, through the school and apprenticeship; deeper social structures of class and the family give them a sense of what they might expect and what their place might be. Associations and structures are imposed by a sense of place – house and home, family and company ties.

The way that designers act depends also on their place on the globe. Designers in Australia have organised themselves into a community based mainly in one city - Melbourne. Their conduct of design depends on their national habitus as pioneers and they actively seek partners abroad to continue their business. In the UK engineering has been structured traditionally in places of industrial intensity with large works and design organisations. Large scale production has disappeared in these places, such as Birmingham and Manchester, but continues in places with little reputation for engineering - Dundee and Peterborough. This geographical structuring also affects designers and the development of their design habitus.

In exposing the structuring influences on design activity some of the interactions which go on within them have been displayed. The next analysis is an examination of those interactions in more detail.

9 Cultural Capital

The analysis in this chapter is based on a classification process where the interactions designers have with different people – colleagues, management, suppliers, subcontractors, customers and clients - have been structured to show exchanges of the different forms of capital - material and symbolic, as defined by Bourdieu (1986). Designers play a central role with the productive system, privileged with an overview of the entire process and the level of compromise needed to make it work. The designers are active, interacting with other people as well as engaging their materials and products.

In analysing the data each instance where the respondents spoke about their interactions and exchanges with other people who were not designers was tagged and collected. These instances were then grouped by categories determined by the place that the other person or people occupied in the structure of the enterprise. The first structural category is concerned with interactions within the firm; it is further subdivided into those exchanges that occur between people in different departments at the same level and interactions with people at different levels in the hierarchy, most importantly the boss. The second category includes interactions with people outside the firm, subdivided into two categories of customers and suppliers. The type of interaction was defined and coded according to the kind of capital being exchanged allowing the conversion of symbolic capital into material capital and the direction of the flow of each form of capital to be clearly shown. A special case where the demonstration and exchange of symbolic capital is clearly exposed through this analysis is the design consultancy.

People who work in the same firm but not as designers can share aspects of the design habitus and this contributes to harmonious ways of working especially among those people at the same hierarchical level in the organisation. Conflicts arise other specialists fail to appreciate the designers' view.

9.1 Other people inside the firm who are not designers

Designers interact with other people within the company who may not be designers but have an interest in the success or failure of the product and the firm. Individuals and groups seek to maintain their position within the firm independent of the contribution they make to the success of the enterprise. Listening to older designers allowed the changes in organisation and their positions in it to be exposed through their histories.

Harry explains how a previous trend to large scale bureaucratic control of interactions between designers and other people in the firm has been arrested. Interactions are now based more on an interpretation of job status than on bureaucratic hierarchy.

> "Harry: No, what happened in the old Victorian day, if you like, the fitter would go to the Foreman and say, "Look, there's a snag here." He would have to go to the Works Manager and the Works Manager would have to make out the paperwork and it would have to go to the Drawing Office through the engineers, down to the section and all that. What a load of rubbish and what a long route. And erm, well, that was the official paper lines."
> Interview 4 p.12

He is describing a bureaucratic procedure for communicating a snag from the shop floor to the design office. The hierarchical structure is clear, through the foreman to the works manager and down through the levels of hierarchy in the drawing office to the people in the section. The structure seems inefficient and Harry thinks it is a "load of rubbish"; the criticism being that it takes an unnecessarily long time to report and correct a fault or snag. On the other hand, records are kept ("paperwork") and there is a lot of communication in the process, so everybody in the chain is kept informed and confusion is avoided. Then again, the fitter has little autonomy in the structure and direct communication between the actual producers - the fitter and the designer – is prevented.

In analysing the last sentence of the passage above, the transcribed elision ("erm, well") and the word "official" imply that the foreman might have had 'unofficial' back door access to the drawing office. On returning to the original tape recording and listening to this particular utterance Harry's somewhat conspiratorial tone is more apparent. In fact, communication between draughtsman and foreman would not have been surprising because their grades, or levels within the company hierarchy, would not have been dissimilar and they might well have seen each other as social equals. They might easily have been apprentices together, and, therefore, communication between them was easier.

Harry's interaction with the foreman is now less formal and bureaucratic. He detailed his recent communications between the D.O. and the shop floor:

> "Harry: (interrupts) No generally, what happens, the fitter would go to, in respect he would go to the Foreman and the Foreman would come and see the Design. The fitter wouldn't really come up here on his own bat. Sometimes

they do but I mean to be ethical I think they do go to the Foreman. They might come up with the Foreman or they might call the Design down."
Interview 4 p. 11

This direct interaction between design and the shop floor has become common. It is still limited but the exchange is now at the equivalent level: between the designer and the foreman. It is important to note that Harry's company now employs in total 50 people - fewer than were in the D.O. (possibly over 100) when he was a young designer. The form of control, as Edwards (1979) would put it, has changed from a bureaucratic one to an entrepreneurial one. The thing that hasn't changed is the occurrence of snags and the requirement for design involvement to sort them out.

When Dave made the improvements to the quarter page folder mentioned in Chapter 5 he worked with a field engineer - Tony Gordon - who performed the necessary modifications on site:

"Dave: They were forever problematic have I said that properly (mumble) . . . . It got the Gordon seal of approval.

PK: Laughs

Dave: He sent me a fax saying "To Dave, winner of the most difficultest holes in the world to position." "
Interview 2 p.6

Dave obviously has a good relationship with Tony and this is supported by the jokey nature of the fax message. The modifications carried out on site were difficult but Tony recognises Dave's authority and makes an internal, field engineer, judgement based on his previous assessment of Dave's competence. He affirms his judgement to Dave in the fax and Dave regards this as being a personal affirmation and values it above his managers undiscriminating words of commendation as the following exchange, introduced by a clumsy leading question from the interviewer, shows:

"PK: Do you find that you're looking for, sort of, affirmation from the shop floor rather than your management?

Dave: Both really - I think from the shop floor its more heartfelt.

PK: Yeah

Dave: Because they speak their mind and if it works - if they say it works and its doing properly then its probably better than coming from a manager who's just doing it to sort of be what's the word? . . . trying to keep you motivated - saying smooth words."
Interview 2 p. 6

Here Dave shows his understanding of the exchange of compliments within the power system of the firm. He views his exchanges with management more as a management ploy to keep him happy than a true recognition of the work he has done. The interaction with the field engineer depends upon an understanding of the product that they share, and demonstrates the specialised engineering habitus they have in common. Dave's most telling judgements are not necessarily exposed to management, but are revealed in his exchange with the field engineer. The field engineer has no axe to grind whereas, as Dave recognises, management think they have to motivate him to get him to do his job.

Dave and Tony exchange knowledge that on occasion functions as symbolic capital; it is directed to making each others' jobs easier. Tony does this by trusting Dave's judgement and following his instructions and also by giving him early warning of any snags that come up on site. Dave helps Tony by making sure all the necessary information is available to him and that all the parts and equipment are correctly specified. This is an exchange of cultural capital at the basic level of the product. Dave and Tony both know the product intimately albeit from different perspectives.

On the other hand Dave's managers cannot have the detailed product knowledge he and Tony share. Dave recognises this and knows that their affirmations of his work are not based on the specialised habitus that he values. He also implies that they misrecognise what it is that keeps him motivated to do his job by condescending to him with vague platitudes.

Steve started his career at MVT in the workshops where prototypes are made. He regards his move to the design office as a progression and considers that he has risen in the company hierarchy. He describes his current relationship with the workshop people and why he thinks it is a good one:

"PK: Now you are on this side of the fence, how's your relationship with, like, the lab and the shop floor?

Steve: Pretty good. I think the shop floor in particular, I think, you sense sometimes there is a bit of them and us but I think my background helps, because I don't tend to go up to people and ask them to do really stupid things, because I've got a pretty good grasp of what it takes to achieve it. So, the likes of the guys in the lab who are now doing what I used to do years ago, I tend not to have any problems, because you know, I don't tend to ask them really stupid things and I've got a pretty easy going manner and I don't tend to wind people up. There is other people who, you know, other people who will just go in, bark a few orders and go out again and expect it all to happen and they'll all sit and mumble and moan about him when he's gone. (laughs)"
Interview 12 p. 8

Steve believes that the nature of the requests he makes to the workshop and his easygoing manner are important to the relationship. He can use his habitus from his previous job to help him in his new job because it enables him to interact more easily with the people in the workshop than other designers might. The model makers in the workshop understand that Steve knows in detail what they can do and how they might do it. It is more difficult for them to obfuscate matters with him. Correspondingly Steve knows the difficulties they face and how they react to certain pressures. He can compose his actions thoughtfully so that his relationship with them is free from tension and can get them to do what he wants.

Different people working on the same product do not always share the detailed product habitus and this leads to tension. Udo tells of an interaction with a mathematical fluid mechanics specialist:

"Udo: And I was working with an extremely accomplished aerodynamic person, who was academically top notch. I still see him, wonderful bloke, but of course he'd never made anything, it was all theory, it was all out of is head really, ever so clever, lovely fella. So I took him one day, and we looked out of this building to something over there called the PCF - precision casting facility, because we make our own blades and vanes here, they are all single crystals, that sort of stuff. So I took him and said, "What's that over there?" He said, "that's the PCF." I said, "What do they do over there?" He said, "They cast

> blades." I said, "Look. They couldn't cast a good shadow in strong sunlight over there. They're fucking useless." Because, within in the technology, you know, he was moving this velocity distribution, you know, one foot a second, two foot a second, it was making three tenths of fuck all to the actual shape. And when we looked at the profile tolerances that they could achieve, he was trying to strive for the optimum, and I gave him a dose of realism. And that's what design is all about. And we still talk."
> Interview 14 p. 6

Udo is careful not to alienate the fluid mechanics expert; and the story shows what can happen when differing views of reality clash. The fluid mechanic was engaging with reality through his computer programme and the nuances of numerical solution of fluid flow problems. In doing so he was striving for an ideal – the most accurate geometry he could produce with his computer. Udo's concern was for the most accurate geometry that could be produced by the foundry. The designer's view is driven by the limits of "profile tolerances" whereas the theoretician's view is driven by the numbers.

Udo's method of dealing with this differing view was subtle. He did not criticise his colleague, he criticised the foundry instead. This reinforced a bond between Udo and the fluid mechanic as if it was them against the foundry. At the same time Udo consolidated his position as the designer with an all-encompassing view of the product and the importance of his pivotal role in the organisation of design. His external judgement of the foundry was exposed to the specialist but Udo also had an internal and pejorative judgement of what the fluid mechanic was doing which he did not expose outside the design domain.

Designers interact with other people in the firm who are seen to be of equivalent level, with foremen and field engineers, and with specialists like the fluid mechanic. As Harry points out this has not always been the case, but even in the times he refers to the foremen and the designers communicated unofficially. This was based on a class habitus where they recognised each other as having equivalent social status. Dave exposes the differences between these exchanges of cultural capital which are based on a shared engineering habitus and those with management where the exchange is inspired more or less consciously by the material concern to get Dave to do more work.
Steve shows how, through shared experience and knowledge conflicts can be avoided contrasting with Udo's exposure of conflict between designers and other people on the

project team. He exposes his judgements selectively to those who are not in the group of designers.

9.1.1 The boss

The most significant person that designers interact with at another level in the organisation is the boss and the relationship can take many forms. The boss can be seen as a functionary, just a position, disembodied from the person, or the relationship can be close and personal, based on respect and shared experiences. Gouldner's (1954) analysis shows the tensions created when a new boss is appointed and how, in that particular case the pattern of bureaucracy changed from an 'indulgent' one to a regime with stricter application of bureaucratic rules. He examines how the new boss altered the informal social structure of the firm by appointing key people and demoting others. Burns and Stalker (1994) examine the role of the boss in more detail ranging from middle managers to director level. They examine the isolation of the boss and the strategies available to overcome it. Most significantly they identify the effect of the personality of the boss on the company culture as a whole. In any case the boss is the personal instrument of domination, the person who controls the activities of other people and in doing so limits their choice.

Yan explains how the hierarchy worked in the traditional drawing office:

> "Yan: It was literally in lines, you know so whoever you looked forward to was in fact your boss although you reported to the chief engineer, somebody else told you what to do but you, the chief engineer was the guy that was your boss."
>
> Interview 17 p. 7

The actual boss was the chief engineer and by his authority the section leaders and team leaders, through their places in the hierarchy, controlled the activities of junior members of staff. The hierarchy was clear and reflected in the actual layout of the office.

Harry outlines how interactions with the boss have changed:

> "Harry: Okay, you know, you're more relaxed now because you can talk to your boss sensibly. You can be rude to your boss and he can, say, he can pull

> you up and say, hang on, hang on, I'm the boss here, just stop effing and blinding or whatever to me and it went from there. "
> Interview 4 p.2

When conflicts with the boss arise they can now be more easily expressed than was possible in the past. The kinds of conflicts that can be exposed are limited and the boss has the ultimate say. Harry's boss over-ruled one of design decisions with a scheme of his own:

> "Harry: The only favourite ones is where you know where you have a disagreement with the General Manager and he makes you do - I can cite one out, with all those, all those drives through the you know - the epicyclic boxes. When it just got like a clockwork bloody clock like, with all these belts and drives and it would have been much easier just to put a couple of DC drives on. And at the end of the day we wander out on the shop and the General Manager stands there in amazement, he looks at all these drives, and he says, "What the bloody hell's all that lot?" and I said, "It's what you wanted with your harmonic drives and I told you the DC drives were better." And the most frustrating thing is he turned round and he said, "In this case, Harry, I agree with you, you were right, we should have put DC drives on." But that's no help to me now, you know, with the frustration, because you've designed it, you've never really agreed with it, you've voiced your opinion on several occasions during the design study to the General Manager, but he's always pulled rank on you and said, "I want it like that." And at the end of the day when he says you were right, you've still got the inferior design solution to it, not the ideal thing, and it even frustrates you even more when he says you were right, so what d'you do, you know, it's very difficult."
> Interview 4 p.19

The product is central to this conflict. Two technologies are competing for use; Harry favours DC drives while his boss prefers harmonic drives. Because of the hierarchical relationship of the boss to Harry he can force Harry to adopt the harmonic drive solution. The conflict is internal to the habitus: the General manager is a former designer. Harry has a detailed view of the design that his boss does not have until he sees the product on the shop floor. Harry is frustrated because the boss has taken over Harry's design authority without engaging with the product at a detail level. In this case the boss did not trust Harry's judgement so this could only be interpreted as a personal slight. Harry is happy to elaborate on his judgement because in the end the boss agreed with him. What are not exposed are the internal judgements each made which made them favour the two different solutions.

The boss has power to make people do what they would not normally do even in the practice of their skill. The symbolic exchange is not between equals and serves only to consolidate the position of the boss. It may seem that Harry came out of the above situation with the advantage, but the boss is still the boss and demonstrates this by affirming Harry's original scheme. When the boss backs down and supports Harry it merely reinforces his position as boss; likewise if Harry backs down it serves to further reflect his position as a subordinate. This kind of symbolic exchange therefore tends to confirm the position of the boss.

The people in the firm have personal interests in its success and these interests influence their interactions with their colleagues. They also have an interest in the success of the enterprise, which almost always involves several firms, large and small, each operating to control its own economic risk within the distributed enterprise. Underlying the interchanges with other partners in the enterprise are considerations that are 'directly material' (Bourdieu, 1990a, p.121), that is to say, compelled by material pressures.

9.2 Other people outside the firm

By considering Harry's firm, Coating Technology, as a node in the enterprise it is possible to see the flow of money capital through the company from the customer to suppliers. Designers are aware of this process as they interact with the partners in the enterprise. Harry explains the process of manufacture, test, and shipping of a machine, involving various suppliers and the customer:

> "Harry: Now when you've got the parts purchased and they all come in, then the Works Manager along with the Foreman and the Chargehand are responsible for building the job then. They have to build the job. So the job's constructed and put together. Now, during the course of the way, if there are any snags or problems while we're building the job, they come back to the Drawing Office. They come back to the Design and say this won't fit together, or you know, that sort of situation, and then the Design and . . . the Design have to look at it and sort out the problem, resolve the problem. And then eventually when they've finished putting it together, the job's then handed over to the

Commissioning Department and they then attempt to start the machine up. Now, before they start the machine there are certain things they check out. All the electrics are checked out and all the features on the machine are checked out. You don't want to just switch on and the bloody thing blow up, so we do check certain features about it. Any things that are sort of dangerous areas they check out. Then they start the machine up in each section the first thing they do is make sure - in our case the whole machine's inside the vacuum chamber - they make sure everything's vacuum tight to the specification. The next thing they do is make sure the winding mechanism will run correctly. Now to do that, we have to bring in the drives engineers from the drive company. Commissioning Engineers from the drive company. So what we're saying is, that some of our subcontractors, which we buy equipment off, deliver it, we put it together, but we still need their commissioning engineers to come in and crank it all up alongside, such as the load cells. The guy from the load cell company comes in, now he has to be here at the same time as the drive man, because the load cells are sending signals to the drive. And then these two guys, they know each other, they've been often enough and they work well together along with our commissioning engineers. Then, once the machine is running successfully, the customer is invited in then. He comes along; he's already had his material delivered to our works for him to witness test in our works. Now the customer may bring his own operators, erm if it's a new machine with sort of different features he may bring his own operators to familiarise themselves whilst the machine's running. So in conjunction with our commissioning engineers, the operators will run the machine in our works. Now once the customer has said, oh yes, that's processed my material satisfactorily, I will now sign the machine off and say I accept it. Then after that it's broken down into major pieces for transport. Right, then it goes off round the world or wherever it's going and then it arrives at site. Now, the customer has to have his site conditions prepared to our drawings, the foundation. We do a foundation drawing telling them what's required, the shape, the concrete, and how many holes and whatever in it, and all the loads on it. We also tell him what water supply, electric supply and all, any other services that's required, air, anything else like that, liquid nitrogen, and such. And then the machine's installed, our fitters go out, install the machine, and then the commissioning engineer goes back, cranks the machine up, starts it and gets the machine running in production. When the people that have bought it are happy, they sign off and that's the end of it."

Interview 4 pp.8-10

This story has a large cast of characters and it shows a variant of the distributed enterprise model in action. All the component parts and sub-assemblies are manufactured by suppliers outside Harry's firm. His firm is concerned with the design and assembly of the machine. This organisation can be contrasted with that of the design consultancies where the involvement in manufacture is different in nature and less direct than Harry's. From within the company are the people involved with assembling the machine - the foremen and chargehands, they interact with the designers to make sure the machine is assembled as intended and they also resolve any conflicts and 'snags and problems'. When the machine is ready to be tested there is a well laid out test regime involving people external to the firm - suppliers of drive systems and load cells - who also have a stake in the distributed enterprise.

At a late stage in the commissioning process the customer gets involved. This is the customer who specified and paid for the machine and is also the user, or operator of the machine. On its acceptance, the machine must be transported by another partner in the enterprise - the transport company. The customer has also probably engaged another firm to prepare the foundation at the site for the machine.

The structure of the enterprise can be analysed by following the flow of economic capital through it. The people buying the machine receive payment for the coated film they produce which ultimately comes from the people who purchase packaged food. Coating Technology's customers pay for the machine and they, in turn, pay their staff and their suppliers.

9.2.1 Suppliers

Harry's firm purchase all the parts and sub-assemblies (such as the drum) from outside suppliers whose role is crucial in the success of the enterprise. In his story about the drum Harry mentions the suppliers of the drum and his relationship with them:

> "Harry: It gets quite worrying as well. A lot of the suppliers won't tell you, you know, they won't freely give out this information, but these guys in this particular case Bragg and Carter who we deal with are very friendly, very helpful and they will explain to you what's going on. And you get this, they

have this rule of the thumb thing, you know, 1 bar pressure will give you I don't know 10 or 15 microns."

Interview 4 p.18

The supplier's willingness to share information with him and the help they give him are important to Harry; he gains confidence that the drum will fulfil its function from his "experience" of the supplier and this directly material symbolic exchange. The supplier trades their intellectual capital with Harry because they know that his confidence as a result of this exchange will influence his decision to buy the drum from them and to continue to buy drums from them.

The vacuum vessel is another important component that must be carefully manufactured and delivered to Harry's firm in the timescale of the project. If the vessel is late then the only sanction Harry has is to say:

"Harry: okay, next time we'll go to another company."

Interview 4 p.7

But he cannot apply this sanction to the ongoing project. The vessel's supplier has cultural capital: their competence at welding, specifying and selecting steel gained through education and practise; they may have won institutionalised cultural capital through their certification by an accrediting body such as Lloyd's of London. Their reputation and prestige as suppliers of vacuum vessels are incorporated as symbolic capital. The supplier's accumulated cultural and symbolic capitals motivate Harry and are his justification for placing trust in them. The vessel embodies their symbolic capital and is directly exchangeable for money capital.

9.2.2 Customers

The place of suppliers in the flow of capital is easy to locate. Placing the customers is more problematic and can be defined either through the flow of capitals or by their relationship to the product in use. Management texts place great emphasis on the relationship with the customer.

'A simple summary of what our research uncovered on the customer attribute is this: the excellent companies really are close to their customers. That's it. Other companies talk about it; the excellent companies do it.' Peters and Waterman, 1982, p. 156

However, it is rare to see a detailed analysis of just what that relationship is. The customer could be the person who pays for the product, the person who uses it, or the person who specifies it. It is difficult to imagine anybody complaining to a supermarket because their sausages are not wrapped in film produced on a machine from Harry's firm – Coating Technology. Coating Technology is only one enterprise in a global web of enterprises that manufacture, supply and use coated film for packaging. Nailing down actually who the customer is and how close they should be is problematic.

Quist's definition of who his customers might be is constructed by his perception of their relationship to the product in use. His money cassette had to handle the abuse given to it by security guards and the people who load the cash dispensers. However, it was the banks who were "really up in arms about it." (Interview 11 p. 10) It appears to Quist that he has to satisfy a competing number of 'customers', the bank, the security guard, himself, and MVT. The internal negotiation that goes on is complex and part of the designer's activity. But ultimately Quist must show the bank, who actually pay for his product that he has considered all the people who will use it. This knowledge, embodied in the product is exchanged for money capital.

Udo also has problems dealing with a range of 'customers':

> "Udo: And that's not very easy because different operators operate our engines differently depending on who they are . . . the Saudis . . . they take off, pull the stick back and that's it, its balls out and 40 minutes later, because it's not that far across Saudi, shutting down again. And with all the sand ingestion and those sorts of problems, they knacker our engines. But people like American, you know, British Airways, say, take off, you know, noisy, can't pull the stick back too far because it's Heathrow, you know, get up to a certain level, certain level 30,000 ft, press the button, mmmmmm, 7 hours, you know, at cruise, that's easy, I mean, the engines are designed for that. Very difficult, same engine, different operator, one's knackered and one isn't, and then design wise of course we have to resolve that."
>
> Interview 14 p. 13/14

Notwithstanding the colourful language this passage does show some important concerns for the designer. The design problems that Udo identifies with the Saudi operation are the sand ingestion, the running of the engine at full power on take off and the short flight time which means that the engine is heating up and cooling down frequently. The problems with sand are obvious – abrasion in the cooler parts of the engine and molten sand deposits in the hotter parts. Full power is less obvious but Udo's criticism is that the pilots do not apply full power gradually. The short heating and cooling cycle will cause fatigue problems, and this is the case for all short haul flights regardless of whether they are in Saudi Arabia.

Cooper Clarke does not make aircraft but they sell engines to aircraft makers as well as to airlines. But the relaitonship is more complicated than that. The contract for maintenance and spare parts for the engines is between the engine manufacturer and the airline. Recently engine manufacturers have moved away from selling actual engines and instead they can now sell flight time at a specified fuel consumption directly to airlines. The flow of material capital is more complex but the symbolic capital exchanges are still in the opposite direction.

Udo's final statement reveals the complexity of the design problem; these are different customers buying the same product - the designer must be aware of all these operating conditions. The acquired cultural capital that comes from a knowledge of all possible operating conditions and the construction of an engine to cope with them must be demonstrated for money capital to be exchanged among the various concerns – the airlines, the aircraft manufacturer and the engine manufacturer.

Categories of suppliers and customers are easy to define in the material structure of economic capital. The flow of economic capital through a node is one way - from customers to suppliers. The flow of symbolic capital is the other way; exchanges of expertise, of confidence and of prestige are mirrored in the flow of material capital.

The relationship of designer to customer is more exposed in the relationship between consultancies and their clients because the capital exchanges are made more apparent.

9.3 Consultancies and clients

In Edwards' (1979) scheme design consultancies are in the periphery, as occasional, subcontracted employees of mainly larger scale, monopoly capital clients. Their position in the distributed enterprise is also peripheral; they do not interact with suppliers in the same way that Harry does.

The consultancies have various strategies for dealing with their customers or clients, as they often call them. Frequent contact with clients is a common strategy because they want to make it clear to the client what they are getting – the client has to be shown the value of the design activity and not just the outcomes. Edwards' (1979) theory indicates that being on the periphery puts the consultancy in an inferior power relationship to the client, especially if the client is a large multinational. However, the consultancies have ways of manipulating the relationship for their own ends.

Cultural capital exchange is central to relationship with the client; the consultancies have a great deal of it in all three forms: institutionalised, embodied and objectified. The consultancy industry is organised differently to the other designers; they have competitions and awards ceremonies like other cultural producers in the media, film and the arts.

> "Jennifer: That's currently in the running for an Australian - for a Victorian Design award? No - an Australian Design Award, we've got - we've won the preliminary round."
> Interview 5 p.6

The institutionalised cultural capital associated with an award may be, and often is, translated into money capital if the surrounding publicity allows the winning designer or the consultancy they work for to command a higher price for their services. Core market industrial clients may engage an award-winning consultancy to gain access to the associated glamour. For a designer working in a core firm this kind of capital conversion takes place in different and less public ways.

The consultancies are also allowed to attach a signature to a design - introducing the idea of authorship. This is partly expected by them because of their (typically) Art School training and the authorship bestowed on practitioners of the fine arts. In a core company it is difficult to credit public authorship.

Authorship, as Foucault (1984) points out, is an important focus for historical analyses of cultural production, being linked, from the Renaissance on, to notions of singularity and creativity. For example, most cities that are promoted as modern or forward looking have a building by Richard Meier whereas in the mediaeval city great buildings such as cathedrals were there by the grace of God. In design an artefact may be given significance merely by attachment to a person whose name or reputation has acquired a magical aura.

rather than by reference to any inherent or objective quality. Thus in the competitive struggles within cultural production, emphasis historically has been put on individual reputation as a guarantee of quality. The indebtedness of the individual author to others in the field and especially to older textual solutions is conveniently downplayed.

In their advertising design consultancies emphasise their relationships with prestigious clients and with their most successful products. These are both forms of objectified cultural capital; they show that the consultancy is discriminating in the clients and products it associates with.

Their embodied capital is in their skill with their materials. The outputs of their work are immediately impressive to clients due to their quality. Whether it is drawing with a pencil quickly to show a client an idea or a computer generated photo-realistic rendering of a product the designer's skill is made immediately apparent to the client. The consultancies are happy to advertise their cultural capital in all its forms and to exchange it with their clients and in doing so manipulate the relationship to directly material ends.

9.3.1 The Melbourne method

A typical example of this symbolic exchange is what will here be called the Melbourne method. This is not to say that this method was invented in Melbourne or that it is not used elsewhere, simply that the first place it was observed was in Melbourne. Luke explains:

> "Luke: I mean, my favourite approach is to give three concepts, one that the clients like, or the client's specified to one we like, on the other hand one that we would prefer to do, and one in between which is sort of a major step forward for the client and it's a major step back for us, but we have a compromise. So that's normally the target one, we've sort of one step back and two steps forward, that's made some progress."
>
> Interview 6 p. 3

Luke is making a break with traditional notions of market choices with his second and third options. In producing them he is applying his own framework of distinction and exposing it in a limited and structured way to the clients. This approach was employed in one form or another by all of the consultancies:

"Ian: It also depends on the structure of the brief, if we are going to be showing clients ahm concept work, we're aiming - we're going to decide all that internally and just show the clients - give the client three options, in terms of finished rendered options."
Interview 5 p.15

"Mike: And so, ah, we'll then normally take those through into three concept versions of which, like most people I suppose, we'd try and look at things from the cutting edge and that's a bit more out there and might challenge the client's idea of what their product, project should be. Something which we feel, ah, we're in the market where they want to be, and then something in between there. So they're getting hopefully, they can see where they should be or they think they should be, and they can see where we think they should be. Normally, say 80% of the time, they will go for the intermediate concept, which is the safe one, it's giving themselves a little bit of excitement but at the same time they don't take too many risks."
Interview 7 p. 2/3

"Nick: So if we're asked to do alternatives what we'll do is, we will say, present our three favoured alternatives, the three that suit the brief and give the most benefit, but we'll always work very hard to make one, the one we believe in, clearly superior in terms of the level of detail that we work it up, to prove that it works and we'll use the others if you like as a comparison along the way, you know, I've got a strategy of that, presentations that say that most clients actually want to see where you've come from to get to the result that you recommended. There are very few clients who just want it put on the table, bang, there it is, there's the solution to your problem."
Interview 8 p.5

The first thing to notice is the use of the magic number three. This is a rhetorical device used in many places, especially by politicians. It is also a mystic number having a place in many religions. In Luke's scheme and also in Mike's it is a device for allowing the client to choose the middle ground. The pitch they are getting from the consultants emphasises the extremes and allows the client to choose the safe middle ground.

Nick is more subtle; his middle concept has been more thoroughly worked through and so can be presented to the client with a higher level of certainty. He also understands the process more because he realises that the client does not want to be presented with one concept and a choice between yes and no. Equally a choice between two concepts could involve a choice for one concept purely in terms of a choice against the other – a kind of lesser of two evils. The consultancies do not want a choice for a least worst case but rather to present the client with a preferred option which allows the client to select it while retaining the illusion that the client is in control.

This is symbolic exchange at a refined level. The consultants are exhibiting to the clients, with a great deal of skill, a range of possibilities that has been manufactured for them by the designers. Distinction comes into play when the client is invited to share the activity of a connoisseur, someone steeped in the culture of design and skilled in its practice, and apply criteria imperceptibly shaped by this culture. This exchange of cultural capital is yet again, directly material.

9.3.2 Nick and his clients

Nick's is the most client centred of all the consultant interviews, he uses the word 'client' 55 times in the interview and the client figures largely in Nick's design process.

The process is discussed in depth and the stages are:

- Proposal/pitch
- Brief/specification
- Research
- Another client meeting
- More research with client confidential information
- Final meeting
- Sketch work of various quality
- Computer representation.
- Alternative concepts are generated and various selection processes are used some of which involve the client and some of which don't.
- Detail design

The process is more complicated than this linear representation suggests and Nick adapts it to deal with different kinds of client. This is demonstrated in the way he varies his application of the Melbourne method.

> "Nick: I think, I don't have an absolute hard and fast rule for this. It depends on the client and on the project, and to an extent on whether it's industrial design or graphic design. Sometimes clients will ask to see a number of alternatives. Sometimes the client will just say I'm not interested in looking at 20 alternatives so I want you to recommend for us what the solution will be. Sometimes a client will be totally non-specific, they'll just want to have a solution developed for them and they'll be happy and confident to get through the stages of the project based on I suppose our track record and their level of confidence, and we may go back with several alternatives or we may go back with one."
>
> Interview 8 p.5

Nick does not present alternatives to clients he has been working with for a long time and who recognise the "track record" - cultural capital in which he has invested so much time and effort. He can apply his own criteria of distinction without having to meet with the client and present the three options. A client may ask for a specific number of alternatives as part of the work that Nick is contracted to do. Nick's skill is in aligning the client with the kinds of things that he will present to them and how he will apply his distinction.

Returning to Nick's design process the research element is obviously very important to him and he explains:

> "Nick: I've found in sort of, oh, let's see - 25 years in the business I've found that the worst possible thing you can do is actually take a preliminary brief as a designer and then go to the sketchbook or go, you know, to the CAD machine and start designing, you know, if that were a client I'd ring up and say, yes, you know, I'm going to give you this project, I'm just about to write you a letter, the worst thing you can do is go and start designing. You've really just to get all the preliminary groundwork done because I think you learn so much at that stage where you're evaluating the capabilities of the client and the capabilities and dynamics of the market place and so on before you're actually sitting down, and what stops you doing is reinventing the wheel or going off on so many tangents."
>
> Interview 8 p.4

This defines the research part of the process during which, according to Nick, no designing is going on. Nick is "evaluating" the client and deciding in what form he will present his cultural capital before he commits his labour. Of course Nick is designing all the time, for his exchange of cultural capital is as valid a design activity as is the exchange of labour. Meetings with the client take place at each stage to make the client feel that they are close to the action. But more subtle things are going on:

> "Nick: So we'll get a bundle of research that we'll have to go through and depending on the feeling we have for the project and the scope of work and scale of the project we'll often ask again to have another debriefing and review meeting before we actually start design work, 'cause we might be suspicious that what they've asked for is not actually really what they want."
> Interview 8 p.3/4

The last comment makes Nick's manipulation of his clients evident; the power relationship is intellectual and not economic. The client may be an international conglomerate with enough economic power to make Nick's company insignificant, but Nick's display gives them a glimpse of his massive cultural capital and powers of distinction that they must pay to get access to. He makes a final comment:

> "Nick: So one of the things that you try to do is you try to demonstrate quite clearly that you're a professional business organisation and you're not strange people that live in the hills and have long beards and, you know, don't own a collar and tie, you have to fit in with their network, you're actually demonstrating to them that although you're a designer, and they don't know much about design, you're really no different from their accountant or their solicitor or their architect, or various other professionals that they're familiar with, it's just that your stock in trade is design. That I think is a very important part of the success rate that Concert Design has, that, we - I don't say we try and paint ourselves a conservative picture, but I think we do try and say to our clients that, you know, we're like you, we're not radical."
> Interview 8 p.6

The alignment with other benign professional groups is telling. He represents the image he wants his clients to see and defines the limits of the relationship with the client, in other words, the limits of his cultural capital. With this professional image Nick is showing the clients the extent of the work they can expect from him. He does so by differentiating the nature of design activity from avant-garde creativity emphasising the realism and awareness of mundane processes through which he approaches his productive work.

9.4 Design Process

The designers in this study did not have recourse to flowchart explanations of their activity or themselves. Some of them structured their work around points in time through deadlines, release dates, or milestones, but none split their activity in a way that it could be put into neatly labelled boxes for presentation on a flowchart. Harry, for instance, sees himself as part of the narrative of the design process; he has to tell a story:

> "Harry: Well, it's been split up a little, because if you take our company, we've got, we start with the Sales Engineer, he sells the job and then you've got the Project Engineer who helps to get the price together and the spec together prior to him selling. So the Sales Engineer gets an enquiry, he goes out, sees a customer, finds out what sort of a machine he wants, comes back and then says to the Project Engineer, "This is what he wants, will you price it up and write a spec?" Now the Project Engineer and the Sales Engineer may decide that there's something a bit different on this machine, something new that needs design input, so they come to the Design, they come to the Chief Design Engineer, if you like, and say, "Er, this is different on this machine, can you design us this feature?" And then we can work out what the cost's going to be and put it in the order. And then, after you've done that, hopefully, the customer gives you the order, he signs the order based on what you've sold him and then you've got to engineer it, so immediately it comes to Design, and in Design, you have to sort out all the major elements in the machine, such as the schematics, and all the major parts of the machine. Then in conjunction with the Design Engineers, you have the draughtsmen then who detail all these parts."
>
> Interview 4 p.8

Harry uses the story to outline his responsibility and his activity. His process is a series of interactions between people. A box in Pahl and Beitz's (1984) scheme that might be simplistically labelled 'specification writing' becomes a complex negotiation between the Chief Engineer (Harry, of course) and the Project and Sales Engineers. Harry's job entails deciding what will be done and who will do it. The other important character in the story is the customer and Harry relates the customer's role to his own more clearly than might be shown in a 'customer requirements' checklist in a text book specification.

More important than these comparisons with other models of process is Harry's positioning of himself within it. His role is defined through his activity and his interaction with other people. His design habitus has been developed and continues to develop through continuing contact with other people in the organisation, through his contact with customers and through his structuring of the activity of the Design Engineers and draughtsmen he works with. His overview of the process is taken for granted as is his positioning of himself centrally in it.

9.5 Design habitus

The design habitus is difficult to escape; it is acquired early and continuously through experience and hard work. Luke is the boss; he has overall responsibility for the firm:

> "Luke: My job, if I can give myself a job description, is basically the overseer of the process from an overall financial and scheduling viewpoint and I also do all the selling and negotiating with the clients."
> Interview 6 p.1

But he also gets involved with the day to day designing in the firm.

> "Luke: Yes, however, I do reserve the right to have a look at the industrial design things, and say I would like that, or I do like that, or why don't you try that instead? I guess I have the philosophy that if I don't like it, it's difficult for me to sell to our clients. I have to be convinced that it's a good product that its a good design before I can actually go and present it."
> Interview 6 p.1

Luke's background and early career was in day to day designing and this is territory where he is comfortable.

Udo, again, has a particular insight:

> "Udo: And designers all want to become involved in the process and even if - if we've got design chiefs they naturally want to get back into the bike sheds

because they are very happy in the bike sheds, that's where they've come from, they are not paid to do that, lets be fair, they are paid to, sort of, steer the company, strategically. But everybody wants to go back to where they came from. So if you happen to have an admiral or a general here that has got a stress background, he is more than interested to talk about the latest theories of crack propagation, why not? Because he was doing it himself 15 years ago."
Interview 14 p. 11/12

The design chiefs, like Luke, still have the design habitus and want to use it whenever they can. Their dispositions, acquired through their early career, are deeply embedded in them and affect their actions without them explicitly realising it even when they are in a management role. They reaffirm themselves with a return to their origins. The behaviour of Harry's boss throughout their conflict over the "clockwork bloody clock" is an example.

Udo also has a particular problem because his role in the company has recently changed from being a designer to getting other people to be designers:

"Udo: And my new job as of 2 weeks ago is now working just there in the same department as Tony concentrating specifically on the people issues."
Interview 14 p. 1

He sees three problems facing him:

"Udo: Demographically we won't be able to recruit very easily in the future, problem number 1. Problem number 2 - we won't be able to retain people in the future unless we motivate them and reward them differently, and problem number 3 is that I was trained in a design environment in a huge organisation,

(points out of window)

used to work over there, where 200 people, designers, spent 20 years together and we learnt by a process of osmosis. And since then everything's changed and people move through very fast, people are expected to come in and although they are academically attuned i.e. knowledge of physics, aerodynamics and the basics, they're not trained to design because they never were trained to

design. So my whole reason for being now is to try and understand how we can train people to design better, because we don't at the moment."
Interview 14 p. 1/2

The third problem concerns him the most because of the lengthy exposition he gives. His concern is that people do not hang around long enough to acquire the detailed habitus that he thinks they need to be designers. And not just designers, the design habitus is also required for Udo in order to become one of the chiefs. He acknowledges other levels such as the academic habitus of basic science, learned at school and college, although he is not explicitly anti-academic, the implied criticism of such education for designers is apparent. Bourdieu recognises this attitude:

'the upholders of old-style education have no difficulty in devaluing a knowledge which, like that of the men of knowledge, bears the marks of having been taught' 1990a p.103

Udo knows that the rules are never refined enough for practice. Their operation in practice is through continued application. Udo can only define in terms of his own experience a higher level, a practical bodily trained logic that goes further than knowledge of the rules. He can only describe this with reference to himself.

10 Conclusions

The definition of good design is the holy grail of design. Various groups are called upon to air their constructions of the properties of artefacts. Products are said to be easy to use if they fulfil ergonomic criteria and suffer the endorsement of their users. By contrast, video recorders and other electronic devices are notoriously difficult to use. Products are deemed successful if they make large profits for their manufacturers. Some are accorded classic status by the consecrations of journalists, critics and design experts. Rarely do products coincidentally meet the criteria of these various groups. But there is one group for which all design is good: designers.

Designers are privileged with an overview of the product that the action of designing bestows on them and the authority to determine its form and properties. They bring to bear their skill and expertise at using the materials of design, a pencil and drawing board in days gone by and now powerful computer workstations and surrounding paraphernalia, to define their intent and exercise their judgement for their audience. Designers are well aware of the constituencies they serve. When a product is singled out for approbation by a critic, or a panel of judges, for an award it is because designers have intended it to be so and have directed their designing to make its approbation more likely.

If designers decide that newer more powerful computers are required they will find some geometry or configuration that requires such a computer. Purchasers, manufacturers and operators of products might like to think that products are designed with them in mind and in most cases they are because it is in the designers' interest to do so. Designers hold the over-riding stake and design products with themselves in mind.

This view runs counter to prevalent views of design that place designers on the dominated pole of the power relationship in the labour process. It counters the engineering textbook perspective that portrays designers as people who do no more apply rational step by step prescriptions to the development of products.

A perceptive theoretical explanation of the dispositions of designers has been found in Bourdieu's generic work concerning the logic of practice. His concepts of habitus, doxa and illusio fit with the experiential and experimental processes of design. Design can be seen as a game where the most skilled exponents of it are playing to the very limits of the rules even to the point of transgression. Much of design is taken for granted, the compromise between weight and strength can sometimes be sorted out with recourse to rationalised optimisation routines if the geometry is not too complex and cost of manufacture is left apart from the cost of design. More often such compromises result from the application of design judgement that are not and may not be rationally articulated.

Recourse to social science methods for collecting and analysing data has led to the adoption of Bourdieu's scheme. The application of the method and the relationship of categories with the guiding theories provided a constructive framework that brought order and purpose to what might otherwise have appeared to be random series of anecdotes.

Designers learn the language of design and how to use it through their practice and from the instant they enter the design office, in the ways that designers do. The language used by designers marks their primary concern with the product in contrast to the academic engineering discourse based on arbitrary disciplinary splits: thermodynamics, mechanics and so on. Analysis of the designers' discourse has revealed a three level scheme. The first level is concerned to product features, the second adds technical context giving reasons for those features and the third level adds an underpinning social context. The designers use their language with skill, unconsciously and effortlessly: their discourse is part of their habitus.

Artefacts have intrinsic properties; whether those properties are judged to be good or bad depends on social construction and on the authority of those making the judgement. Designers have the ability to distinguish those plans and schemes that will work from those that will not. They can recognise the intrinsic qualities in things that make them work. Designers behave as connoisseurs, applying their own criteria of distinction. Criteria identified in this study include simplicity, invention, conformity to standards and market success. An example of simplicity is the reduction of the number of components in a product reducing its cost and making it easier to manufacture. Invention of something new is especially valued and is most prized when a mundane problem such as a drain cover is addressed with novelty and innovation.

Designers apply these criteria in two coincident ways: within the design field for themselves and other designers and outside the design field for other people. Criteria of simplicity are applied within the field in an unspoken competition among designers in the redesign of products; they are exposed outside the field in simplistic ways such as by the attachment of a number quantifying a design or performance parameter. The introduction of the product to the market marks the ultimate external exposure of design distinction, for then sales and profit levels measure success independently of designers' judgements. Designers value the external judgements that they hear, seeing them as an approbation of their internal distinction. But they do not confuse such external judgements with their own. Most importantly they learn to apply their judgement through their feel for the game more than their knowledge of its rules.

If the application of their judgement is designers' cultural universal then the materials they use to perform their designing are their cultural arbitrary. Interviewing older designers has yielded a detailed social history of the development of the technology used for design from the traditional drawing office with its rows of boards to contemporary CAD that challenges the view expressed by labour process sociologists.

The story related by the respondents provides a counter to the pessimistic view promoted by labour theorists. Predicted tendencies for de-skilling of designers and a reduction in their autonomy have not materialised. The designers involved might not describe the introduction and development of CAD as a struggle but hard battles were indeed fought. Designers were able to take advantage of the evident bewilderment of their managers to acquire greater autonomy and the ability to present their work more selectively in a computer environment.

The political and economic background to the introduction of new technology to business in a wider sense and to design in particular was typified by a wider economic tendency towards a reduction in the turnover time of capital. CAD was initially introduced to design offices to reduce production times by generating digitised geometry for NC machine tools. Designers pushed for the computers to be used by them for designing from the moment the technology arrived in the office and even from the first job they used it for. It is the business of designers to create new things and hardly surprising that when confronted with something new they engage it with enthusiasm and on their terms.

Eventually, in no small part due to the lobbying of designers operating the equipment, the computers moved into the office to replace the traditional drawing board as the platform where design takes place. The physical layout of the office has changed from the traditional rows of drawing boards to today's networked office with integrated computer workstations. In the intervening period many different layouts were tested. Early computers were cantankerous and unreliable requiring temperature controlled buildings. Their displays were difficult to read in bright light and computers were housed in darkened rooms away from the main office. Designers continuously lobbied for the equipment to be adapted for their use and the incremental changes they have won a cumulated in the design office of today.

The social organisation has changed from departmentalised production to team based working. The technology allows and promotes this because the data can be shared and used by everyone in the enterprise from design to analysis and manufacture. Designers have day to day contact with their computers that their bosses do not. Even with the instant accessibility of information it is difficult for a manager to keep track of everything that is happening in a computer integrated design environment, given that designers inhabit it also. Designers' authority, autonomy and skill have therefore been augmented by the introduction and use of CAD.

David Harvey's (1990) time-space compression theory has been extended by the development of a case study in design production using data transfer and rapid prototyping technology. Harvey's thesis holds that people's subjective experience and expectations of space and time are compressed by the pressure to reduce turnover time of capital. Time compression in design is provided by new production technologies in general and rapid prototyping specifically. The time required to produce a functional prototype has been reduced significantly over previous manual methods. Space compression results from the rapidity of data transfer around the globe. Designers can and do share their geometry and data instantaneously with others around the globe. Space is compressed by making the distance between contributors to the enterprise irrelevant. The combination of these two, resulting in a vastly reduced turnover time in design, and the accompanying changes in phenomenological experience of production illustrates and advances Harvey's theory.

The designers reported diverse routes into the design profession and the acquisition of a disciplinary identity; considerable more work would have to be done to identify a general theory of entry into the profession if there is one. The life histories reported by the respondents of their individual progress into design nevertheless provide valuable case studies. However they enter the profession each one must first of all commit to the illusio of it - recognise that it is a game worth playing. They must learn the rules of the game and through their practice gain a feel for the game that allows them to apply the rules in the creative and imaginative ways that they must in order to do their work as designers.

Designers do not submit to labels that have been given to them by other people. Instead, they adopt labels that emphasise the otherness of colleagues and clients who are not designers. Disciplinary identity takes time and effort to build and requires the company of members of the same discipline. The predominating organisational structure for design is the project team comprising members of different occupational disciplines. Each is expected to leave their occupational group where they feel comfortable and throw in their lot with a team assembled to work on a project less enduring than their occupational group to which they have allegiance. Team members do not commit wholeheartedly to the team because they retain links with their discipline group that last longer than project. Allegiance to the team ends with the project but their commitment to design is lifelong. Designers in particular are concerned for the tacit knowledge gained during the course of a project might be lost to their discipline and to the organisation as a whole when the team is eventually split up.

The designers co-operated fruitfully with others in the enterprise who were not designers but shared the same product based view. This is particularly apparent in their dealings with the shop floor where designers may have served their apprenticeship. Their communications with the workshop subsequent to their becoming a designer are made easier because they know the codes and practices of shop floor life. Designers asserted their authority when a colleague's perspective did not agree with the designer's imperative. On the occasions when their supervisors over-ruled them on matters of design judgement the response was resentful and grudging compliance.

Designers choose to live in places where engineering is carried on and although that may seem obvious engineering happens in different places in different ways. Places with concentrations of engineering activity went through a change in the late 70s. Large companies with their design operations side by side with their manufacturing facilities were replaced through receiverships and consolidation with many more smaller companies that are derivative of elements of the original companies. This concentration of engineering in certain areas has allowed and indeed encouraged the free movement of skilled staff among companies without the upheaval of moving house and family. When they moved these staff, including designers, took with them ideas about practices and procedures, and sometimes physical documentation, that became common to the different companies. The smaller companies that replaced the larger ones now associate in distributed enterprises with many of the same people still working together using the same procedures and effectively doing the same job.

In cities with smaller engineering operations this restructuring was not possible and large engineering concerns remain as they were. With less freedom of movement for their staff practices and procedures are more distinctive; this is evident in their language and in their documentation. In general their design and manufacture operations are co-located leading to their earlier exploitation of CAD technology. Through their staff choosing to remain in the same place these companies can maintain their intellectual capital and market niche.

The structure of the design field can also be defined through exchanges of capital, both economic and symbolic. The points at which exchange takes place determine the limits of the field. The core and periphery model of economic capital is intricately interdependent with a core and periphery of cultural capital where organisations with large amounts of cultural capital in the form of specific expertise can gain a dominant position.

Designers endorse and enforce the limits of their involvement with the product. These limits are seemingly set up by the structure of the enterprise and the imperative to communicate design intent to manufacture. The position of design consultancies within the wider enterprise shows these limits more strikingly because they contribute to a wider range of products than designers working in larger firms and their exchanges of capital are more apparent. All designers limit their involvement in order to minimise their risk; the reported practices of the consultants make this more apparent.

The distributed enterprise operates on capital exchange. The flow of economic capital is easy to see and track. Less obvious are the accompanying flows of symbolic capital - prestige, expertise and confidence - that flows in the opposite direction to the economic capital. Design consultancies accumulate cultural and symbolic capital that they exchange with their clients for payment. A large proportion of their effort goes into maintaining their image, prestige and the clients' confidence in them, in other words, they are investing in their symbolic capital. Designers do not associate themselves with firms who supply them with materials or services whose cultural capital they do not recognise.

Designers make designerly decisions because they have a design habitus accumulated through years of practice at a high level and comprising embodied cultural capital. Nobody would employ them if they did not. Designers are concerned for the future of their habitus and the cultural capital embodied in them. They recognise the changes in engineering production and education that they have in part brought about and worry about how these changes will affect the habitus, its reproduction and development.

This study has concentrated on the features of the design habitus held in common by designers in a wide range of industries. All of the designers are specialists in a way, relating to the sector of industry they work in: some are concerned with aircraft engines, some with printing machinery and some with cash boxes. Differences between design sectors have been explored but further analysis and research should be undertaken to explain how people might be limited by the sector they find themselves in. Designers do, nevertheless, retain much in common whatever sector they work in.

Older designers have given an insight into design production over the last 40 years and the accompanying upheavals and developments. New insights might be discovered by targeting older designers who have worked in different economies, in the Far East, such as South Korea or Singapore where large scale manufacturing industry is relatively new and stereotypes of unfettered market capitalism may be contested. A further possible area is the former communist states of Eastern Europe where study might challenge normative Western perceptions of a lack of innovation under state socialism.

The focus on older designers in this study has revealed their roles in the introduction of CAD, the different mechanisms for entering the design profession, their design habitus and the way it is reproduced. Some conclusions about the mobility of older designers in different centres of design activity would bear a more quantitative statistical analysis. Data could be gathered about employment histories through survey methods or from Engineering Institutions' records. Likewise younger designers have a different set of aspirations to their older colleagues and a study focusing on them would reveal more about their careers, aspirations and attitudes to mobility.

The future of the design habitus is a matter for continuing speculation. Design is now securely placed within the division of labour; the need for designers, with their special skills in the creative distinction of the intrinsic and constructed qualities of schemes for production will continue as long as production continues. The existing division of labour might change: a recombination of conception and execution is entirely possible; yet further divisions of labour into design specialisms might be introduced. This research has demonstrated the position of the designer as the pivot around which the specialisms of production rotate. Designers' tendency for the creative engagement with the new and the flexibility to take on whatever tools are needed are fundamental parts of their habitus.

The future means for reproduction of the habitus are also under question. The apprenticeship schemes where Udo, Quist and Harry got their design training are no longer. The route for a young designer now is through university and then on to employment and possibly a company training scheme if they are lucky. The early acquisition of habitus and the realisation of the possibilities open to a young designer are moved from an arena close to production to the university system. The differences this change will produce are difficult to predict. The movement of design education away from production complements the physical move of design activity away from production through the distributed enterprise model where products designed in Australia are manufactured in Singapore. The move into the universities of inculcation of a design habitus is more problematic for students must learn to take things for granted and this is another area for further research.

The future basis for design distinction remains with designers. They will continue to exercise their judgement to their own ends. It remains to be seen how designers will continue to develop and apply technology to their work and their products.. Distinctions based on the intrinsic properties of products may be replaced by altogether different ways of interacting with them. Designers already use an artificial, virtual world in the computer to construct and develop their schemes. It may not be long before those schemes remain in the virtual world and interaction with them is through the medium of more complex and interactive computer hardware rather than going to the bother of creating the thing in physical matter. Vicarious thrills and spectacles will be presented to consumers in new, virtual, ways.

Postscript

"PK: So you find it's still worth doing?

Luke: Oh yes, you get a real buzz. I mean industrial design is a long drawn out process and the unfortunate thing is that it takes 8 months or a year or sometimes more to get from the first concept to the finished product, with so much blood and guts spilled in between. But you forget the highlights, the good bits, and you remember the bad bits, and they tend to sort of discolour the whole event. But then it sort of comes up again when you see it finished proper. So it's fantastic, you know, after all the work."
Interview 6 p. 19

Appendix A: Interview Prompts

Interview Schedule

What do you do in your job?

How do you fit in to the company structure?

What have you done previously?

Enjoyable experiences?

Difficult experiences? Failures?

What is your favourite story about designing?

Appendix B: Flyer requesting access

RESEARCH INTO ENGINEERING DESIGN ACTIVITY

I am undertaking a research project which looks at the development of engineering design activity in the last few decades. There have been several trends since the 60s, the most important of which have been the introduction of IT and the move from large single site concerns to multiple small site concerns. These trends along with other developments in new materials and the growth of international standards organisations have affected the way that designers work.

Designers think and behave in “designerly” ways (ways in which, perhaps, for example, a lawyer does not). A hypothesis of this study is that this behaviour is the result of social influences (in the broadest sense) in the educational and work environments.

This study aims to uncover the way that these social influences have changed with the changes in the technological and industrial environments and how designers' activity has been influenced.

I am undertaking a programme of interviews with practising designers. The focus of the research is such that there is a target group. Good interviewees would probably be in their fifties, and have come through the graduate apprentice or the HND route. They would probably have started their career in one of the big industrials (GEC, Ferranti, Plessey, Metro- Vickers) and subsequently moved to a smaller company. They would be CAD users and have gone through the introduction of CAD and related (e.g. MRP) technologies. I would like to interview anybody with a background close to this profile.

Any help that you could give me with this research would be greatly appreciated.

Paul Kennedy
11 Nov 1997

Appendix C

Page from Staveley Machine Tools standards manual found in several different companies:

STAVELEY MACHINE TOOLS LTD

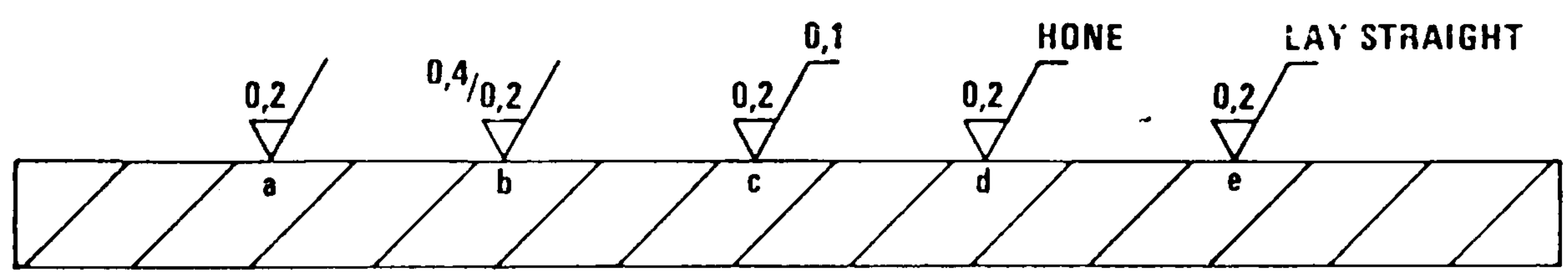
SURFACE TEXTURE

05214/02

RELATED STANDARD: BS 1134

ISSUE DATE: SEPT. 71

3.3 Should it be necessary to provide additional information the following should be noted.



(a) Specifies max roughness value.
(b) Specifies max and min roughness values.
(c) Specifies max roughness and required metre cut off.
(d) Specifies max roughness and finishing process.
(e) Specifies max roughness and direction of lay.

3.4 Normally the symbol is shown with its appropriate CLA value, where machining is required.

4 STATEMENTS OF SURFACE TEXTURE

In statements of surface texture the sub multiple μ shall be used to indicate the expansion in micrometers.

Example 3.2 μ CLA.

4.1 Preferred CLA values. The preferred metric values and their inch equivalents are given in table 1.

MICROMETRE	MICRO INCH	MICROMETRE	MICRO INCH	MICROMETRE	MICRO INCH
0,025	1	0,4 N5	16	6,3 N9	250
0,05	2	0,8	32	12,5	500
0,1	4	1,6 N7	63	25	1000
0,2 N4	8	3,2	125		

Table 1

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