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THE WELWYN NOTEBOOKS

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Foreword

In the early 1990s, we undertook a study of the design teams at the Xerox facility in Welwyn Garden City. The fieldwork was carried out by Wes Sharrock with a little assistance from Graham Button. The original intention was to publish the findings of the study as a book to be called *Inside Design*. However, this never came to fruition. Some of the results of the study did find their way into print in a small number of papers on design. The contents of these notebooks are the early drafts for the projected design book and were written in 1995. We publish them because we believe they offer a useful view on the day to day life of engineering design, albeit one which is somewhat underdeveloped.

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1.0 Crisis? What Crisis?

INTRODUCTION

During the late 1970s and early 1980s it seemed everyone was talking about the need to re-think the design process, and in particular the design process for interactive computationally rich systems.The topics which most pre-occupied the discussion were aspects or elements of three deep puzzles:

Why do software projects get out of control?

What is so special about software which makes it so intractable to engineering discipline? In reports such as Brooks' The Mythical Man Month we find reflections and recommendations for how better to organise and manage the business of software design. Here is Brooks' by now famous depiction

> *Large-system programming has over the past decade been....a tar pit, and many great and powerful beasts have thrashed violently in it. Most have emerged with running systems few have met goals, schedules and budgets. Large and small, massive or wiry, team after team has become entangled in the tar. (Brooks, F.P. The Mythical Man Month, Adison Wesley 1982, p 4).*

Only recently, with the collapse of the Taurus project at the London Stock Exchange, have we been reminded that the situatiion does not seemed to have changed all that much.

Why are people so difficult?

What makes interactive systems so difficult to design? Arnold Wasserman has described in great detail how even a Company like Xerox which prides itself on knowing its market and its customers can make catastrophic mistakes in product design and positioning simply through assuming issues relating to users and usage were well understood and documented problems.

Two new copier machines had been introduced shortly before we began fieldwork. The marketplace rejected them — literally, threw them back. This had never happened before to Xerox. Customers were saying, "This is no good. It doesn't work. Take it away." The machines made perfectly good copies when they worked. And they seemed to work in the lab.......

The failure was not technological but psychological and sociological. The engineers had refused to give any credence to the warning from the human factors specialists that the users of Xerox machines were not a homogeneous population, but two different groups. Traditionally, the big sophisticated, complex Xerox machines in central reproduction departments and print shops were run by highly trained operators.

These people knew everything about their machines. They tended them., "tweaked" them, lived with their machines all day in high production environments.

A second population consisted of secretaries and office workers, called "casual operators", using what are called walk-up convenience copiers. These people are not highly trained, and they use the copier only occasionally........(Arnold Wasserman Redesigning Xerox in E. Klemmer Ergonomics 198?)

Wasserman goes on to point out that while pushing the complex functionality demanded by the operators of the production machines "down to the mid-range and low-end", might provide good grist for the marketing mill, it is totally out of touch with the users' needs or interests. They simply were not prepared to learn all the complex prestidigitation required to get the machine to do the simplest of tasks. Hence the rejection of the machines as unusable.

More recently, the well documented case of the London Ambulance fiasco has shown (among other things) that designing without paying attention to the critical issues of how and where a system will be used and what effect its modus operandi will have on working practices embedded in the local work culture can only lead to dissatisfaction and failure.

When is a team not a team?

The success of many small groups had led program managers to want to reproduce the 'teaming' phenomenon in large product programs. The teaming phenomenon is ability of small groups of highly integrated individuals to sustain amazing levels of motivation and productivity, often against all odds. The problem which managers wanting to mimic the teaming phenomenon faced (indeed still do face) is that it seems extraordinarily difficult to translate the DEC Alpha Chip experience or 3MÕs "skunk works" into a larger setting. Once the arrangements are "scaled up" all the impetus seems to get lost. Management scientists and social scientists familiar with this problem of creating stable innovative structures ("the routinisation of charisma" is one name for it) have suggested that it is bureaucratisation which is primarily the problem. Bureaucracies are hierarchic, inflexible, slow moving and non-adaptive. Everything, that is, that one does not want a high technology product development program to be! In recognising the need to move away from the bureaucratic form of command and control organisation for industrial production, managers knew, or so those like Hirscheim and Klein argued, that they need to choose another management paradigm.

As we said earlier, these puzzles are but aspects of the engineering problem of design. Unlike other design domains such as civil engineering, marine engineering, and aviation, where there were always project problems and difficulties, in software engineering projects sheer indiscipline as measured by the usual standards of productivity seemed to be endemic. This led many to feel that what was required was more formally constructed methods and tools together with an appropriate set of work practices. Ultimately many turned to CASE tools for the former and to notions such as 'software re-use' and 'software factories' for the latter. In helping to remedy the productivity problem, these two responses were expected to contribute to the solution of what might be called design's first order problems.

PRODUCTIVITY

In referring productivity as a first order problem, I mean quite simply that failure to deliver product on time, at cost, and to specification was the most visible defect of the design process. This failure, though, was in fact composed of two distinct elements. Software design and development was not only inefficient; it was ineffective.

Inefficiency

It is important to remember that throughout the 1980Õs interactive computational systems became an increasingly prominent feature of our daily lives. We used them everywhere: from ATMs and card readers, programmable video recorders and microwaves, to digital telephone services. Since they were becoming normalised in our everyday artefacts, their design and development became increasingly crucial to competitive product positioning. It was in that sense that there was a "software crisis". With the domination of Asian (and especially Japanese) companies in the micro-electronic marketplace, software offered the one hope of maintaining competitive advantage. If we could bring the same concerns with lean design, quality, and value engineering to software which the Japanese had brought to manufacturing then perhaps we would be able to maintain our pre-eminent position. The concern became, therefore, how to ensure time to market, cost and quality control, and timely decision making.

It was the concern with inefficiency which led to the determination to develop methods and tools to support the design process. In methodising design and development, there was a deliberate attempt to shift it from a craft to a discipline, with all that that entails.

Ineffectiveness

It was with concerns about effectiveness of the design process that issues of usability surfaced and hence where the interactive character of interactive systems came to the fore. The classic model of system design has a linear separation of phases in the design process (analysis, implementation, evaluation), proceeds by problem decomposition, assumes a single shot in which everything will go "right first time", and where the "soft and fuzzy" issues of usability are marginalised. In the context of this predominant paradigm, a number of counter-movements emerged all of which were premised in an increasing reflectiveness about design itself. As part of the movement towards CASE came UI tools and toolkits. A discipline of HCI devoting itself to user interface issues emerged. Finally, a design ideology (user centred design) came to predominate in this domain.

Strategy

Just now, we mentioned the importance of the marketplaces in which the consumers of software were playing. Throughout the 1980Õs, it became increasingly clear that to attain a sustainable competitive position, it was necessary to follow a number of complementary product development strategies. The first was rapid incremental product iteration. The aim here was "to learn from the market" by cycling very quickly through marginal adjustments to products, adding and deleting features. The second strategy was defined as "out of the box thinking" in which whole new products and marketplaces could be created by new designs which acted as "destabilising events" in a marketplace. The third is "architectural innovation" where the elements of a design are reconfigured to open up new product possibilities. The electronics industry has many examples of all three strategies at work. Sharp, for example, is regarded as the past master of incremental product design. Sony, with the invention of the walkman, changed the product architecture for audio products. At the moment, everyone is expecting that the new "Information Superhighways" will create the opportunity for entirely new products and services to be supplied to the home. [These examples want strengthening. How about battery powered calculators?]. "Incremental innovation" and "architectural innovation" are the terms which Henderson and Clark (1990, Amin Sci Quarterly, Architectural Innovation: the reconfiguration of existing product technologies and the failure of established firms vol 35 pp 9-30) use to describe these strategies. As they make clear, incremental and architectural innovation requires radically different design organisation. In particular, architectural innovation may need to challenge the existing mind set within the enterprise.

Architectural innovation presents established firms with a more subtle challenge. Much of what the firm knows is still useful and needs to be applied to the new product, but much of what it knows is not only not useful but may actually handicap the firm. Recognising what is useful and what not and acquiring and applying new knowledge when necessary may be quite difficult for an established firm because of the way knowledge — particularly architectural knowledge is organised and managed. Henderson & Clark p 13 check quote in original)

How do you create a design environment where incremental, radical and architectural architectural design and development can occur? This then was the strategic question which research and development managers were struggling with.

THE DEMISE OF VOODOO R&D

In a coruscating rejoinder to George Gilder, Charles Ferguson (1988) inveighed against attempts to apply the logic of pure market forces to competition in global high technology industries. Relying as it does on explanations which invoke a "hidden hand" guiding the consequences of entrepreneurial motivation, Gilder's celebration of "the spirit of enterprise" is a outlook which Ferguson vilifies as "voodoo competition". In Ferguson's view, it thoroughly misrepresents and misunderstands the recent history of the semi-conductor business, one of the major cases which Gilder cites in support of his argument.

Voodoo competition is a theory of economic innovation. It has a direct equivalent in the sphere of technological innovation. As Hamel and Prahalad (1988) put it, according to this theory all one has to do is put a few bright people in a dark room, pour in money, and wait. However, as once again the semi-conductor and related businesses themselves show, the rate of change in the basic technologies and the speed of propagation of innovation within those technologies mean that voodoo R&D no longer works (Kodama 1992). Furthermore, relying on technological innovation on its own to create mouse-trap entrepreneurial profits cannot provide a sustainable strategy. Preserving the technological edge required to generate such profits on a recurring basis means making a commitment to continous radical technological innovation of a kind that very few Corporations are likely to be able maintain.

In their search first to understand what generates sustained leadership in a marketplace and second to determine what will provide the basis for the next great competitive leap forward, strategists have looked beyond technology to the dynamics of the marketplace within which competition is being fought out. Having a newer, better, faster, more efficient mousetrap will be of little value if you cannot turn the edge you have been given into a core competence which maintains a sustainable lead. Many (Hamel and Prahalad 1988, 1990, Porter 1980, 1983 Dussauge et al (1992) have suggested that doing this requires the ability to build in turn upon economies of scale and learning curve gains in cost reductions; speed and leanness of production; quality control and customer focus; and most recently a consistent commitment to strategic intent. As this incrementalism takes hold new competitive spaces are created.

For the most part, the global battles of the 1980s were fought on the basis of incremental cost and quality advantages in well defined markets. In the 1990s action will center on the battle to build fundamentally new markets. The goal will be to create new, and largely uncontested competitive space, rather than fight rearguard actions to preserve one's psition in existing competitive space. This is a battle to create the future rather than protect the past. (Hamel and Prahalad 1991, p. 1)

What is important about this for design is that Corporate strategy increasingly demanded innovatory research and development be managed in line with long term Corporate objectives. Indeed, it shuld be directed to systematically searching out and and surveying the new competitive spaces to which Hamel and Prahalad refer. In one sense, it was this desire to make research and development more market and strategy connected which forced the breaking of the classic "pipeline model". R&D entities had to be given and to accept responsibility to "re-invent the Corporation" (Brown 1992 HBR article), create de-stabilising events (Hamel & Prahalad) in existing markets.

One response to the "re-invent the Corporation" instruction might be that this is exactly what R&D has been doing all along. After all, in that all radical technological breakthroughs open up new markets, donÕt they all re-invent the Corporation? A corollary of this view would be, then, that we should simply carry on as before only more so. We should prime the R&D pump with yet more funding and other resources.

Although this is an understandable response, it is not one to which much houseroom was given. It was recognised that for R&D, more would never be enough. The question was not to spend more on R&D but how to spend what was being spent more effectively? There was no doubt that those Corporations which invested heavily in R&D were the ones which achieved sustained profitability. But since there was no clear upper limit on how much to invest, that decision had to be a strategic one; that is a decision made relative to market share, long term product planning, stockholder value and the like. In short, R&D was not just a functional issue, it had become a strategic one.

There were other forces at work which pushed in the same general direction. The Òcycle timeÓ of the marketplace (all marketplaces) had rapidly shortened. Not only were product revisons occuring more quickly, but ideas were moving from the laboratory to the marketplace at in a shorter and shorter time span. This was highlighted under the banner of ÒTime to MarketÓ by the Boston Consulting Group. Shortening cycle times mean that effort and energies have to be focused and targeted. Choices have to be made. The decisons which areas are likely to yield most value to the Corporation has to be made at the strategic level. A bread scattering strategy is, ultimately, one in which time is not a primary driver.

In addition, it was widely recognised that the technical base of innovation was narrowing, at least in the Western Economies. The population of graduate engineering was declining rapidly - in fact more rapidly than the fall in the size of the relevant population. Educational choice was acting as an accelerator to demography. The response to this by the Engineering Schools was international recruitment. While this solved the Schools' problem, it created one for innovation-based companies. The skills which they depended upon were becoming scarcer and scarcer in their home base. What is more, what level of skill was being created was being exported to overseas competitors. In face of this, Companies had to focus the skills they could call upon in areas with the greatest leverage.

The outcome of all of these was a concern with understanding the strategic position of R&D. This led to the development of taxonomies of R&D processes (perhaps the most famous is Roussel et al.'s distinction between first, second and third generation R&D. The first is the "strategy of hope" of casting bread upon the waters and waiting for good things to happen. The second is "portfolio management". Third generation R&D ties R&D to strategic decisions and asks that investment choices be supported by analyses of the likely risks and rewards, contribution to strategic intent and other important variables. The technology in and of itself is no longer enough.

In the third generation, guidelines for measuring results and progress are rooted in management by objective. .....The The desired technological results are specified at the outset in light of business objectives. Progress is reviewed and results to date are re-evaluated against expectations when ever significant external technological or business events warrant such a review — not only in the light of internal project developments and certainly not simply on an arbitrary time schedule. (Roussel, Saad & Erikson. Third Generation R&D. HBS Press 1991, p 40).

Rothwell (1992) takes the next logical step and calls for a fifth generation innovation process. This fifth generation incorporates the emphasis on the integration of R&D, manufacturing and customers which defined the fourth generation, with a search for strategic alliances with collaborating companies.

The impacts of the issues we have been discussing were felt at three distinct levels with R&D community. Senior managers found themselves having to look out into the business and the marketplace for guidance on how to make the investment calls they had to make. The 'bets' were increasingly on the intersection of market opportunity, Corporate strategy and technical feasibility. Second, project management processes were transformed into business management process. Or, perhaps more correctly, R&D became a business process. Thus questions were asked of the kind 'Is this a technology/business we want to get into?' rather than 'Does this look to be an interesting problem with some tricky technical issues?' Third, at the bench and project team level, more and more attention was paid to project organisation processes and in particular te use of technologies to support project activities. Lab notebooks went on-line. Experiments were simulated. Finally, as the shortfall on skill mentioned just now encouraged the formation of distributed groups were formed to attack particular problems, project activities were supported by computational (email, shared file systems, internet) and communicational technologies.

CONCLUSION

In all of this turbulence, there was one enduring question. Do we know enough about how design teams design? This question often presaged a second: Are there ways we could apply this knowledge to designing design? Empirical studies of programmers and design teams were mounted to provide the information sought. In their introduction to one of the original collections of such studies, Ben Scheiderman and Jack Carroll prophesy:

> *We see the emergence of a more proactive role for cognitive and social science in the invention of new software technology as critically important to the more traditional goals of software psychology, namely, facilitating productivity and quality in software, and developing more powerful and conceptually interesting theoretical models.....To play a directive role in the development of these technologies, one must be intimately and broadly involved; ideas come from the informed confrontation of what is with what should be/needs to be. It is our sense that the field of software psychology has matured to a point where it can play a leading role in this invention/exploration process. (B. Shneiderman & J.M. Carroll. Intro. Ecological Studies of Professional Pprogrammers. Communications of the ACM, vol 31, no 11 1988)*

It was against this background that the study of the Welwyn was undertaken. By looking at the day in day out working lives of software engineers, it was hoped that some insight might be gained into the large and open questions that we have just summarised. We did not expect to provide answers to all of them, of course. Indeed, we did not expect to be offer complete answers to *any* of them. What we hoped to do was to offer an understanding of what software design in a large corporate setting looked like as ordinary working life. Once we understand the realities of such work, senior managers might be able to workable solutions to the key questions being asked. What we were absolutely sure of was that without such an understanding, such solutions as they did design would not work.

2.0 The Turn to the Social in Studies of Design

INTRODUCTION

Over the past 20 years or so, academic researchers and professional analysts have increasingly pointed to the importance of the social for the sciences of design. By and large what has been termed a turn to the social has been taken in one of two ways. There have been those who have treated it as indicating yet another disciplinary or topic area to be incorporated (or at least reckoned with) by design. For them, the social characterises a set of properties or features of the object under design which are the specialised domain of the Social Sciences. Incorporating the social means incorporating Social Science. For others, the social refers to one of the influences (to put it at its vaguest) working on the design process itself. While the Social Sciences have something of a proprietorial interest in both versions of the social thus defined, everyone working within design understands something of its import. These two approaches (or perhaps better, responses) merge when the object of design is the design process itself. Then the social becomes both a topic for investigation and analysis utilising Social Science and a conventionally understood contributory factor to the design outcome.

Since our interest here is in understanding the design process rather than contributing directly to design outcomes, we place ourselves firmly in the last group. We want to use Social Science methods to elaborate and illuminate the design environment which we studied. In so doing, we will play up the collective character of designing as we encountered it as opposed to the more usual cognitive interpretation found in accounts of the individual, creative experience in design.

In this chapter, we sketch a brief history of the turn to the social in the context of the design process. We show that from a primary concern with the creative impulse of the individual 'master designer' there has emerged a tradition of work that focuses on design in commercial and industrial settings and on the design teams to be found there. The transition from the master designer's studio to the shop floor work of the design team coincides with the relative increase in the weight placed upon the contribution of the social to design.

TRANSITION IN THE CONCEPT OF DESIGN.

We do not want to make too sharp a contrast here. Certainly, we don't want to dismiss all relevance of individual creativity in design, replacing it with an exclusive emphasis upon the workaday character of design. We recognise, of course, that there are design tasks - some architectural and computing ones, for example, which are predominantly individual tasks and which may involve powerfully imaginative operations. What we want to do is simply to question whether the 'reflective practitioner' ruminating upon profoundly principled problems of design, should be treated as the essence or paradigm of designing. In our view, it is, rather, just one kind of design work. There are others which are conducted as collectively, commonly carried out within teams , and where the work is the routine activity of a bureaucratic organisation. If the design process is to be understood properly and if effective tools to support it are to be developed, then it is design within these environments which we need to understand.

We are not alone in proposing this shift of attention. Many of those who study design and design settings have also come to this conclusion. In the rest of this section, we will sketch briefly and only in the barest outline the kinds of considerations which have them to suggest this. We will begin by laying out the base line against which all seem to demarcate themselves, namely the insights contained in Donald Schon's widely discussed and much praised book *The Reflective Practitioner*.

In his studies, Schon has developed the notion of "design as a reflective conversation with the situation". His whole approach is captured in this phrase and expressed in one of his central examples, the instructive transaction between "a master designer" (79) and one of his students, who undertake a "common design task". What for Schon is common in his example is the task not the solving of the task. Both student and master pursue their design privately and in parallel so that each may produce their "own version of the design".(80).

When the designs are complete, the designer introduces the student to reflection on the process of design. The analysis focuses upon the way in which the designer because of both his skill as a designer and his ability to reflect on the process of design is able to resolve problems which defeat the student. In describing the design encounter, Schon provides a depiction of what we have elsewhere have called "the unfolding course of the design reasoning". In sum, Schon's concern is to show that good design is a principled activity. The application of general principles is not mechanical and *apriori*, but flexible, responsive, and reflective. It is directed to taking into account the complexities and specificities of the materials with which it works.

While Schon's work has been very influential on thinking about design, it is clear that the solitary reflective attitude he identifies as the essence of creative design is unlikely to be typical be typical of much commercial and industrial design work. There design takes place in teams and the predominant characteristic of design work is that it is co-operative and collaborative. Gary and Judy Olson (and colleagues), for example, have conducted a number of studies of "the sequential structure of design activities during face to face meetings". Their reason for doing so was that "the design of systems is an extremely complex and intensely collaborative activity" and that it was the organisation of collaboration - specifically of coordination - which Brooks' pioneering study had shown to be "one of the biggest sources of failure and inefficiency".

The realisation that design is a collaborative activity had already stimulated the development of tools intended to support design reasoning as a conjoint activity. The various conceptions of design rationale were perhaps the leading example of this. The concept of design rationale is a recognition that the reaching of design decisions is very commonly a dialogic, even an argumentative process. In the process of discussing their way to a solution of a particular design solution, design teams can lose track of just which matters were decisive in the selection of the solution,. The various design rationale tools are, therefore, first devices to record the grounds on which the decision was made, of the alternatives which were considered and of the criteria used to discard them as well as the decisions themselves Second, it was assumed that the process of negotiating design decisions was often disorderly. It was felt that the unregulated process of argument within a design team would not necessary enable the systematic exploration of design opportunities nor allow a most rational selection of the option chosen.

Thus design rationale tools, in some at least of their actualisations, were developed as forced disciplines, in the sense of purportedly introducing a more constrained organisation into decision making and imposing on designers (through the provision of a formal apparatus) the necessity to be more reflective-in-action about their design decision making. Thirdly, design rationale was conceived in relation to the structure of the design process as a whole. It provided a means of capturing and preserving information which could be useful to those involved in the 'downstream' design, development and maintenance

The research on design rationale indicated that it was important to recognise that design reasoning went on just as much in the meeting room as it did in the head.. The Olsons (and their collaborators) sought to push this further by arguing

> *whether a design rationale system is intended mainly to generate a useful record of the design process or is actually intended to alter it, the influence it has on the interactions of the designers, the structuring of their design activities, and the quality of the product are all of obvious interest. Investigating the influence of design rationale tools, however, is possible only if we have a reasonably rich knowledge of how design is done now, and a baseline of empirical data against which to compare the performance of designers using innovative tools and methods .*

On this basis they initiated a series of studies of design meetings in field settings, which, in the first instance, questioned the supposition that the progression of design reasoning in such an environment was lacking in structure. They find that "despite their informal and highly interactive nature, design meetings contain a fair amount of structure." For example, they focus upon the transition between what they term "categories of activity" (roughly topic) and report an highly ordered and organised alternation between the discussion of design activity and management matters across many different meetings and many different projects. They make a contrast between a "surface" appearance of chaos and a reality, revealed by close inspection, of a structured, orderly progression of business, attributable perhaps to (*inter alia*) the fact that the designers under study were experienced in the work, trained even in the conduct of meetings.

Taking the study of design out of the laboratory and into the field (as the Olsons did) marks an important stage in the transition we are describing However useful laboratory explorations might be, for understanding design thinking and for experimenting with design techniques and tools, the laboratory is a highly simplified environment when compared to a large development team working under industrial conditions. Moreover, as the Olsons maintained, it is not that the simplification involved in laboratory inquiry involves the controlled simplification of known complexities. The nature and character of the actual character of development teams was and is neither well known nor well understood.

Bill Curtis recognised the need to understand the actual practice of real-world industrial design earlier than most. Based upon extensive field work and interviews with designers, he developed a "model" of design which construed it as a series of "nested" environments of increasing size, complexity and remoteness. Each environment is capable of making decisive impacts upon the work of the designer.

[Put Curtis diagram here]

Curtis et al. term their model a `layered behavioural model' (1269). The layers are `individual', `team', `project', `company' and `business milieu' — necessitated by fact that many design and development tasks exceed the cognitive and practical capacities of the individual developer and involve the formation of teams. The attend to three elements in the large scale design process and to ways in which these impact upon the different layers. The three elements are the (i) thin spread of application domain knowledge; (ii) fluctuating and conflicting requirements and (iii) communication and coordination breakdowns

Thin spread of knowledge

There is characteristically a thin spread of domain knowledge throughout the project. Many software engineers are novices within the business in which they work, and have been trained in software engineering skills, but know little about the nature of the application for which they will be designing. The knowledge will be distributed throughout the organisation, and, overall, will be spread thinly, but the relevant knowledge must be integrated in the design, and design errors could originate in misconceptions about the nature of the application domain. This was, however, often compensated for by the inclusion within the project of what are sometimes called `gurus', Curtis et al term them `exceptional designers', individuals who have a deep understanding of the application and a comprehensive grasp of the project's purposes. At the team level, this meant the domination of the project by a small group - a coalition of individuals - who dominated primarily through their expertise. The project was impacted particularly by the learning overheads, which resulted from the thin spread of domain knowledge and the necessity of designers to familiarise themselves with the application, overheads which were included in neither the costing nor the schedules, and which meant, therefore, delays in the project. For the company, the passage of time meant both the migration of expert knowledge into management, and, at the same time, the obviating of the technical knowledge, as the manager was removed from close contact with changing technical consideration.

Fluctuating and conflicting requirements

Fluctuating and conflicting requirements can arise from the inadequacies of the team's efforts to define these, but the ones to which Curtis et al attend are those coming from outside the team. The business milieu was a main source of these difficulties, it being difficult to obtain representative data on an assortment of customers for the design or, where a single large customer was involved, where the customer's demands kept changing, either under pressure from changes in the customer's circumstances or as a result of the requirements capture process itself. The difficulties for the design team were often a result of the company organisation , and the fact that the marketing team mediated between them and the customer. Projects are often affected by the fact that little systematic effort is invested in working out the requirements, it being more important (for all kinds of organisational reasons) to get the project initiated and on the road than to define clearly the objectives of the project and its attendant requirements. Indeed, the requirements might well be manipulated to make the project appear more viable or less costly. The team was then presented with the necessity of living within the requirements

Communication and co-ordination breakdowns

Communication and coordination breakdowns could be engendered by distance - social (in the sense of the remoteness of levels in the organisational hierarchy), cultural and geographical - and the sheer paucity of contact between the design team and others relevant to their activities was a source for this. Documentation was a problematic basis for sustaining communication between individuals - there was not enough of it for a given purpose, there was too much to read and individuals used informal communication networks to rationalise their effort and time. The team found it necessary - a time consuming task - to establish a standard format for representation to coordinate amongst its many sub-components. Communication between project members and their managers could be hard to achieve and different teams within the project would not communicate with others, though some individuals could act as go-betweens (Curtis et al call them `boundary spanners'] amongst groups. The company's formal procedures could obstruct communication because the managerial flows of information differed from those functional for the design and development work, and there were often discrepancies in understanding and difficulties of communication at handover points between teams in the project. Again, the necessities for direct and flexible communication between the requirements source - i.e. end user and the design teams were inhibited by the formal channels of communication, which must proceed through mediatory groups in both the design and the client organisation. Characteristically, then, and where they could, designers would establish informal modes of communication to supplement or bypass those formally prescribed.

Finally, in our brief survey of the development, from within the design community itself, of the recognition of the increasing relevance of the organised, collective situation of much design activity we must mention the work of Jonathon Grudin. It is he who comes closest to the point of view from which we ourselves approach the topic. For Grudin the natural place to start is with design as work in organisations. Grudin has been astute in pointing out, for example, the extent to which the relationship between the design team and the organisation for which it is working impacts the practice of design whether it is in a contractual relationship, is engaged in product development (the kind of case on which we report) or is doing in-house development. He further emphasises (with respect to the development of interactive systems) the importance of at least these factors:

> *the size, charter and structure of the development organisation; the nature of the user population; the degree of design uncertainty; the presence or absence of other partners or contributors to the project; the nature of the commitments and agreements among the parties involved; societal conditions over which the partners may have little control; and changes encountered over the life of the project.*

Thus, Grudin emphasises the heterogeneity of the considerations which enter into defining and conducting the design tasks, and highlights the degree to which the integration of these heterogenous elements into any kind of coherence is an organisational problem. Resolving these problems would, they suggest involve the introduction of more open direct, and flexible relations between designers and end users and iterative design approaches with rapid prototyping - and finds, comparably with Curtis et al, that one of the key obstacles is the mediation between the designers and their intended end-user of the organisation's marketing organisation. The functional division of specialities within an organisation is not something that organisations are particularly keen to revise, nor is the marketing arm necessarily interested in facilitating contact between the designer and the customer, not least because this may reveal deficiencies in marketing's assessment of customer needs. Direct contact between designers and users is a low priority item within organisations. However, the `obstructiveness' of marketing in this connection must not be put down only to defensive self-interest, for it is, after all, the marketing department's charged task to manage relations with significant customer organisations and to preserve the commercial viability of the company's products, and from the point of view of conducting its business, the intervention of designers may be a destabilising force.

Iterative design is often recommended as a solution to usability problems, but, again , there are `good organisational reasons' inhibiting such processes. The design of an interface is a focus for many different groups within an organisational process - Grudin and Poltrock identify the hardware, software, documentation, training development and marketing units amongst others, and iterative design would involve the redoing of work across a broad front of departments, and would, in any case, involve the introduction of a new practice which does not naturally integrate with a culturally entrenched conception of `thorough up front' design. Though Grudin and Poltrock do not put it in these terms, they do highlight the extent to which the incorporation of `the user' through (loosely) more participative design methods tends to conflict with the extent work practices of designers, who do not necessarily see either (a) that the problems which are purportedly to be solved by more participative methods cannot be resolved by methods already in their possession and [b] that the processes of such participative design can be meshed with existing - and practically immutable - practices. There is, further, an indication that the kind of work which is involved in interacting with users and working with rapid protyping is regarded as work of a lowly order - they say that there is some `distaste' for it. The unity of a being united in a single design process does not ensure close working integration within the project, where the different specialisms within may be distributed under different managements - as hardware, software, documentation and training may be - and where the participation of the different departments is distributed not just spatially but temporally, which means that usability issues are dispersed across the project. There is, then, no single focus for usability issues, and those who must deal with deal with one or other usability issue do not necessarily give much priority to, or have much interest in or expertise with those issues with the result that therefore they can often fall between two or more stools.

Thus Grudin and Poltrock treat examine the design issues as involving primarily organisational problems, involving problems of introducing new and consequential practices into an organisational environment, where the changes required to effect the new practices would extend far beyond the deployment of its constituent techiques itself, but would ramify quite far across the organisation's formal departmental structure, and which, further, presents problems in integrating the practice with the existing ways of the organisation, ways which, unless substantially modified will not support or facilitate the new practice.

SUMMARY SO FAR

In brief, we would want to claim that those who have tried to move the focus of studies of design away from the individually created designer and to take the study of design out of the studio and laboratory and into the design shop, have come face to face with two incontrovertible facts. In design teams, design is an interactional as well as cognitive activity. Second, design teams do their designing in an organisationally specified milieu. Both make up what we will, for short, call the social context of design. In going about their daily work, designers know this to be the case; manage it; and trade on it to ensure that the work they do is successful.

Our pre-occupation is with understanding this social context. We come to design interested first and foremost in how the actual work of doing the design gets done in this social context. What resources, understandings, rules and regulations, procedures and processes, etc etc etc are seen by designers to be relevant to their design work? How they invoked, deployed and assessed? What do they expect of themselves? Of each other? Of the organisation which employs them and which uses the outcomes of their work? What artefacts do they use and how are they used in the daily round of design?

SHOP FLOOR STUDIES OF DESIGN

For us, these questions add up to an interest in the working culture of shop floor design. What, as they go about their daily chores, does design look like to designers? Such an interest is Sociological in orientation since it takes its departure from a set of sociological concerns with how to describe and theorise social context. For our present purposes, though, it is unnecessary to elaborate the origins and distinctiveness of the approach we take. However, we would assert very strongly that such elaboration will be required when (or if) any attempt is made to align the foundations of the design sciences with those of Social Science in order to map theories, methods and findings onto one another in a systematic and structured way.

For the moment, we will be content to lay out three themes which we think typify the approach which we adopt and which contrasts with other (social science) approaches to technology and technologists. We will do this without argument and with only the minimal explanation. Teasing out the points of difference and coupling the various levels of argument by which such differences might be sustained would be an unnecessary distraction now and ought to be left to another occasion and audience.

Studying an activity for its own sake

Our interest is in design, and design for its own sake. We are interested in the activity of design, in studying its minutiae, its practicalities, its routines. We are not, however, very much concerned with the significance of design, be that significance assessed at the project, Corporate or societal level. We disattend to questions concerning the function of design and the contribution which design in general or design-in-this-instance makes to preservation or undermining of the social, economic and political structures within which design can be positioned. We do not say these questions are unimportant, for clearly they arouse considerable angst and agitation. But, for us and for the point of view which we seek to pursue, they are irrelevant. Of course, we recognise that arguments can be proposed to demonstrate their relevance. Such arguments, or so it seems to us, always lead to the transmogrification of the phenomena we were originally interested in.

Instead of studying design (say) for its own sake, we end up studying it as a species of political hegemony, the expropriation of surplus value, or the reproduction of capitalistic labour relations. To be sure, you can study design in these ways (and many do). It is just that these are not the questions we are interested in.

Now, of course, there are those who say we must be interested in the significance of design; that we cannot escape it and to try to do so is a dereliction. When faced with these arguments, we turn aside. We have little to say to those who want to regulate what interests other people should have.

What's in the news?

If you take an interest in some mundane activity for its own sake, you have to be pretty clear what you are finding out and who it might be of interest to. To put it another way, you run the serious risk of sounding as if you want to develop a "science of the obvious". To cast yourself in the role of making discoveries in the same vein as physicists or astronomers might make discoveries is extremely dangerous. The observations you make and the generalisations you come up with are likely to be no news at all to those whom you have studied. And this is exactly as it should be. The Social Science which studies activities for their own sake is always going to play back (but in a re-cast form) what its subjects know about their environment and what they do on the basis of that knowledge. Where, of course, it might be news is in those places and for those people who do not have direct access to and understanding of the setting in question. This makes such findings more like the discoveries of explorers. What is brought back is news of places scarcely known and yet to be fully understood. This news is shaped for those who wish to hear it and for the interests which they have. And, of course, it is news about what has been learned from the subjects in question. One, perhaps, the measure of our success is just how faithful we are, just how much our understand matches that of our subjects.

The contrast, in a phrase, is between discovery in the Newtonian and discovery in the Livingstonian mode. The Social Science to which we contribute definitely sees itself as akin to the latter. This is not to say that Social Science should not aspire to Newtonian discoveries. Let those who would, follow that Holy Grail. We do not feel impelled to do so.

Local Knowledge-Local Logics

One of the things which might as news for some is the discovery that engineering, design, any technical enterprise, was riven with disagreement. This discovery might be buttressed by the further revelation that engineers, designers, technologists spend a significant proportion of their working time dealing with disagreement, promoting their own causes, campaigning for resources, and generally 'playing politics'.

As we say, this fact or facts might be news to some. But it will be absolutely no news at all to any practising engineer. He or she knows that because engineering is a socially organised activity, it requires attention to be paid to power, obligation, authority, responsibility and control, indeed all of the variables traditionally dubbed as 'politics'. The fact that engineering is 'political' in this sense, is then the most obvious and unremarkable thing in the world. It has no wider significance for the engineers.

This commonsense understanding of the interconnection between a collectively organised and managed activity and the requirement to attend to the processes by which that is organised and managed, is for us a topic for investigation not a finding from our research. We want to know how engineers manage design collectively? How do they attend to the interactional processes through which decisions are made and outcomes secured. The ways they do this will, of course be institutionalised within their engineering culture while at the same time interestingly different across projects and, indeed, within projects. How do they know, learn, what needs to be done when, where and to whom?

We think of this local knowledge as being underpinned by a range of local logics each of which is associated with particular contexts. What the seasoned engineer knows and is able to count on others knowing is what the local logics are and how to use them. Here are some facets to such understandings.

Work has to be decomposed and distributed effectively across team members and within the division of labour. Arrangements have to ensure that tasks are done in a timely fashion, are paced with respect to the project objectives, ordered with respect to dependencies, allocated to those who are competent to do them , and so on. Many of the mandatory features of their work are purportedly directed to achieving these outcomes, but everyone knows that conformity with the procedures will not automatically ensure they are accomplished.

Working-with-others brings inevitable problems. People are different and their differences arise from the differences between individuals, from their different positions within the division of labour, from the ways in which they balance assorted priorities, from the variable commitment that they give to the purportedly shared objectives, and from the responses which they make to circumstances. In other words, the fact that those with whom they work are (as they are themselves) other than characterless occupants of functional positions, but are combinations of (perceived) strengths and weaknesses, and that their sensitivities are impacted by the working division of labour all have to be understood and taken into account. Others must, perforce, be depended on, but this does not mean that they can be counted on.

Engineers know these things and know that if they are to achieve the ends they have been set or have set themselves, they will have to be attended to. Attending to them is 'playing politics' but not playing at politics.

To reiterate. That the course of technological development is dependent upon (inter alia) such considerations, that it may be decided by departmental rivalries, and that the objective of realising the technological objective may be subordinated to departmental (or other organisational interests) may be news to sociologists (and to academic researchers of design) but it is not, of course, news to those involved in engineering. The fact that such elements can (sometimes) seem to dominate design and determine design outcomes are recognisable as instances (or at least products of) bad engineering practice of difficulties risked and, often, avoided within the engineering process, of troubles to which, in various ways, and with varying degrees of success, the engineers have themselves made pro-active and pre-emptive responses. The need to take account of, to manage, the social organisation of technological work is known to be an integral part of their work by the engineers. The point for them is that the intractabilities of both material and social phenomena have to be managed in the production of a technological outcome, and that the successful conjunct management of them is problematic indeed. Rather than thinking, as some studies try to persuade us, of social considerations as forcing outcomes away from the achievement of optimal engineering solutions, let us think - as the engineers do - of consideration of social organisation as being integral to their aspiration for the optimal outcome.

CONCLUSION

It seems patent to us, and is practically known to the engineers that engineering is a socially organised task. Doing their work is, in important respects, organising their work . And organising their work is, in many important respects organising and managing the collaborative conduct of that work. The carrying out of their strictly engineering tasks is only a part of their work and the way in which their carry out their their strictly engineering tasks has to be shaped within and to articulate with the organisation and management of the collaborative conduct of their work. Our proposal to look at the organisation of the engineering work for its own sake turns out to be, very much, an attempt to look at the organisation of that work from the point of view of the engineers' themselves. And for them most of the time it is the conduct of the work which is uppermost in their minds. They want to ensure that good engineering practices can be identified and complied with; that the work in hand results in, if not an entirely optimal then an acceptable solution to an engineering problem, and that the work in hand fits into the programme of work intended to result in as good a product as possible in the circumstances.

Taking up this interest in the shop floor work of engineering design leads us to seek to understand and lay bare the engineer's concern with the orderliness of work. In the Chapters which follow we will draw out and explicate how the engineers whom we studied sought to create and implement ways of ordering their work. We will look at the practices they used to sequence the work they had to get done and how these practices were, for them, part and parcel of doing the designing they were employed to do.

3.0 Working at Welwyn

THE SITE

Our investigations were conducted at a site in South East England. The site is owned by a large multi-national company, primarily known for office machinery and is one of a number in England and the rest of Europe. Work at the site was, when we began our studies, primarily oriented towards design and development. within the Development and Manufacturing Division (D&M) function. Until recently the site had housed some manufacturing operations but these had been closed and relocated as part of a major restructuring. This re-structuring had also significantly reduced the size of the design and development operations. Customer Services and Education continued to be housed on the site.

The site covered approximately five acres within an industrial estate alongside the railway line. Elsewhere on the estate was a mixture of major manufacturers - the most notable being the next door Shredded Wheat Company.

The design and development work was mainly carried out on the upper two floors of a building known as H Block because of its layout which (when viewed from above) took the form of an H. The lower two floors of the building housed, inter alia , some managerial functions - personnel, for example - the site library, the various 'laboratories', the quite substantial printing operations and a model shop. The 'laboratories' were rooms — equipped with work benches — in which engineers could work on actual machines, stripping them down, testing them, examining rival machines, and the like. There was a strong emphasis on the security of the laboratories, which were to be kept locked at all times, even stronger than the general stress on security within the building, to which passes were essential. Anyone who was not an employed had to be escorted into the building by an employee and accompanied throughout their visit. After signing in, the pass they were issued had to be visible hroughout the visit. Indeed employees had to display their permanent passes There was a constant flow of visitors to the site, from other sites within the company, and from other companies with which the site had dealings.

WORKING SPACE

The two upper floors on which we spent the majority of out time were largely based on open plan arrangements, within which the pig pens as the working areas were known, had been erected. These would house three to four individuals and were created by moveable, shoulder height partitions. Within each pen there would be desk space, on which was placed a shared work station, except when the work was software engineering when there could be two work stations per engineer. The general workstations ran the Company's proprietary software environment. Often as not, the workstations would be showing the writhing bikinied body of a young, dancing woman as screen saver. The software engineers also used a development environment. The furnishings were completed by two (glass fronted) shelves, one which could be locked, which usually held a few manuals and project documents; a filing cabinet for each engineer; a desk with a drawer and a roller equipped chair. Sometimes there was a small round table.

These work spaces were most apt to be filled in the early part of the working day as engineers took the opportunity to read their email, to work on or print out the documentation that they would need for their day's work, listen to their answering machines and reply to phone calls. For large stretches of the working day, the pig pens would be deserted while engineers went to meetings, went out on visits of various kinds or worked in their laboratories. Typically, they would be occupied again in the latter part of the working day, again for much the same general purposes as in the morning. Some of the more senior engineers with project management functions had individual spaces, whilst the managerial staff proper had their own offices with adjoining secretarial space. The provision for managers was of a superior kind but was more functional than decorative.

The general impression was of basic, functional provision, with acoustic tiles and reflective lighting designed to provide a congenial and calming environment to reduce noise and ambient lighting.

Coffee/tea, soft drink and candy machines were located at various points. Shortly after we began our fieldwork, part of the wage bargaining process involved a concession that these coin operated coffee and teach machines be replaced with ones which were free. Notice boards containing policy notices, exhortations to productivity, invitations to participate in various organisational functions, job vacancies, club announcements and, of course, cars for sale, were distributed about the walls, along with displays of statistical print out from the projects. Surprisingly, there was little in the way of Company identification or exhortation material on display. Neither was there much in the way of personalisation of working space, though sometimes a family photograph or project souvenirs, particularly team photographs taken at the end of successful projects, were displayed.

Apart from the personal working space, there were also three main meeting rooms. These varied in size but were large enough for a meeting of twenty or so. Each had an overhead projector and tables, chairs and the ubiquitous flip chart support. Meeting rooms could be booked as needed (from whom?).

The partitions to the work spaces were easily moved, making it a readily reconfigurable environment, which could be adjusted to conform to the requirements for staffing a project. This means the floors were basically large areas of open space (except for the permanent fitting of the managers' offices) which could be assigned to a project,. The earliest decisions on any project (and perhaps the most difficult!) had to do with how space was to be laid out to accommodate the project's staff and to combine them in working units. All in all, the impression was of the provisional character of much of the layout, of how easily and quickly things could be dismantled or rearranged.

The occupation of the project areas was not a clear cut issue because the project teams were only one configuration taken for the organisation of the engineers. Another was by department. Projects were staffed from engineers drawn from different departments, such as electrical and mechanical engineering, which were housed on different floors. The software engineers on Archer, one of the projects we worked on, were housed in their own space. They all worked exclusively on Archer. However, they were located close to other software engineering teams work on other projects, but not near the hardware engineers who were also working on Archer. Indeed, the latter were not even located in the same country but at the company's site in Holland. On another project, the Thames project, the software engineers were also located together in the software engineering department's area. The systems integration group who also had their own working space, however, were located adjacent to the mechanical engineers in the engineering department. The mechanical engineers on Thames were scattered about the mechanical engineering department and unlike the software engineers did not really having their own "Thames" space. Sometimes, as we will expand upon later, engineers might be assigned to more than one project. In these cases they would not relocate as they worked on different projects but would be located within the project area that occupied the majority of their time.

THE PROJECTS

[This section should contain all the summary stuff on the projects.]

We began our studies in the aftermath of the restructuring of the site in which voluntary redundancy and relocation had led to staff reduction. Large parts of the main building were unoccupied. There was a subdued anxiety about the future of the site, whether it could continue as viable unit and what possible alternative futures there might be.

During its recent history, the Company had successfully responded to challenges in its main markets. These challenges had not been met without difficulty and without considerable adjustment in managerial and business practices. Senior management recognised that, to compete successfully, the Company need to go through a similar order of magnitude change moving away from its 'heartland' in light lens copying towards what was increasingly being called "the digital revolution". A number of high level initiatives had been launched to foster this transition. The most important was the re-organisation of the development, manufacturing and marketing functions around Business Divisions focusing on particular markets segments. Part of the purpose of this strategy was to enable the new "digital" technologies to be nurtured while at the same time maintaining a holding pattern within the existing profitable businesses.

The three projects we studied were part of this "hold-and-extend" strategy. The first, code named Centaur, was to design, develop and manufacture within a year a high capacity feeder for an existing model. This project lasted some five months before it was cancelled. At that point, the Manager of the Electronics Department, Don Campari, who had originally provided us with access to the site offered us another project, Thames. This a five year project (then in its fourth year) to produce a digital networked printer. Don also facilitated access to another of the projects, Archer, which was a three year programme to re-engineer a copier produced by the Japanese arm of the Corporation and sold in the Japanese and Asian market, for use within the European and American markets.

From the point of view of the engineers on the Centaur project, it was verging on the impossible to meet the schedule. Centaur had been conceived in informal negotiations between a marketing representative from the local UK site and members of the Company's central — US based — marketing department: World Wide Marketing. It was intended to seize a market opportunity and as a strategic solution to one of the company's pressing problems. The latter concerned a new model photocopier which was not selling well, and which was now comprising a substantial element in the inventory, at a time when the Company's overall budget position was poor. It was, as we have indicated, therefore regarded as a matter of some urgency to reduce the inventory and to make contributions to income. However, although not appealing to a general market it was thought that the machine might have a niche advantage. This was because many of the features of the machine made it particularly attractive for book copying, and thus as something which could have an appeal to libraries in the US higher education market.

However, the machine, as it stood, would not sell in this market because the libraries required that the machines be coin operated ones enclosed within locked steel jackets. Also, the extant machine did not have a high capacity paper tray, which would be needed in the US market because the responsible operators would not want to be constantly unlocking the steel jacket just to load paper. The machine needed, then, a high capacity feeder and it was this that the Centaur project was to design and develop. The window of opportunity was a limited one, however, so much so that, as we have noted, the usual initiation of a project would need to be bypassed. If the project was to have any chance to seize the opportunity it would have to be get underway as quickly as possible, through informal understandings, rather than properly worked out formal specifications etc. The limitations on the time-scale were placed by the urgency of the need for some response to the inventory problem, thus if Centaur was going to be of help with this then it needed to be on the market within no more than a year. In addition, the opportunity of selling to the US libraries would only work if the marketing of Centaur fitted in to the college library buying cycle. The purchases were characteristically made at the beginning of the financial year, in the Spring, and if the machine was not available by that time in the year-after-next, then it would not sell. There was, furthermore, every chance that one of the rival companies would produce an identical product.

The assumption that everything would go ™right first time›, whilst not inconceivable, was, however, more of an hopeful possibility. It could do, but it was not to be counted on. In addition, the Unit Manufacturing Price (UMC) set for the feeder was $400 dollars was, from the point of view of the project's initial position, totally impractical. The project was aimed at a specific, modestly sized marketing niche, and would, if successful, clear about a thousand copiers from the inventory, and thus the production run for the project was of a thousand units which meant that the UMC could not be brought within range of the $400 dollar target. The costs of designing the unit, tooling up for production and manufacturing it could not realistically be defrayed over such a small production run, and it was expected that the actual UMC would be somewhere in the region of three times the UMC.

Centaur's scheduling and budgeting set them a task which was bordering on the impossible. Getting a design to work out without the prospect of a second prototype, of compacting the design, development and manufacturing activities within the time-span allowed and bringing the UMC within sight of the $400 figure all seemed like things which could not be done. The engineers did not know if the project could be done, how they were going to do it, and they were not confident that it could be done. This was an occasion when the aggressive scheduling produced a ˜project from hell".

Schedules and budgets are not always so rigorously fixed as they were for Centaur. The initial setting up of the Archer project had substantially under-estimated the time it would take to make information available to the project. Archer involved the customisation of a Japanese machine, and there had been negotiations between managers from the UK and Japanese sites in which it had been agreed that there would be information available from the Japanese engineers who had participated in the original design. They were available by telephone and email to respond to inquiries. However, what was not allowed for was the fact that, unlike their managers, the Japanese engineers could not speak English, and that, therefore, far from their being the rapid exchange of information by telephone and email there was in fact considerable delays whilst the query in English was translated into Japanese and the response in Japanese then translated back into English. This meant, too, that the acquisition of the information was a much more significant charge on the Japanese than had been envisaged, and one that had not been budgeted for.

As these problems involved in the development became apparent Archer was rescheduled, but the project began again falling behind the new schedule, this time as a result of the mentioned engineering difficulty of perpetuating what had seemed a nominal engineering requirement, namely the retention of the machine's high speed capacity. In addition, the attempt to use new software engineering tools that we have seen were being used on the project was also holding up the work. These were not matters which could have, entirely, been ascertained prior to the project, and were, perhaps, things which could be found only by actually undertaking the work, finding out how long things actually take, how difficult things are to work out etc.

The fact that projects depart from schedule and exceed budgets is, then, something which is only to be expected, even if it is only to be expected after the fact. The engineers have to discover what it takes to do the work by doing the work, and though they can themselves make estimates of the realism of schedules and budgets, they can also only determine, in the course of the work, just what will be involved in doing it, just what difficulties will be encountered, and just how long it will take to get through the actual work. The schedules which are set are often ones which it is acknowledged will be problematic to meet. With the Centaur case, the engineers did not see how they could work within the project's constraints, but this did not discourage them from looking for ways of doing so. Though falling behind schedule was only to be expected it was, at the same time, to be as assiduously avoided as possible.

Engineers engaged in their projects under the overwhelming probability that things would go wrong, and though engineers could anticipate some of the ways in which things might go wrong in terms of there being clear recognised risks, they were also aware that things would go wrong in ways they could not anticipate. Often, they felt, that trouble would often emanate from sources where they would be least expected. The fact that things did go wrong, that projects were thrown off course, was not, however, something which disoriented and disorganised the engineers, for this was the very stuff of their work. The fact that what they were being asked to do work which bordered on the impossible, did not , as remarked, discourage the Centaur engineers. The UMC was patently a massive problem for them, and, at the outset, they did not see what they could possibly do about this, but they laboured on, seeking to make cost savings wherever they could, recognising the disproportion between cost-paring efforts they were making and the massive cost reduction that they would need to make to meet the UMC. The cost parings were in many respects all that they could do about the UMC since they could not, in most of their design and development work see any major ways in which they could affect cost. As the project progressed they could begin to consider ways in which they might achieve extensive savings - finding ways of extending the production run, seeing if they could find anyone who would be interested in , could find a market for the high capacity feeders, was one possibility they considered. Another was to save costs on tooling. The usual pattern was to use ™soft tooling› to produce the parts for the prototype, to use tools made out of aluminium, which were cheap to produce, but which were not very durable, and then to use ™hard tooling› i.e. harder metals to provide the production-run manufacturing tools. They began to contemplate the possibility that they could make a major saving by using soft-tooling only. Since the production run was for a thousand units, it was conceivable that though the ™soft tooling› might not be durable, it would be durable enough for a short production run of a thousand units.

WORKING PRACTICE

Work within the site centred upon project teams. Engineers were drawn from Departments and so were managed on a matrix scheme. As we have seen, projects could vary in both time and size. The Centaur project was an unusually short project, conceived to be carried out in little over a year. The Thames project, at five years, was more usual, and was for the development of an entire machine, albeit based on the infrastructure of a previous model. Centaur was a small project, with some eighteen staff, most of whom were to be attached to it for its duration. Thames was a large project, and in its main development phase had somewhat over two hundred people working on it. The staffing of a project would usually vary over its life. A relatively small number of people would be involved at the inception phase. Staff would build up as as the work intensified only to dwindle again during the "winding down" phase.

There were engineers working on other tasks than those involved in projects. These tasks being sometimes assigned as ways of giving engineers who were temporarily without project attachment something to do until they could be assigned. Thus, after a project cancellation, one engineer was assigned to collecting data about the faults of the print cartridge on a machine which was already on the market and receiving complaints about cartridge failure.

The matrix management scheme meant that engineers were attached to different departments, most prominently: mechanical engineering and electrical engineering, but also human factors, industrial design and systems integration. The departments were under the control of departmental managers, whose primary task was to ensure that projects could be supported. It was their task to assign staff to the projects, and to ensure that their availability was such that they could take up work on the projects as needed. Projects were based upon the permanent engineering employees, but could be supplemented by additional temporary staff or people re-assigned from other sites within the company. The latter often commuted for the period of their assignment. Thus, there were engineers on two of the projects who commuted weekly between the UK and the Dutch site. These engineers were brought in to provide expertise that was lacking in the UK site but essential to the projects. At any time an engineer might be full-time on a project, or part-time. At the same time, he or she might be working on two or three different projects.

Projects were managed by a project manager, who was mainly concerned with organisation and co-ordination of work on the project as a whole. The primary responsibility of the project manager was to ensure that the project would deliver its product on time, budget and up to standard. Other tasks included interfacing between the site and other sites involved in the project, and between the project and the rest of the organisation. Like the engineers who worked for him, the project manager might be involved in more than one project, depending on the size of those he had to manage. The product development manager would be concerned with ensuring that the engineering work on the product was properly done. It was up to him (and in our examples they were all male) to deal with the engineering problems that arose, and to ensure that all aspects of product design and development were taken care of.

The projects were sometimes organised around the architecture of the product being developed. The design of the product might well have a modular structure, being composed of identifiable sub sections such as stacker, fuser, belt, processor and software, for example. Engineers within the project would be subdivided amongst groups identified withsuch components. The subgroups had their own leaders who reported to the project manger. Thus, the software sub-group on the Archer project which consisted of seventeen engineers had a team leader with direct responsibility for the day-to-day organisation of the engineers, closely involved with their work and to whom they were directly accountable.

Centaur, however, was not organised on that basis, being concerned with the production only of an "add on" unit and involving only a small number of people. In Centaur's case, with the exception of the electrical engineers, there was one individual for each specialism on the team. where one locally based engineer represented a permanent interest relative to the Venray based Belgian engineer who had only a part time, commuting involvement.

Work on the projects was organised under the Product Delivery Process "life cycle" model run in conjunction with the Company's Total Quality Procedures. PDP specified a succession of phases through which the project as a whole had to pass, with associated milestones and review procedures to permit the transition from one phase to another together with the release of further expenditure on the project. The PDP was guided by the QCD criteria - quality, cost and delivery - and provided, in a hierarchically structured format, increasingly specific sequences of operation for the different aspects of a project. Thus, for instance, summarised in some thirty single spaced pages were the detailed procedures for the development of software within the project.

MANAGEMENT BY PROBLEM SOLVING

The organisation of workloads followed a management by problem solving strategy. The work proceeded through the identification of problems on formatted problem report forms, which provided a statement of the problem as it was encountered. These forms were then transmitted to a person who entered them onto a VAX computer, where they would then become a basis for printing out as a enumerated series of problems , each with their individual number. This enabled the assembly of a project problem list, which would total and print out the problems currently encountered, in a variety of combinations and ways. Engineers were assigned responsibility for a collection of specific, numbered problems, which were the ones on which they were to work, which comprised their current workload, and they could be provided with individualised print outs of their problems. On the other hand, the team leader could be provided with a print out of all the current problems being worked by the engineers he was responsible for. The print outs could be more or less detailed, containing some specification of the problem or merely an identification of features of its organisational processing such as what number it was, who was working it, how they were progressing on it, when it was scheduled to be completed, what was the date for review of its progress etc.

The problems were graded according to three types , critical, major and ordinary according to their seriousness and intractability. These categories reflected the threat that the problems represented to the QCD›s. Critical problems could not be resolved without delaying the project interminably, at other than unacceptable cost, or in technically effective ways and, thus, threatened its very continuation of the project. They were such as to call its viability into doubt at the next review,. Major problems threatened serious consequences for the QCD›s, but did not threaten the existence of the project. They might mean substantial sacrifices in the quality aimed at, or make a significant ™hit› on the product's cost or result in extensive delay and the postponement of the target delivery date. Ordinary problems were those problems which could be resolved routinely enough through the application of the engineer's skills, and without any meaning for the QCD›s. The accumulation and clearance rates, and the proportion of problems in the different categories, was one of the main bases on which the project judged its progress. Knowing how they were doing on the various categories of problem was a vital and pervasive feature of the engineer's engagement with their work.

It was expected that the project would, initially, accumulate problems, and the rate at which they would be cleared would be significantly less than that at which they were accumulated. However, experience told them that , at some point, new problems would slow down and the clearance rate would advance. Also, critical and major problems were to be expected in the early phase of the work, but these should be eliminated as early as possible, certainly prior to reviews. A typical project was expected to develop a few critical problems, more numerous major problems and a vastly more substantial number of ordinary problems. Ordinary problems are ones that can and will (given time) be solved; the major problems should be soluble, though this may involve some revision of project objectives for example, some reduction of standards Critical problems were the key. They may not prove soluble - at least, not within any acceptable parameters of the QCDÕs. Progress on problems and the general progress and outlook for a project is reviewed in periodically scheduled formal reviews which are very serious affairs providing for the release of further funds for the project or the termination of projects.

CONCLUSION

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4.0 Project Problems

We have been consistently making the point that engineering is a type of problem solving and we have been providing illustrations of this and other points by dipping into the various projects that we observed the engineers working on. However, the projects were not all of a piece and they had their own problems which were not necessarily shared by other projects. They were also examples of the range of engineering projects that were engaged in at the site. In this, the last chapter, we turn to the individual projects and highlight their own particular problems in order to expand upon the idea of engineering as problem solving by emphasising the range of engineering problems engineers confront.

CENTAUR

Team Composition

There was, as mentioned, a shortage of work on the site which was matched by a shortage of appropriate staff. The recent "downsizing" had been indiscriminate with respect to engineering needs, having been dictated by the need to achieve voluntary reduction. Thus the downsizing involved letting those go who were willing to go, either by taking voluntary redundancy, early retirement or relocating to other sites. This meant that there was an over availability of senior staff, and that Centaur was somewhat ™top heavy› with senior engineers who were the ones who were available for assignment to it. Indeed there were a number of staff who had equal seniority to the product development manager, whose first project this was. Further, there was not an appropriated skill mix on the project, for example, the project required an electrical engineer who was deeply familiar with the model of machine which was to serve as host to the Centaur attachment, but the only engineer who was available for this was currently at the Belguim site and not available at the commencement of the project. This meant that an engineer from the local site had to be assigned to the project pending the arrival of the Belgian engineer. However, the local engineer was loth to make anything other than the most general and provisional decisions, was unwilling to pre-empt to decision making space of the engineer for whom he was temporarily deputising.

It transpired that the Belgian engineer was not going to be able to come to the site for the full working week, and that he was not relieved entirely of duties at his home site, and that, therefore, the work on Centaur would have to be fitted into three days. After a couple of weeks involvement in the project, the Belgian failed to materialise for Centaur's weekly project meeting. Investigation quickly revealed that he had been forbidden to travel overnight from his home site. His supervisor in Holland had found that he was leaving their site at mid-afternoon in order to catch the last evening flight to the UK but had forbidden this as he was travelling on working time allocated to the Dutch site, not to Centaur's. The earliest morning flight, did not, however, allow him to arrive until midday on one of the insufficient number of days he was actually available. The project manager , on learning this, disappeared to make phone calls, and by the following week the arrangements had been sorted out in Centaur's favour. This meant, though, that other work on the project, especially that requiring collaboration or consultation with the Belgian, had to be organised around his timetable.

Holding off Commitment

Engineering projects face a problem of holding off making a decision too soon but needing to begin the engineering work. If they make a decision before they have assembled the necessary resources then that decision may have to be re-visited with the attended waste of resources that will incur. But if they hold off making a decision until they have assembled the necessary resources they may never begin the project. There is thus a trading off between holding off on commitments for as long as possible whilst they try to work out as much as possible before starting to make specific decisions, and commencing the engineering work.

In the day to day engineering there are the same problems - how to decide one thing before others, how to decide some things so you can start work but how to delay things until other things are properly worked out - thus, Centaur's chronic problem, how to get started on things so it could make some progress with a really difficult timetable, but, on the other hand, the need to wait for things to be worked out, things which couldn't be worked out yet, or things which it would take some time to work out, or things which couldn't be worked out until yet other things had been settled. Thus, the size of things was a problem for them - the workings of the Centaur had to be packed into compact space, and the amount of space involved in the design of (a) the printed circuit boards and (b) the electric motor were both problems like this - the design and configuration of the printed circuit boards were important, with respect to the amount of volume they consumed but these could not be worked out at the start, since it had to be clarified just what the electrics and software were to do, and, furthermore, the working out of the printed circuits (and the software) awaited the arrival of the Belgian engineer, since it would be foolish to start trying to work these things out in detail without his expert knowledge, and, of course, once he was Ôon boardÕ there was the further necessity to await the actual working out of this to arrive at some firm decisions as to how much space they would need.

It was part of their engineering lore that the size of the motor increased over the project, that problems are resolved by using more power, which requires a bigger motor, so that almost certainly you are going to need a much bigger motor than you thought you would - but how long to do you wait to see how big your power requirements are going to be, when are you going to be able to make a decision about the size of the motor? At least, they could start investigating the motors available and looking to see what options were available, and what timescales might be attached to them.

In the brief period spend at the commercial software house, the notable feature of the discussions was the insistence that various things needed to be promised to the contractors, that deliverables needed to be specified, which was matched by the equal persistence of one of this small team (of six) that it be recognised that these agreements were being made only on the insistence that they were not ™set in concrete›, that they were provisional, and revisable. The timeliness of the point at which one makes firm decisions and goes ahead on the basis of them is something important. For Centaur, their problem was that they needed to get some things decided in order to get things moving, but the conditions of their operation were holding them back, that the absence of the Belgian engineer meant they couldn't settle things in his absence, that, without the information he brought with him, they did not have the requisite knowledge to make some decisions, and that they took the risk, in making decisions, of having to revise them when his assistance became available. The time pressure on Centaur was being added to by the problems of team composition. Is now the time to decide something, and if now is the time to decide it, can we now make the decision.

It is not necessarily until you begin to work out a decision that you find what might be involved in making it - thus, the design for Centaur involved relating the new HCF to the sensors on the existing machine in order that the central processor and the interface would be able to register the states of the paper trays - open, full, empty etc. However, when it came to working out the placement of the sensors it then became apparent that it was not merely the sensor directly related to the feeder which it was necessary to deal with, but the pattern of the relationship amongst the sensors for the other trays also, and first efforts to work this out were proving complicated - it was beginning to look as though they could not achieve, through the existing arrangement of sensors, the appropriate registration of the state of the paper trays. However, one of the requirements on the design was that it avoid modification of relationships to the host machine›s central processor - there were patent ™good reasons› for this, in that keeping the installation as simple and brief as possible was a desirable thing to achieve.

The Timing Diagrams

The issue of "the timing diagrams" also arose as a problem of judgement. The timing diagrams for the host machine were important to Centaur - the feeding of paper from Centaur had to coordinate with the movement of paper from the other paper trays, and with the organisation of the ™paper path› and, particularly, of the movement from roller to roller along that route. The gap between one sheet of paper and another was judged in milliseconds, and the availability of the timing diagrams would allow the calculation of the way Centaur's paper feeding would integrate into the movement of the paper path. The production of timing diagrams was recognised to be a skilled job, one which required a good familiarity with the machine for which they were being drawn, and a member of the original design team for the host machine, Angela Thomas, was currently working on another project. There was a prospect that she might know where the original timing diagrams were, if they had been kept, and that she might be freed from her current work long enough to redraw them - this would save time, if it could be worked, since it would mean one someone else would be freed from the task, and, additionally, there was the fact that there was no one on the project properly equipped to do the job. There was someone - Doug - who would do it - who would have to do it , if it came to it, though Doug was neither really knowledgeable or skilled in the relevant respects, but he was the nearest thing to it on the project. The product development manager was confident that he would be able to effect the Angela Thomas option but there were others who thought that this was a time wasting procedure, that the timing diagrams were important and that they should be started on as soon as possible but, as noted above, these dissenters did not want to make an issue of it - the product development manager was firmly confident that he could get the favourable outcome, and that it would be worth it, and the others, who were more sceptical about the prospect of a favourable outcome, acceeded to his judgement, though they were no less confident that a mistake had thereby been made.

The desired outcome was not forthcoming. The other project would not agree to the release of Angela Thomas, and now the diagrams had to be worked out again and redrawn, by somebody who could do this, but only slowly, and only by taking time off from other and equally pressing work to be done - his was the task of developing the 'controller', a control based on a computer keyboard that would enable them to run the prototype in simulation of actual machine operations, to operate it for test purposes. This was something to be done in anticipation of the completion of the prototype, since they needed to start test-running it immediately the prototype was available, and the production of the controller was a relatively protracted thing, which hard to be started in "good time", allowing for the fact that it would have to be threaded into Dave's other work. There was a real problem in relation to the work that needed to be done, what could be put aside or must be got on with, and whilst Dave had to find time to progress with the controller board, he also had other work to get on with - he couldn't give up one in favour of the other. The hope that someone else might be able to do the timing diagrams was, then, the hope was that this would lighten Dave's stretched workload, but now this had to be put back on Dave's shoulders - Dave had only a vague idea of how to work out the timing diagrams, and their development involve the use of the CAD (computer assisted drawing) facilities, but Dave was not properly trained for these and was very rusty in their use, which meant that he often spent more time re-working out how to use the equipment than he did progressing with the drawing. For example, he spent an hour and a half attempting to link two lines with another line, but found that each time he identified the trajectory of the line it shot beyond its intended end point and went off the screen. Naturally, Dave couldn't see why he couldn't get the line to go, and he made numerous efforts to redraw it without success, and it was only after ninety minutes that he checked back to the range of drawing devices available on the machine and realised that he had been using the wrong one — having now identified the right icon, he was immediately able to position the points and join them.

Salami Slicing as a Way of Working

The pressure on Centaur to expedite its proceedings meant there was a pervasive looking for savings, and that each and every avenue of activity might be scrutinised for either/and a quicker and a cheaper way to do it. One of the ways in which to attempt this was through reducing the number of design tasks - rather than treating the project as subject to the full range of design requirements, the project team began to wonder if they could reduce those. They began by operating on the assumption that they were designing, as they usually would, a machine that would be marketed world wide, and that they had, therefore, to incorporate the requirements of different markets into their design. For example, the range of papers - in terms of quality and size - which a machine could contend with normally had to encompass the variety that would be met across a full range of user sites. Climatic conditions, too, had to be designed for - the proclivity of paper to curl and thus to generate jams varies with humidity. Under pressure to get all this done, the team began to ask themselves whether they could get out of it? Since the purpose-in-mind for the project was to achieve a thousand sales in the North American college library market, perhaps it was unnecessary to design for the full range of possibilities - perhaps they could design specifically for that market, perhaps they could design only for the sizes and qualities of paper and climatic conditions expected within that market? And, if they were to design only for the North American college perhaps they could also dispose with the need for translation of interface messages and of the language on the packaging?

At the same time as they were contemplating these possibilities, they were also exploring the possibility that they could widen the range of actual markets, that they could increase the potential market and thus the production run, and thus reduce the UMC to something more akin to the target they had been given - something they could not hope to achieve on the production run set, even with "soft tooling" arrangements. There was, of course, no contradiction here, between looking, on the one hand, to ascertain that the project was restricted to the niche market, with the savings that they thought could be thus induced, and, on the other, attempting to conjure up new markets, which would mean the design would require the full diversity of papers and conditions, not to mention a range of translations.

Problem Solving as a Way of Working

The engineers were looking for any and all ways to solve their problems, in the full recognition that they probably couldn't solve them all, and that, in certain important respects, the decisions were out of their hands, would be decided in the review process or by management - the UMC might well end up a largely irreducible problem, whatever they did about the meeting deadlines and getting the product designed and out, but they should consider anything that might help expedite the execution of the work.

Thus, they raised and adopted the proposal to provide less-than-finished drawings to suitable vendors, as the suppliers of parts were known. The suitable vendors were those who were well enough known to the project team to be dependable, to be parties upon whom they could rely to be able to work from less than fully finished diagrams, who could be counted upon to know what these would mean. The engineering drawings are, of course, instructions to the manufacturer's of parts, and the finished drawing is meant to be fully explicit as to what is required from the manufacturer, but it was felt that some vendors were familiar with company practice and design to be able to work from "rough" rather than fully finished drawings, and that this would reduce the time in producing the drawings and initiating the production of prototype parts.

The desire to simplify the requirements was associated, also, with a desire to clarify the requirements. As we mentioned, the project was set up speed, and on an informal basis, with commitments from those in World Wide Marketing to provide further information on their requirements and as required for design purposes - one promised service was to conduct and report on a survey of the various kinds of papers in use in the niche market. The intent was to move from the informal basis for the project to a more formal one, but the steps to do this, to meet the formal requirements for a worked out "business case", had not actually been taken - having got the thing agreed to and initiated, then the move to the formal situation was deferred, and then the individuals within Worldwide marketing with whom the initial agreements had been made had changed position, in one case, and left the company in another, which meant that working out the formal support was now a problem - those who had taken over were not familiar with the project and its specific rationales and requirements. Getting responses became problematical - people would not respond to telephone calls, emails and so forth, or, if contacted and ostensibly agreeable to doing something - they would be delayed in their delivery of the response - they would keep promising the survey of papers, but this kept failing to materialise. The engineers wanted information on these things to try to work out the arrangement of the paper trays and the location of sensors.

The engineers were, of course, quite capable of adopting the attitude that they would face problems when they came to them - though there were many unresolved matters which could affect their design, they had no choice but to press on with design activities, to try to make allowance for eventual design outcomes - assuming, for example, that more space will be required for the motor than is currently specified - and to work out some solutions without knowing what the eventual outcomes will be , but having to make decisions now and to face any problems arising from subsequent developments when they come to them - hoping, perhaps, that they would never come. It wasn't a matter - in this case at least - of putting off evil necessities as long as possible, of postponing things rather than facing up to them, but, rather, of knowing there were things that needed to be done but that just could not be done, that the conditions for making those decisions were not available or did not apply.

Getting it 'Right First Time'

The pacing of the Centaur work was governed by the fact that they had only one shot at the prototype - they had both to expedite the work, but also to pace it so that they got it "right first time". There are cases - we shall shortly discuss one in connection with Archer - where engineers count on the fact that they will be able to go back and do work over, where they satisfy themselves with inferior or incomplete work to manage a time pressure, confident that they will subsequently have an opportunity to go back to it and improve and/or complete it, but in Centaur's case this was not so - they could not count on opportunities to improve aspects of the design after the first prototype had been produced, and so they could not expedite the work by doing it other than properly the first time, and this was the another limit on their "design space". They had to keep the time spent on exploring design issues, problems and possibilities down to the necessary minimum, but ensure that they were dealt with carefully enough to provide adequate solutions to the design problem. They could not, of course, be confident that the prototype would be satisfactory, that it would work out when put together and tried, for, of course, the painstaking attempt to ensure adequacy does not guarantee it, and they must wait to find out whether the thing will assemble and whether, when assembled, it will work anywhere near properly. It was a big relief to find that the prototype did assemble, and that the measures needed to get it to do so involved only minor matters, such as the cutting of different spaces and the relocation of screw holes. It was also encouraging that the very briefest attempt to operate it had "moved paper", but that was the point at which the project was cancelled and they were left, only, with the judgement that the prototype was promising and the judgement of the manager of the mechanical engineering department that it was time for a "value engineering" exercise, to see if the product was, so to speak, over-designed - for example, he observed, pointing at the prototype - there was a lucite door on the feeder, but what was that for, given the thing was to be contained within an outer steel jacket — nobody would see it, and it didn't serve any safety purpose — did they need a door at all, and if they did, need it be made of such good material?

We have already discussed the way in which Centaur's engineers sought organisational ways around their engineering problems and have outlined the problems with the timing of manufacturing expenditure, the

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5.0 The Working Environment

INTRODUCTION

During one of the Centaur Project meetings, it was the leading engineering draftsmanÕs turn to report on progress, which, in his case, refered to the production of finished engineering drawings. He stood up and announced that first he had to explain something elseÐthe scheme he had developed for tracking progress on the work for which he was responsible. Based on his experience, he had created measures of difficulty to be applied to each task. The scale ran from 1 to 6 and could be used not just to evaluate the amount of drawing work that to be done on a project, but also for assessing the complexity of jobs. Using the scale, he claimed to be able to assess progress while at the same time allowing for the fact that some jobs took much longer than others. He could graph the actual progress of the work and use the distance between it and expected progress to measure the extent to which the work was Òfalling behindÓ and hence remedial action was required..

Both the project and product managers were excited by this technique. For the moment, the business of the meeting was set aside. Interest centred on the technique and how it worked. To everyone it seemed that the lead draughtsman had found a solution to a very general engineering problem, namely the Ô90% finishedÕ problem which we described earlier. As we saw, there, the 90% finished problem is often compounded by the Òmythical man monthÓ problem. That is the provision of additional man months to the project to help claw back slippage does not always bring it back on schedule.

Since it did not rate all jobs as equally difficult and equally time consuming, the lead draftsman's solution would not make the "90% finished" mistake. The "percentage finished" calculation would depend upon the number of tasks completed and their comparative difficulty. Not only would this prevent the "90% finished" error, it would also provide early identification of points at which the production of drawings was beginning to fall behind schedule. Corrective action could be taken before the work moved significantly off schedule. In the classic "90% finished" case, by the time it is realised that the work has fallen behind schedule it is then too late to make the necessary corrections. Before the meeting finally returned to the progress of Centaur itself, the lead draughtsman was congratulated and advised that he would have to present an account of this to more senior managers .

"90% finished" and "the mythical man month" problems were not how our engineers talked about things. They knew the problems, rather, as difficulties they had in keeping work on schedule, in working out when it was drifting off schedule, and of being able to get it back on schedule. That there might have been discussion of these and related problems in the engineering management literature would have come as no surprise to them. But, as working engineers, they had little inclination and less time to pursue such concerns for themselves

What our little story demonstrates is the interweaving of two very prominent themes of the working environment at Welwyn. These are the serious professionalism of the engineers on the one hand and on the other the concern for career progression and personal accomplishment. All of those who were at the meeting saw that the lead draughtsman, through the development of his new technique, had created the possibility of generating "some visibility" for himself. Moreover, they saw (or at least the senior managers saw) that it was part of their responsibility to encourage him to maximise that opportunity.

What the lead draftsman was faced with was the possibility of playing simultaneously in two arenas, that of the professional engineer and that of the aspiring employee, without needing, for once, to have to trade one off against the other. The trick would be to use the good professionalism to demonstrate good Corporate citizenship. Many years ago, in an endeavour to capture this aspect of institutions and organisations, Norton Long talked of settings as ecologies of games. Individuals participate in numerous games and part of what it takes to be a fully accepted member of the culture in any environment is knowing which games to be active in and when; and how to ensure the demands of one game do not interfere overmuch with those of others.

As we have indicated, two of the most important games at the Welwyn site are those concerned with the professional practice of engineering and with personal achievement. As are all such games, these are played out at many levels. In this chapter we will focus on how they appear and are managed at the project level. The need to manage participation in both games is, of course, crucial since the demands of one may well be at odds with the other. In our view, the prevailing cultural ethos of our engineers is one which manages the potentialities for conflicts such as these. By requiring conformity to their culture, the regulate the boundaries of these two games. In what follows, we will describe the ways in which these boundaries are marked and the resources which engineers themselves use to promote each 'game' and keep them separate. In the first section, we discuss locally required procedures are used to ensure dependable professional practice. In the second, we take up the management of the obligations which engineers have to advance themselves through promoting the project.

SHAPING ENGINEER'S ORIENTATIONS

What the lead draftsman was trying to do was develop a new dependable work practice. In common with other engineers, he showed a pre-occupation with ways of doing things which can be counted upon and which will provide sure fire ways of delivering the end that is sought from them. Of course, engineers already have a considerable number of such practices. But they also know that their dependability varies widely. Often things fall well short of the "sure fire". Their concern for this is not just a reflection of the need to get the job done but also of their deep and serious professionalism. As engineers they want to improve their practices. Moreover, they are not just concerned with the development of dependable engineering practices, in the sense of a better understanding and control of the principles underlying engineering phenomena and operations and more reliable or exact methods of calculation. They are also interested in the development of more dependable ways of organising the project work.

Before beginning, we should enter a cautionary note. In talking of the engineers' search for more dependable practices, we should not be heard to assert that their current ones are arbitrary, ill-thought out, or rarely adhered to. Rather, what we are pointing to is the well known fact that it is impossible to provide totally dependable and totally consistent procedures. Things always go wrong, as the eponymous Murphy reminds us. Engineers know this, as is attested to by our story. And so do engineering managers. The latter have devised a number of formal procedures to ensure that the outputs of the development process satisfies the quality and other requirements set doen for them. These procedures are collectively known as the Product Development Process (PDP).

Ostensibly, PDP is a management process. In saying this, we do not want propose a universal and irreconcilable opposition between management and engineering. No doubt, there are occasions on every project where management concerns run counter to engineering ones. But such occasions are just that, occasions, not the rule. At the same time, we do not want to be overly starry-eyed. To be sure, PDP does, now and then, elicit resistance from the experienced and jaundiced engineer. For the most part, however, the constituent procedures of the PDP tend to be evaluated selectively. Many of them are treated as embodiments of engineering good sense.

Moreover, when we call PDP a management process invoked to ensure quality and timeliness, we do not mean that left to themselves, engineers would totally disregard these criteria and, out of ignorance and inertia, lapse into "bad practice"; a tendency which managers would need to pre-empt. This is not how things were treated. It is not that the management suppose that they "know better" than their engineers do, but that, very often, the engineers themselves "know better" than they (in practice) do. Regularly, because, as they would say, "It seemed like a good idea at the time.", they engage in what they themselves know to be bad engineering practice.

What this highlights, both for us and for our engineers, is that hindsight is only available after the fact. In the heat of engineering work, how things will eventually turn out can only be guessed at and actions based upon those 'guesstimates'. Naturally enough, what seems like a good if unconventional and unsanctioned idea at the time will often (but hopefully not too often) turn out to have been bad engineering practice.

What the PDP is primarily directed to is managing the complexity of large scale projects. Senior Development Managers recognise the pressures upon project leaders. People constantly come and go; knowledge about the project and its progress is distributed in space and time; problems multiply and compound one another. And everything has to be worked out and worked through in the detail. In what follows, we show some of the ways in this engineering culture, PDP was regularly used by project managers to handle the day to day problems which they faced. When they used it in this way, the engineers contrasted it with working "without of their heads on" that is relying on their own experience and insight to define and prioritise problems. That it was also used as a management device to check progress on the projects at the specified times was another, somewhat ancillary function it performed. At the risk of over-dramatising things, we might say that our engineers deployed a number of tactics by which their projects were first subjugated and then kept under control. We will summarise these tactics as engineering maxims. Everyone (well, the senior engineers at least) at the site could, if asked, have provided versions of these maxims

(Use) the PDP as an aide memoire ..

Many of the complexities the engineer is trying to juggle have to do not with the effective accomplishment of the task, but with ensuring that the task is accomplished in ways which integrate it with the rest of the work on the project. This means that there are often occasions when the requirements of the final product transcend the specific requirements of the task in hand. Given the engineer's natural focus on the tasks in hand, there is a very real possibility the full range of relevant considerations and the domains to which they are applicable will slip the mind.

Centaur was our product manager's first development project. Although he had worked at the site for over twenty years and was extensively familiar with design and development procedures, he was not confident that he could ensure that he was aware of, or would appropriately recall, everything needed to be attended to in keeping on top of the project. As a consequence, the manager would often consult the formal PDP to remind himself what needed to be done and to check the right things were in hand.. One example of this tactic and how beneficial this proved related to the development of packaging. and to ensuring that the packaging labels and product documents were translated into the appropriate language. Since this was not tied into the immediate work of designing and developing the High Capacity Feeder, it was unlikely that in the course of normal day to day activities, his memory would have been "jogged" to organise the packaging. And yet, it was crucial that correct labelling and documentation be initiated early enough to allow the design of the packaging and the translations to be available at product launch. By consulting the PDP, the project leader was reminded of the need to ensure that this crucial work was initiated.

Similarly, planning the testing of the prototype was also something that need to be planned for well in advance of its initiation. Once again, thinking about the testing was not something that the Product Development Manager was accustomed to do. As a mechanical engineer he had not previously concerned himself very much with the planning of testing. he might well have taken it for granted that the testing would be organised when necessary. In his new position, however, it was his responsibility to ensure the testing phase was planned. By checking with the PDP, he was able to provide himself with a just-in-time reminder that this needed to be done.

For the development projects we worked on (and presumably for every similar project) "the Devil was in the detail". Although robust machines, photocopiers are intricate and complex structures, whose elements need to be closely integrated. The timings of events in the machineÕs operations are often of the order of milliseconds, and, of course, the machines were themselves composites of large numbers of parts and of substantial numbers of lines of code. There was thus always the possibility that some detail might be overlooked, that something might not be done, or that it might be done in the wrong way. Again the PDP manual provided numerous checklists of things to do in particular aspects or phases of projects. The manual was not, however, employed to ensure the details were covered, but as a check, as something to be looked up just the relevant manager/engineer had overlooked anything. In that sense, rather than being the first priority, the manual was a fallback device, something to be consulted as needed, and to be consulted for detail. The formal procedures as such were ones with which the engineers were quite familiar, and which they could invoke without need to consult the manual. Rather, what we are pointing to is the mnemonic role which the manual had, particularly in respect of the detailed specifications of what needed to be done.

Use Specifications Documents to define problems

One prevailing concerns on the projects was to ensure not only that things were done right but that the right thing was done. That is, that the problem which was solved would be the right problem to be solved. Although the engineers may be very successful in solving what they see as their problems, the worry was that I) they may have departed from the specifications and thus created new problems and ii) could have failed to solve the problem they really should have been solving. The latter was a concern not simply because it was a waste of time. It cold be that the solution they had arrived at might just make the original problem worse.

The worry was, then, that engineers would mis-identify a problem because they had not consulted the specifications. Problems with a machine had to be construed in a certain way and were not to be defined simply by the fact that a machine did not operate in an effective way, gave strange interface messages, ot the like. Problems were, rather, defined in terms of a discrepancy between what the machine was supposed to do, according to the specifications and what the machine was actually doing. This is not to say, though, that the specifications were inviolable. Sometimes it was recognised that they might be inappropriate and need to be revised - but they were not to be disregarded. In the first instance always, a problem was to be conceived strictly as the deviation from the specification; that is, as the departure from what should be as specified in the most up-to-date version of the project documentation. It was expected, though, that engineers, if left to themselves, are likely diagnose a problem and what it would take to correct it either without bearing the specifications in mind or depending on unreliable recall for what it was that the specifications actually required.

What this maxim actually attends to is the natural tendency in all of us not to want to interrupt the flow of work, of getting on with the task, to check out that our interpretation or recall of the procedure we are supposed to be following actual matches "the documentation". When this occurs, not only is the fault left unrectified, it might even be undetected and hence re-appear later in ways which will make it even more difficult to define let alone resolve.

To ensure that problems were defined in terms of specifications, engineers were required to use Fault Report Forms (FRFs) These forms have two components for stating the problem: 'what is' and 'what should be'. The 'what should be' had to be a word-for-word citation from the Specification Document. Since it had to be literally word for word, the engineers were forced to look up the specifications. The forms were also designed to force a consideration of the way in which the description 'what is' related to the 'what should be' entry. It thus provided the engineer with an opportunity to reconsider any conceptions already formed about the actual problem.

Don't Jump to Conclusions - Stick to the Method.

Related to the issue of solving the wrong problem is the problem "jumping to conclusions". The 'problem' behind a malfunction is seen as 'symptom' and the solution of the problem is understood as the elimination of the cause. In ad hoc problem solving, there is the risk that the engineer will treat the symptom as the problem, and will eliminate it rather than the cause. However, the cause may give rise to a plurality of symptoms, and the fact that the engineer can make the identified problem 'go away' does not mean that those same symptoms may not later recur, or that the actual problem will not manifest itself in other symptoms. The risk is, then, that the engineer will 'jump to conclusions' about what the problem is and about how to resolve it and will take what is, from the project's point of view, precipitate action.

The 'problem solving wheel' is an organisational device intended to counter this problem. It is a method for problem solving. It involves a series of stages each identified by a name and a colour, and which are portrayed in the form of a circle (or wheel). The segments of the wheel are to be followed through in a prescribed, step wise fashion. Before the solution can be described, the nature of the problem should be first investigated. Data should be systematically collected on "the problem" and should be subjected to various forms of statistical analysis to ensure that the problem was correctly identified. Only when these processes have been completed and problem was correctly identified should solutions be sought. In their turn, solutions should comparatively appraised before a candidate settled upon. The promotion of the method and the display of 'problem wheel' diagrams on the walls of meeting rooms throughout the building encouraged engineers to bear in mind the risks that were run if problems were wrongly identified because they had jumped to conclusions about what should be done.

The enforcement of the 'problem wheel' approach was managed through the 'problem list' documentation. This would consist of print outs with entries such as "blue two" which would indicate that whoever was 'working the problem' was still collecting data. "Yellow five" would indicate that they were in the penultimate stage of the operation, and were ascertaining that a candidate solution actually did work. The recording of progress in this way allowed simple and straightforward answers to the perennial and pressing questions of "Where someone was on X or Y problem". The print outs showed exactly where in the process they were.

Make sure the documentation gets done

The reciprocal of enforcing the pursuit of the problem wheel method through the documentation was, of course, the problem of actually enforcing that documentation gets done. Documenting what they are doing is something to which designers are notoriously indifferent. It is something which, at best, is seen as a necessary evil, and very commonly something which is seen as an extrinsic management imposition upon their work. For engineers, it is dirty work, even though they recognise its importance.

The engineer's approach to producing documentation is, therefore, considered to be no more than a dutiful one, and to be exposed to strong risk of neglect. Completing the record does not articulate with the problem solving and designing itself, and thus it does not comprise a step in the carrying out of the work. The danger is then that because it is not a necessary feature in the work of problem solving which is, as we suggest, how engineering work is done, it will be postponed. Rather than stop or interrupt, what one is currently doing to record it, one can intend to make the record later, but, being postponed, it might eventually not be done.

It was to address this problem that CASE tools had been introduced into Archer. One of the justifications for introducing the CASE tool was that it would result in improved documentation. The argument was that whilst the tools would assist the engineers in their engineering, it would only do so if documentation was adhered to. And building the documentation was largely automated in the tool. Thus, the attempt was made to build the documentation into the organisation of the work. Under the tool, completing the documentation was a precondition of taking the next steps in the conduct of the work. However, given the general view of documentation, the tool was to be built in such a way that it alleviated some of that work for the engineer. The net effect was a re-graded of the work. Creating the documentation was part of the flow of work

Don't treat problems as ends in themselves.

If left to themselves, the engineers risk becoming somewhat parochial in their outlook. They could be so engrossed with the task in hand and with working out of a "good engineering solution" to a problem entirely to their own satisfaction that they might disregard other considerations that might have a higher priority where the project as a whole is concerned. For example, the engineers at the site were only involved in the design and development of the product until it is ™out of the door› i.e. until it is launched, after which the product would be "somebody else's business". Thus, although maintenance is an important priority feature for the project, the fact that it did not impinge upon the work of development meant that often the design and documentation of the software would be undertaken without care for the needs of those who must subsequently design it.

Engineering decisions could also create problems for those who were to manufacture the product. The production line assembly of the machine might, for example, be undertaken by women who would not have the physical strength required for certain kinds of assembly operations. One example of a problem in this regard arose on the assembly of the prototype on the Centaur project . This involved the insertion of a roller housing into a groove; when fully installed the roll housing should have two sets of rollers kept apart by a spring. The insertion of the housing into the slot it was to occupy turned out to require more-than-usual strength and dexterity and after a number of aborted attempts the task fell to the engineer who was regarded as the stronger, and more dextrous of them. Even he found the insertion to be matter of considerable difficulty. To effect the insertion he had to compress the spring, which required a strong grip, and then manoeuvre the part into position to slide it into its grooves, without relaxing the pressure on this spring, and it was in sustaining the pressure whilst orienting the piece that the main difficulty lay. Finally, after twenty or so minuets the piece was inserted.

Centaur also provides another illustration of the problem. The designers had taken a number of design decisions without regard to, or knowledge of a decisions that had been made by the marketing department. Centaur was developing a high capacity feeder for attachment to existing machines and the designers had made certain assumptions about where this would be done and by whom. They assumed that it would be attached by a "Techrep" in the field but it came to their attention some way along the development process that the Marketing organisation had taken a decision to have the feeders attached to the machines in the warehouse, and then to have the assembled machine transported to customer sites. This promptly occasioned in the Centaur team the worry as to whether the heavy feeder attachment would, under the conditions of transport in a lorry over possibly bad roads might be too heavy and might distort the frame on the host machine. They had not taken this assembly issue into account in designing the feeder

There is a variety of ways in which the problem here is addressed. One is to make the ™maintenance›, ™manufacture›, ™assembly› and ™safety› part of the design and development work. Thus, for example, ™maintenance› has now been included as a phase within product ™life cycle› model as a way of depicting it not as something that begins when design is over, but as something which is an integral phase of the design and development process, and, as such, not something which should be left entirely to someone else. As part of the product life cycle it should be prepared for in earlier phases of the project, and should be anticipated when making design decisions in earlier phases.

Other solutions are more ephemeral. Thus the engineers are asked to practice ™design for assembly› and ™design for manufacture›. These are practices that are intended to encourage the engineers to keep in mind the technical difficulties that may be involved in the manufacture or assembly of the parts of the machine they are designing as they design it. Another solution is to have those responsible for design decisions be part of the prototype assembly team so that they can re-address their design decisions as they see for themselves the problems that may be displayed for assembly or manufacture. Thus the engineering draughtsmen who had designed the parts that were causing the problem for the Centaur prototype assembly was present when the roller housing difficulty was encountered, which allowed him to witness first hand how attempts to design it for easy assembly worked out in practice.

METHODISING THE WORK

The engineers overwhelmingly employed a "process conception" of their work. They worked on the assumption that tasks were to be conceived in terms of ordered processes, and that if care were taken with the processes then the outputs would look after themselves. The engineers would not, therefore, immediately commence upon any [substantial] task but would first define some process according to which they would undertake the task. They were enjoined to to this by the Total Quality Management procedures which governed their work, and they were accountable for the provision of a process for work in that in, for example, project meetings and project management meetings they could be called upon - if some particular task was under consideration - to provide a specification of the process that they were following to carry it out.

Engineering is, after all, a means/ends affair, and the business of connecting ends to means must differ from the "common sense" way of proceeding, which is often adopted in the social sciences, for example. Garfinkel (1967, 97) sketches out some features of that way of proceeding, which involve, when, starting from a present situation under the intention of producing some future state, then the actions which need to be taken to bring about that future state are

[WHAT DID THEY DO? HOW DID THEY TURN ACTIVITIES INTO PROCESSES? WHAT STRATEGIES WERE DEPLOYED? WHAT RECOGNISABLE GAMBITS? WHAT WAS THE VOCABULARY?]

MANAGING THE "NON-ENGINEERING" RELEVANCES.

We have, to this point, been talking primarily about the engineering relevances of our engineers. We have seen how as a feature of day to day life their professional ethos sustained and reinforced. At the same time, the project work was being carried on in the context of a broader organisation which largely controlled the human and other resources they needed. Lastly, all of the engineers we knew were concerned about their futuresÐeither to protect them or promote them. And, of course, the prime resource available to them to achieve this was their work on the project. For them, the task was to ensure that what they did on the project contributed in some way to the goals which they had set for themselves. As we shall see, this did not appear prima facie always to possible. In such instances, a mixture of professionalism and good citizenship was counted upon to prevent the mixing of personal competiveness and organisational politics. The culture of engineering was designed to counteract that potentially explosive brew.

Careers and engineering decisions.

It is no less familiar to the engineers than to anyone else that parties within organisations can be more concerned with their position and career in the organisation than they are with any of the substantive issues which comprise the stuff of the organisation's work. That they take up any particular issue is not, then, because of its intrinsic merits, but because of its perceived relevance to their career. Thus an engineering decisions or issue might be pursued by an ambitious manager because it is felt that it will find favour with those higher up the organisational ladder, the engineering merit thereby becoming secondary.

As we hinted earlier, though, being concerned with personal success and engineering good practice are not seen as mutually exclusive. Indeed, it is expected that the one will be used as a platform for the other. Engineering skills should form the basis of networking and career development. In our projects, the expectation that this would be so is neatly shown by the relative levels of respect (and support) given to two managers. One who had poor engineering skills, but excellent career developing abilities was seen as mainly using these skills to rise within the organisation and regarded somewhat contemptuously. The other was seen to be possessed of both considerable engineering abilities and irresistible career promoting gifts - and whose ambitions were treated at least indulgently, if not as wholly admirable.

On the other hand, there is the kind of organisational politics which arises from making engineering matters into causes , into becoming an enthusiast - or as the literature sometimes terms it, a champion - of some idea or tool. Becoming the champion of some engineering cause can, of course, be understood as a careerist matter and consequently somewhat risky. It was alleged, for example, that the downfall of the previous site manager, who was in the process of being replaced at one point in our studies, was due to the fact that he had taken up the cause of a new design for print cartridges, and had "pushed it through". However, this had been proven to have been an engineering mistake, for the print cartridge had performed badly a fact which had cost him his job. In the same way, the manager mentioned above saw the introduction of CASE tools onto Archer as a "thin end of the wedge", a political move by those who had acquired a partisan attachment to those tools.

Confusing politics with engineering.

Yet again, there is the case in which "organisational political" and "engineering" matters become interwoven, not to say, confused. We have mentioned the relations between the managers of the two sites involved in the design of the software on the Mersey project, which was seen by those around them to involve personal animosities expressed in virulent criticism of each others technical and administrative judgements. As far as others were concerned, the two parties could not see the difference between their personal animosities and the merits of the matters they were disputing.

The point is not whether, in these cases, the judgements made about the interplay between "politics" and "engineering" were correct, whether we could confirm these judgements but only, rather, to establish that the engineers understood the distinction and relationship between "politics" and "engineering". The reports we received of the relations between "engineering" and "politics" were, however, often meant to provide us with lessons about organisational life. Thus, for example, it was not fortuitous that we were told about the former site manager's enthusiasm for a faulty print cartridge. The story related a small morality: this is what can happen when you become an enthusiast for something and promote it, overriding the reservations, if not opposition, of other competent engineers. It was recognised, then, that "politics" could distort engineering judgements, and that the two should consequently be separated or in balance. It was not to be expected that "political" and "engineering" considerations would be invariably inimical to each other, and they could certainly run together, but it was possible that political considerations would intrude upon or displace engineering considerations. On the Archer project, for example, the software engineers had continually to try to combine "keeping people happy" with "doing a good engineering job", which led them to engage in concealment and deception in order to keep their managers happy and to retain the confidence of their fellow engineers.

Disentangling politics and engineering.

The problems concerning the interface of the ESS and IOT on the Mersey project were in part caused by the relationship between the two mangers. The problem became so bad that it was necessary to organise a meeting between the engineers to work out a solution. The ESS/IOT meeting was an opportunity for the software engineers to bypass the organisational politics, conduct their relations independently of their two contending managers, and to ascertain just how far, if at all, they might have conflicting interests resulting from their different organisational positions. Certainly their difficulties had been exacerbated by organisational considerations. They did not know each other and had no basis for judging each others' competence independently of the technical information (about the testing problems attributed to the ESS) being transmitted to them. The UK engineers could very well understand how their US counterparts could have come to disregard the test results they were transmitting hence disregard what the UK engineers were recommending should be done. The only solution was to have a face-to-face meeting in the UK. Everyone could see for themselves what was happening, and be free to talk to anyone they wanted and to observe the test operations at first hand. This would be followed by a meeting at which the engineers could explore their capacity to work together and would have the opportunity to focus down on the purely technical questions. The treatment of the technical questions in such a context should, as it proved, enable the relatively easy finding of agreed solutions to these problems.

Politicking in a good engineering cause.

Bucciarelli paints a picture of engineers seeking impractical, rigid, engineering solutions to organisational problems, but our experience was more of engineers seeking organisational ways around engineering problems. The engineers were certainly willing to engage in "politicking in a good engineering cause" when necessary. For example the Centaur team sought to achieve such results as informalising the project review; establishing an alternative manufacturing structure to the official one; and soliciting "customers" for the product.

As we have mentioned, Centaur had serious problems in developing its prototype and initiating its manufacturing operations in order to meet its deadline, as well as the pressure of an unrealistically high UMC (unit manufacturing cost), and though they sought engineering solutions to these problems, through expediting the work, paring costs etc., they recognised that these were, at best, partial answers to their problems. Thus, they set about looking for other, organisational solutions to these problems.

They also faced the problem of needing to initiate manufacturing processes at an earlier stage than the project review necessary to authorise the release of the money necessary for such initiation. A first resort was to seek to bypass the formal procedures of the review process. These processes would mean that, from the point of view of the project, time would be wasted waiting for the review to be set up, for those participating in it to be available, and for the material for the review to be prepared and circulated. Centaur's project manager undertook to see if he could convince his managers to accept an informalisation of the review process that we described in CHAPTER ???. This would enable much speedier assembly of the review panel, would enable their early availability, and would minimise preparation and documentation of the materials. These managers would, however, have to be convinced that the review was an authentic equivalent of the formal review, and not an attempt simply to ease the demands on the project's performance. So the assembly of the review panel would have to be a judicious balance of those who could be informally involved in such a process but who were also of sufficient independence and objectivity to be trusted to make a demanding engineering judgement.

As we have seen, the project manager was eventually successful in this, but whilst working on the informalisation of the review he also understood to seek to set up an alternative manufacturing arrangement. As part of the project's establishment, it had been determined that the manufacturing would be done at one of the Company's continental European sites, and the project and product development manager were making visits there to discuss project problems. At the local site, however, there been considerable downsizing and restructuring, and the "Materials and Acquisitions" section of the organisation had found itself short of work. The project manager had found this out in casual conversation with the head of Materials and Acquisitions, and it seemed to him that since this individual was deeply knowledgeable of the company's production processes and of the "vendor base" i.e. of the organisations that supplied parts and other equipment to the company, he might be able to develop arrangements whereby the manufacture could be done locally and more expeditiously than at the French site.

It was during the review that the fact that such an alternative manufacturing base was being canvassed became known to the manager of the European manufacturing site, which occasioned what was later described by the Chair of the Review panel as a "pissing contest" between that manager and Centaur's project manager. The former was deeply angered by the fact that this process had been taking place which he saw as totally illicit and treacherous. The review condemned this attempt to develop the alternative manufacturing base as bad practice and recommended that relations with the European management must be repaired immediately.

The solicitation of "customers" involved exploring various parts of the organisation to see if anyone might be interested in Centaur's product, to see if the project team could think of any basis on which it might be made to seem an attractive product to others than those who were initially identified as its customers. If other departments could be provided with a conception of how Centaur would be good for them then there was a chance that the production run could be extended and the UMC proportionately reduced. This strategy had not yielded any significant result when Centaur was cancelled.

Cancelling projects for political reasons.

It was, as we have indicated, felt by the Centaur team that the cancellation was on the basis of "politics" not "engineering". The team were pleased with their design-and-prototype, inviting people round to look admiringly at the prototype as soon as it was assembled. They were optimistic that when it was connected to its controller it would run as well as could be expected at this point in its developments and they did actually connect the prototype up to a machine and its controller and feed some paper through as a last act attendant upon the cancellation of the project. Further, the Review had been complementary about the quality of the engineering in the machine. However, they knew that the decision about the fate of projects, in relation to the budget cuts, would be made for "organisational reasons" as much as, and potentially more than for "engineering reasons" and that questions of what was at stake in the completion and abandonment of projects would be decisive.

Centaur's cancellation would not be consequential in the way that the cancellation of major projects would be. Centaur itself was motivated by the budget problems as it was intended to enable the realisation of inventory, but Centaur was not the only possible solution to the inventory problem and alternative proposals were rumoured, including one to greatly reduce the price of the model. Further, the extent to which the decision process would involve the extent to which people on the decision making body regarded the project as important to them, and this was a respect in which Centaur was badly placed for it was a small, organisationally insignificant project.

Relationship between departments.

Although we have mentioned that there are different departments from which the engineers on the projects are drawn, we have tended to refer to ™engineers› in an undifferentiated fashion that does not make a distinction between software and mechanical engineers, for example. However, the specialist engineering trades does give rise to different standpoints within the engineers as a whole. Certainly, the mechanical and electrical engineers would differentiate themselves and engage in ™joking relationships› and certainly the mechanical and electrical engineers treatment of HF/IDO had mild patronising elements in it. There was an attitude to HF/IDO as something to be attended to but as not-quite-proper-engineering , and certainly when reduced (after the downsizing) to ™a boy and his dog› i.e. a couple of young men and a young girl on a student placement, it was in an even weaker position and could not even guarantee to have people at meetings where its attentions might be needed.

Also the position of the software engineers on projects was delicate, in the sense that it was regarded as more trouble than other kinds of engineering, and as a source of trouble for other people. The size of the software problem on Mersey was taken as a saying something about software engineering. The software manager certainly felt that software was being (unfairly) blamed for project problems, and that the software problem figures misrepresented the real nature of the problems. He felt that software was getting blamed for what was not its fault, that it was being called on to solve other kinds of engineering problems. Sometimes in Sunrise meetings, for example, he displayed that he felt that criticism was implied in things that were said. He also felt that software was marginalised and referenced the meeting we previously mention where Big Mike in the course of a project meeting to announced that there was a problem, but being a software problem it was not so serious because of the speed with which solutions could be implemented.

CONCLUSION

In this chapter, we have had our eyes on two of the most prominent aspects of what we have called the engineering culture at Welwyn. The first was the sturdy professionalism of the engineers and the ways in which they sought by one means or another to improve the dependability of their engineering practices. We have shown how they used the various organisationally specified processes such as PDP and Quality make their work more dependable, predictable, and likely to be successful. The second aspect we have examined is the ways in which engineers orient to and manage "non-engineering" relevances of their engineering work. These relevances are, usually, summarised as "organisational politics" and may involve the management of career, the relationships to other project and departments, or even managing "upwards" or "downwards". We have shown that engineers are wholly aware and often amazingly astute at both playing and managing the bounds of these "games". This awareness and this astuteness are two of the qualities a seasoned engineer at Welwyn was expected to have in addition to deep professional expertise.

6.0 The Organisational Environement

THE ENGINEER AS ORGANISATIONAL ACTOR

In our discussion of "engineering" and "non-engineering" relevances, we talk of the ways in which the requirements which other stakeholders in the design process can manifest themselves and have to be taken into consideration. Part of what we are discussing there is the way in which engineers can balance or 'trade off' requirements and priorities. Some people and some groups, though, cannot be traded off in this way. They can have what amounts to veto power on the project. Health and Safety and the group which is for assessing health and safety aspects is one such group. Often, the putative view of 'safety' may be enough to preempt discussion of a particular solution. On other occasions, 'safety' decisions may force re-design. This happened on Centaur. The engineers invented an ingenious way of raising and lowering the paper trays using chains. The Safety Inspector deemed that the method posed a potential risk to the fingers of maintenance personnel. Even though they disagreed with this judgement, felt the likelihood of such an accident more imagined than real, nonetheless they resigned themselves to re-designing the tray mechanism. They have to get through the safety inspection.

What the safety case represents is an example of the organisational setting within which design takes place. Centaur's engineers knew that Safety have a veto, just as they knew that there had to be a marketing case made out for their product, and that they had to manage within their allotted (and constantly reviewed) budget. These and many other aspects make up the organisational environment of design. In this chapter, we will home in on this more generally. In it we will examine the engineer as an organisational actor..

WORKING WITHIN FORMAL PROCEDURES

"Divide and conquer" might be considered the working engineer's motto, with modularisation being a general method of dealing with projects. Treating their constructions as composites of (relatively) independent sub-parts provides a basis for organising work into a set of discrete tasks. The decomposition of complex tasks into a multiplicity of small tasks gives rise to problems of standards and standardisation. They have all kinds of ways of dealing with this, stretching from formal procedures to professional practices and dispositions. In turn, each of these contains its own 'problematic elements'. Standardisation, for example, involves the elements of:

- coherence - with everyone following the same plan or versions which are reasonably related;
- consistency - what gets done will be recognisable, acceptable and useable by others;
- synchronisation - that things will be done when they are needed.

Coherence, consistency and synchronisation are chronic problems for large scales enterprises, be they fighting battles or building photocopiers. What formal procedures are directed to is the reduction of the 'overheads' of coordination. If followed, the procedures enable participants to make decisions about how to do their work without needing endlessly to work these out either for themselves or in conjunction with those with whom their work is to be concerted.

Means and ends

General discussions of large scale organisations (especially of bureaucratic organisations) tend to warn of the potential of goal displacement especially in relation to formal procedures and processes. Although they might be introduced as means to ends, very soon adhering to process becomes an end in itself. Such displacement may become even more dysfunctional if adherence to the process actually prevents accomplishing the original purpose. In such cases, "adherence to the procedures" has become almost ritual in character.

Not surprisingly, since it is consistent with their generally pragmatic attitude, our engineers did not display much of a reverence for or suggest that there was much 'sacred' about the formal systems and procedures they utilised. They did regard following the formal procedures to a beneficial thing, but this was mostly out of consideration for those with whom they had to work. In other words, they assessed the value of the procedures against the practical value of keeping the project on track and getting the work done.

Partial solutions

In this respect the formal procedures were seen as partial solutions to the standardisation problem. Many project troubles could be traced back to the failure of engineers to work according to the same procedures, methods or plans. They are perceived as partial solutions because the problems of coordinating work are chronic ones. No formal system can fully specify all the conditions under which it is to apply. This is, of course, the reason for the 'normally' and 'etc' clauses in such systems, as well as for the "exception mechanisms" that they feature.

Applying the procedures

The engineers were not, however, naive about these formal procedures. They certainly did not suppose that simply carrying out the procedure would produce the desired standardisation. They wanted to make sure that their project was successful and that what they did contributed to this success. So, they frequently undertook one on one consultation with relevant individuals, above and beyond anything required by the formal procedures. They could not, of course, always do this and would often be subject to the practical constraint that they had no alternative (because of time, availability etc.) but to count on others to do what they were supposed to.

As well as frequently going well beyond the call of duty, our project teams knew full well that the formal procedures were not always applied and where applied were not always applied consistently. They knew (because they had in their own work had occasion to turn to them) that every procedure has its list of "exception handling" mechanisms the invoking of which could be negotiated with project management. The Centaur team were, in many ways, an extreme case of the normal variability. Being both small and ™fast track› and it was, therefore, a condition of Centaur's operation that it would need, where necessary, to operate outside the formal procedures.

Organisational acumen.

In matching the needs of the procedure to the ends it was meant to serve, engineers place a high value on what Egon Bittner termed "organisational acumen". This is the capacity to be able to interpret the formal procedures so that they can be found to permit doing whatever it is necessary to do. Bittner is not taking a cynical view here or suggesting that people use formal procedures as mere rationalisations for their actions. Rather, he recognises the fact that people very much treat organisational affairs as serious business and do not make light of the rules. Some people seem able to find ways of utilising the organisation to address the particular practical problems at hand.

Organisational acumen means seeking ways of complying with them in the circumstances. Organisational acumen involves finding a way within the formal procedures to do what needs to be or even must be done. It seeks to find ways of making a proposed course of action legitimate under the rule. Any interpretative work done on the rules has to satisfy others, potentially others in authority, that the interpretation is indeed in accord with the rule.

The engineers knew that how the procedures would be applied depended upon who was applying them and they valued organisational acumen. Thus they appreciated managers who would show an understanding of their engineering and practical problems, and could consider matters relative to what was needed to get the work done. Alternatively, they denigrated those managers who could be expected to show little flexibility and would almost certainly stick to the formal procedures, whatever happened.

Both Jeff and Jack were considered, in their different ways, to be managers to whom to turn when there were difficulties with the formal procedures. Jeff, the head of mechanical engineering, was considered to have been an excellent engineer himself, who had a long career and a lot of experience behind him and was someone to whom to look for constructive advice in a situation where formal procedures were getting in the way. By contrast, Jack, the project manager of Centaur, was not considered to be much of an engineer. But he was felt to be inventive with a high degree of organisational acumen (which, it was sometimes complained, was mostly devoted to advancing his own career) and who could be expected to conceive some way around a current difficulty. Ahmed, the software engineering manager, was, as we indicated in the previous chapter, regarded as a difficult, insecure, disobliging and inflexible character. He was thought to operate strictly within formal procedures and was unwilling to do anything except stick to the procedures, to insist upon compliance with the hierarchical order of things and to the following of the specified procedures for getting anything done. There was, therefore, little point in approaching him with any kind of problem that required creativity with regard to the procedures. Those who worked for him would keep their problems from him and contrive their own solutions. Part of their difficulty with Ahmed was that he was unwilling to reveal problems to his own superiors. He was reluctant to admit the existence of any problem that he might have to report Òup the lineÓ and that might reflect on his own managerial competence. In the end, a modus operandi emerged. Ahmed did not inquire too closely into what his subordinates were actually doing, and they did not take problems to him.

Situated Flexibility

The extent to which exemption from the procedures could be sought or appropriated varied not only with respect to the people involved but also with the extent to which the deviation from prescription could be counted upon, and the extent to which those engaged in carrying out the task could be sure of getting the result without compliance with the procedure. The delivery of the end result was the rationale for the procedure. If the outcome could be assuredly produced without meticulous, or even any, regard for the procedure, then there was no felt necessity to follow it, especially if an alternative to it could be quicker, more convenient or easier.

One of the engineering draftsmen, for example, was allowed to be a "law unto himself". He absented himself from all meetings and from the procedures for the conduct and supervision of his work because he was regarded as outstandingly competent. He would not only deliver the work, it would also be of the highest quality. At the same time, he was a strange and difficult character who vociferously resented being made to conform to the supervisory and procedural arrangements governing draftsmen's work. For Graham, the lead engineer, it was "not worth the hassle" of trying to get him to conform, given that the work would be done, and done well .

CONSEQUENCES OF FORMAL PROCEDURES.

Following the formal procedures can have consequences for engineers that go beyond the intended jurisdiction of a particular procedure. One case which brought this home to us happened on Centaur when the draftsmen "revolted" against the formal procedures. The same draftsman we mentioned just now was the most vociferous amongst those involved. A number of the draftsmen refused to follow the procedure for the completion of fault report forms in the assembly of the prototype unless they were given assurances there would be "no witch-hunts". The fault report forms display the faults of the test machines and are recorded by the test operators. The draftsmen wanted guarantees that the fault report forms would be treated merely as materials for reworking the design and not as the basis for allocating blame for any problems in assembling the prototype and getting it working. Without these assurances, they would assemble the prototype but would not play their role in the completion of the fault report forms.

The fault report forms were an essential tool in the design and development process. They were used to record features of the work that were necessary to assemble the prototype. The identified, therefore, the ways in which the prototype would need to be redesigned to be assembled under industrial conditions. Having a working prototype without that knowledge was of little use to the project. If the engineers did not have the fault report forms they could not know how the prototype had been made to work, and could not be sure how far the assembled prototype conformed to the original design. The draftsmen were called upon to assemble the prototype since they had worked out the fine detail of its design. It was felt they had the best understanding of the intricacies of getting all the parts into place. It was they who would know if the parts had departed from the plan, and could tell which difficulties in assembly might be products of the design itself. Past experience, however, told them that they were only too likely to get the blame for any faults in the prototype, whether genuinely their fault or not. They were simply not therefore willing to expose themselves to this risk. In the event, the required assurances were given. The need to get the prototype assembled and to have the fault reports was great enough to demand the concession.

ADAPTING PROCEDURES TO CIRCUMSTANCES

Two of the projects illustrated different ways in which departure from the formal procedures was organised. In both cases the departure was done in order to achieve precisely the outcomes that the procedures were intended to provide but which in the circumstances were felt likely to obstruct. In the case of Centaur, to meet the deadlines the engineers had to informalise the review processes. In the case of Archer the engineers had to make the organisational procedures work despite the organisation.

Informalising The Processes

As a "fast track" project, Centaur had not conformed to the formal procedures from the very beginning. Getting such a fast track the project off the ground could not be done within the formal procedures. The usual arrangements for formal exchanges between the initiating parties, the clarification of their agreements, the working out of the specifications and so forth would have taken almost all project's life time. Even expediting the initial phases of the project still left problems in carrying it through to schedule. And, as noted in the previous chapter, with Centaur meeting the schedule was all . The project did, however, offer the possibility of a substantial contribution to a pressing organisational problem, namely the reduction of inventory. It also had the great merit of being one of the few possibilities then being canvassed. The problem of clearing the inventory was an overriding problem. This meant that whatever was needed to the "get up and running" had to be done.

Informalising the review.

Although Centaur was not expected to conform all the way down the line, it was required to conform as far as possible. One of the major respects in which it was allowed to deviate was with respect to the informalising of its review.

Reviews of projects are serious events which are governed by a strict set of procedures. One of the functions of the review is to ensure that the project is properly paced to meet its timetable and to ensure that the constituent activities are related in appropriate ways. Initiation of manufacturing, for example, has to conform to the design "lead times". As we indicated in the previous chapter, it is only when the design processes has been successfully reviewed that funds will be released to enable the next stages in the project to commence. If money was released prior to the review, if the review resulted in the cancellation of a project, such expenditure would be wasted

In Centaur's case, given its "fast track" character, the normal staging would mean that the product would miss its launch date. To hit that target, tooling up for manufacture, the next stage in the PDP, had to be initiated before the design review could be organised.. Not only is the review process tightly constrained, the selection of a review panel is itself subject to tight control. Under formal procedures, the review team could not be assembled in time, let alone and conduct the review be completed in time to allow the release of the required funding.

The expenditure was not to be released without a review, but the review processes could themselves be modified in various ways. At the same time, the fact that the review was an informal one meant that it had to be circumspectly organised. The rigour of the review had to be guaranteed by the composition of the review team not the procedures developed for carrying it out. The organisation of the review had to make up for the informality of the process. In sum, it had to deliver just what a formal review would have done.

Preserving the need for procedures in the face of a deviant case.

Somewhat to the surprise of the Centaur team, the review was positive one. The engineering was approved. However, the project was faulted because it lacked of a worked out "business case". The project was given provisional approval, with permission for a month's further work pending the preparation of an adequate business case. The inadequacy of the business case was the occasion for a small homily about the risks of deviating from formal procedures. The lesson, however, was not that one ought invariably to adhere to the formal procedures. In operating outside the formal procedures, one should take notice of the problems those procedures were meant to guard against and ensure that the informal procedures covered them. It was not that the business case should have been worked out according to the formal procedures (since everyone recognised the project could never have been got going on that basis) but that the engineers should have had the good sense to make sure that some kind of "business case" was worked out at some point prior to the review. It was something they should have known they would have to be done.

MAKING FORMAL PROCEDURES WORK

The previous section discussed PDP, a formal organisationally specified process. In this section, we will turn to another formal process (namely the Yourdon software engineering methodology) but one which was not mandated by the Corporation's senior managers. Rather, it was one of a number of professional practices being promoted to ensure that good engineering was complied with. Introducing the process (or "methodology") and tools to support it was part of a campaign being carried out by some to upgrade the software engineering skills at the site. Naturally, there were others who were inclined to reject the need for this innovation.

Tools to support the processes.

What happened with Archer was that the engineer's efforts to comply with formal procedures were frustrated by the organisation itself. The Yourdon method was intended to impose a discipline on the way in which the Archer team developed code. It provided for a proper requirements analysis and controlled the development sequence and ensured tasks (eg documentation) were performed at the appropriate time., completing requirements analysis before making design decisions, for instance. The CASE tools were intended to provide a way of enforcing the use of the Yourdon method and to ensure that the documentation was done. The aim was to enforce a development method on the software engineers and to make them "write to requirements". Many of the problems inherent in software development were diagnosed as originating in the engineer's lack of discipline in writing and documenting their code.

The engineers did not, however, resent the "imposition" of Yourdon procedures. Far from it. The prospect of gaining experience with these procedures and tools was actually what had attracted, even lured, them to the project. Experience with Yourdon and CASE were good "CV items" and the engineers were keen to add them to their own CVs. Furthermore, the engineers were not just attracted to Yourdon and CASE by the personal opportunities they offered, but saw them (especially Yourdon) as engineering good sense.

The engineering context of using the tools.

However, the engineers were inexperienced with their new tools and had to learn how to use them Òon the flyÓ as they said. This fact was recognised by the managers involved who laid on courses and brought in a CASE expert to work alongside them. Nevertheless, the practicalities of learning-whilst-doing had not been adequately accommodated within the project's schedules . Even with classes and expert help, the progress on the project was much slower than it would otherwise have been.

While the Yourdon method provided a promising new means for developing better code, it did not conform with the schedule as laid down for the project. In particular, it had a different approach to the integration of software and hardware. Yourdon presumes that, in a multi-engineering environment, software and hardware would be developed in conjunction. This was not the case for many of the projects at Welwyn such as Archer which involved re-engineering existing machines. As a re-engineering project, the hardware was already developed and was merely being only modified to suit Western markets. Following Yourdon development procedures for the software would put the development of the software well out of synchronisation with the hardware engineering, leaving the hard ware engineers with nothing to do and further delaying the project relative to its already rescheduled and troubled deadlines. This situation would not be acceptable to the project management. The engineers had to give priority to getting software far enough developed for the hardware engineers' purposes. They could do this only do by abandoning the Yourdon process of thoroughly testing and debugging the software before any release.

The political context of using the tools.

To add to their problems was the fact that the Archer project had become embroiled in organisational politics (a topic we will explore in greater detail later). Bringing Yourdon and CASE tools into the project was viewed by some as a possible first step in their more general deployment within the organisation. This suggestion had met with some considerable opposition. There was scepticism as to the real usefulness of the tools - especially CASE. Their employment on the Archer project was, then, something of a test-bed application. More was at stake than just the success of the project.

The Archer engineers therefore felt that they could not make a public issue of their predicament. To do so, and to insist on following the methodology to the letter would only cause more tension between the hardware and software divisions. In the end, they decided to only make the most nominal use of Yourdon and CASE but to keep quiet about this fact.

Procedural impression management.

The Archer engineers had to do something. But they felt they could not discuss these things with their manager. Ahmed was too difficult a character; too worried about the project's current difficulties. It was impossible to reach practical arrangements with him. The engineers had to decide what to do for themselves, and then to try to conceal the divergence between what they were doing and what they were supposed to be doing from their manager and from others within the project. In order to get the software developed in time, they eventually "decided" to do their work in ways that were actually contrary to the use of Yourdon methodology. At the same time, they continued to maintain they were using Yourdon. Thus as one engineer put it "we are not using Yourdon we are saying that we are using Yourdon".

The term "decided" might be misleading. The engineers did not meet together in a corner work out a strategy. Rather. in order to deal with their practical problems they did things which were retrospectively defined by them as a "decision". They went ahead and responded to particular situations in ways that got the work done even though at the time they know it was a violation of the Yourdon procedures. It was only later that these responses came to be described as a decision.

The important point here is that the differences between following and not following the formal methods were not ones which the software engineers thought would materially affect the outcome of work. The engineers had always been capable of writing the software, and they did not need Yourdon and CASE to do their work.

The point about being able to use Yourdon and CASE was that although experienced and able to do the job, they did not suppose that their software writing practice could not be better organised. They recognised that though their extant practices were effective, they suspected things were not always done in the best way. In this respect they knew that the progression defined by Yourdon and the support by CASE could certainly be an improvement the order of their practice.

Providing early releases of software to meet hardware engineer's needs meant putting out software which would need further work was one of the same old problems the Yourdon methods were supposed to counter. While delaying the delivery of the software by using Yourdon made good sense to them, it would hold up the project. Thus, the engineers got on and wrote the software without Yourdon and CASE. The software would work, it would run the machines as required, though it might not be so meticulously or neatly developed as it might have been.

Though they did not think it made any material difference to the deliverables, the engineers were concerned that others might think their departure from the requirements of Yourdon would make such a difference. In particular, they were worried that insofar as other people were taking compliance with the Yourdon and CASE procedures as assurances of quality, their confidence in the quality of the software engineers' work might be eroded. Further, the deployment of Yourdon and CASE was, as we mentioned, a political issue and the engineers wanted to promote its cause. In both respects it was considered necessary to keep the discrepancy between adhering to formal procedure and their actual practice to themselves. These engineers saw themselves as in an organisational corner. As far as they were concerned, no choice other than to work in the way they were doing . At the same time, they couldn›t afford to let this get out.

BALANCING THE CONSTRAINTS

Organisational givens

We have been examining the way in which the engineers work within a structure of formal organisational procedures. The formal procedures are, in a sense, a set of constraints. They make up part of a framework of organisational "givens" within which projects are undertaken. Decisions as to the requirements a design is to satisfy; the cost at which it is to do so; the conditions under which the design is to be created, and their relationship to the necessary or optimal conditions for creating the design are all things which are often set and given for the designer.

Negotiating "givens".

Once decided, givens are not necessarily fixed. Thus, although working within a framework of organisational givens, they are negotiable, and may be modified in the light of transactions with clients or with managers. "Negotiate" is a somewhat metaphoric expression, though, for very often the designer can request, and argue for improvements rather than enter into anything that might literally be described as a negotiation. In general though, the designers day to day work involves seeking to make and imlement decisions within these givens. They seek to balance, combine, prioritise, trade off and integrate the various demands upon the design, and upon the work required to produce the design.

In the case of the Archer project, for example, one of the problems the engineers sought to solve was the localisation of the Japanese machine. They were particularly concerned about the translation of its user interface from Japanese to European symbols without compromising the high speed of the machine. The speed of the machine was only marginally higher than that of its competitors, but that marginal difference nonetheless was significant. It was the fastest of its kind and this was worth felt to give it "marketing edge".

Achieving a marginal operating advantage can be a considerable engineering difficulty. The need to maintain the speed advantage, for example, was a considerable burden for the Archer engineers. It complicated their work and slowed them down.. Marketing's insistence upon its importance as a selling point meant that such difficulties had to be put up with. However, this did not stop them from negotiating the omission of another "asked for" feature (the provision of 'covers and inserts' functionality) in return for maintaining the rated speed of the machine. Similar decisions were negotiated with respect to other "nice to have" features of the design. The "nice to have" features were ones which it was technically feasible to incorporate without too much difficulty (and without significant impact on costings) and which were judged by marketing to be attractive or useful to the users. These "nice to haves" would be noted and the possibility of providing them entertained in relation to the difficulty that was encountered in providing the strictly necessary ("need to have") features.

AD HOC DECISIONS MAKING.

The engineers made their decisions on a circumstantial, ad hoc basis and there was no formal procedure for the implementation of the assorted demands they faced, and certainly no calculus according to which the requirements were to be combined or tensions between them resolved. Deciding on the best engineering solution was always understood to be a contextual matter. Our engineers persistently sought the best engineering solution relative to the conditions under which the decision was to be made and in relation to the parameters set for the decision. Although ad hoc in the sense of not proceduralised, the discussions and decisons were carried out methodically. The engineers tried to take into account as many of the relevant factors as they could. The following are some of the more important:

How long will it take to reach a decision?

We have already indicated that some of the engineers divided their time among many projects. Others, even if they were full time on a project, had several problems which they were pursing at the same time. As a consequence, simply getting enough time "freed up" to be able to make a decision could be problematic. This was more than just a simple problem for problem trade off. Even going to the meeting to discuss what the problem was and how it should be solved would involve not doing something else (eg going to another meeting, working of a pressing problem). As a consequence, estimations of the efficiency of even considering whether to solve a problem were crucial. After all, they always had more problems than they could solve, so some by default, would have to be dropped. The question was always how critical is this problem at this moment?

Can it be made "round the table"?

Designing is as much meeting work as anything else. The search for solutions was always bounded by the concern to reach a decision with the materials to hand and the participants around the table. Certainly the deferring of decisions to "next time" or "to collect more data" was only reluctantly agreed to. If a discussion of an issue which did not affect everyone was extended or looked as if it might not reach consensus then it was transferred "off line" since it was taking up the time of people not concerned with it.

What are the knock on effects and can we wait?

Decisions, of course, ramify, and the engineers must seek to manage if not control these. The interdependence of decisions is something that they are continually concerned with. In this respect, there is a prevailing concern for timeliness. It was felt to be important to know when a commitment should be made and to ensure it was not made "too soon" or "not soon enough".

An example

We have said the above considerations are not calculable in any precise sense. The are often argued over at length and judgements will only retrospectively be confirmed (or otherwise). Engineers are well aware of all of this and, indeed, couch their disputes in just these terms. The "issue" of the Centaur timing diagrams illustrates this.

The decision to delay the working out of the timing diagrams for Centaur was something whichwas definitely a matter which it was not clear what the right thing to do was. The timing diagrams were important, and they needed to be produced. Other things hinged upon them, and they would also provide a test of the design-so-far . If the timing diagrams worked out, then the engineers could be satisfied that they had designed the paper path correctly and had worked out the initiation of paper feeds and sequences successfully. The optimal course of action thus seemed to be to start work on the diagrams straight away.

On the other hand, these were quite skilled artefacts, and the person attached to the project upon whom the work would fall was not particularly skilled in CAD (computer assisted drawing) work, nor particularly familiar with the model of machine the CAD system ran. Moreover, the work had already been done. The person who had done the diagrams for that model of machine worked at the site the site, though attached to another project. However, there was the prospect of obtaining her assistance and of locating the original diagrams for updating. If this could be done, it would ensure that the problem was dealt with more competently. Hence, it seemed it was worth postponing working on the diagrams whilst the possibility of help with them was explored. In any case, Centaur was sufficiently stretched that any assistance with the work would be to its advantage.

These latter considerations weighed with the product manager. They did not count, however, with those who opposed them and thought it was important to get the diagrams done, and to get on with them right away. However, though they felt this strongly, and would say so outside of meetings, they were not willing to press the issue in the project's meetings. Keeping up their opposition would have caused unnecessary trouble and bad feeling, and could be misconstrued. They did not want it interpreted as Ôsour grapesÕ. Thus, keeping up the opposition might have been unsuccessful in any case, and would have made matters worse within the project team.

There was also an element of protecting long standing and valued friendships. The project was top heavy with senior staff, since the layoffs had left comparatively more of them on the staff. Those who were in subordinate positions on the project could, in several cases, feel as entitled to be product development manager as the man who was in charge. Thus, any trouble making could be (mis)construed as an expression of resentments about this, and not just as honest disagreement.

However, attempts to obtain the expert assistance and to recover the original drawings both came to nothing, and the work had to be done after all. But now it was "late" and, possibly, too late. Getting the diagrams done was a tricky and time consuming matter for the engineer who had to do them. He was the best person available from the point of view of the team, i.e. the one who could be spared from other work and could do the diagrams, but, his experience with the drawing equipment was minimal and rusty, and his familiarity with the machine was superficial. Thus although he could be spared to do the diagrams he could not do so either easily or quickly.

How things would turned out would depend on whether the timings "worked out" i.e. on what the diagrams showed. If they showed the paper path was not well designed, then it would be too late. The timings of the paper movements were in milliseconds, which meant, of course, that whether or not they would work could not be judged in a gross eyeballing way but had to be worked through precisely . If the design did not work out, then it would be too late to redesign the paper path before the project review. As it happened, the timing diagrams did work out, but the product development manager regarded the lateness of the solution as "too close for comfort". He observed that the main thing he had learned from the experience was that he should have had the work on the timing diagrams started straight away.

WORK IN THE REAL WORLD

While we would not want to argue that the engineering environment we studied was any harsher than elsewhere, and indeed personal relationships were at least cordially maintained even under stress, it was still a quite unsentimental place. Decisions were taken sometimes quickly and unexpectedly which had major impacts on projects and personal commitments. Engineers (and others) were expected to recognise that this would be the case; to accept that there would be good business reasons for making such decisions;

and to accept the inevitable implications with a minimum of fuss. Two aspects of project life in particular bring this aspect to the fore.

Project cancellation

It is a bland fact that many projects will either be abandoned or will significantly fail to meet the targets set for them such as delivery dates, budget or customer acceptance. All of the projects we studied felt themselves to be (and were) under some sort of threat. Of the projects we studies, Thames was cancelled even before our fieldwork was really underway. Centaur, was "on probation" following a review. Eventually, itit was cancelled as part of a company budgeting exercise. During our fieldwork, the Mersey project was struggling with the possibility of a major schedule slippage. Crossbow had been entirely rescheduled and when we studied it was already falling behind its new schedule.

Reactions to cancellation.

We mentioned in the previous chapter that one engineering draftsman on the Centaur project was particularly disturbed by the prospect of cancellation, and had agreed to sign up to the project only because he had been given assurances that there was no prospect of that happening. The fact that the project was fast track and its relevance to critical inventory problems serve only to reinforce his expectations.

[This discussion of the background to cancellation should be part of the intro stuff on the projects if it isn't already.]

Despite these re-assurances, only six months into the project rumours began to circulate about the need to achieve major savings by cancelling projects. The methods by which the decision was to be made were also the subject of rumour. It was understood that there would be a ranking of all the projects and that those "below the line" would be cancelled. At this point, the confidence about Centaur's fate evaporated for on such a ranking scale Centaur was a small and insignificant project in which relatively little had been invested. Moreover, no-one who was to be involved in making the decision was to be part of the decision making and one which had, as well, few ™friends at court› for nobody who cared about Centaur's fate was going to have a say in the final decision making.

In the event, Centaur was indeed cancelled as part of a general cost cutting exercise. Given the re-assurances about its "security", the project manager was subject to some criticism. He responded by asking for "realism" with regard to the context in which they were working. This was met with stoical (if disconsolate) silence. At the end of the meeting, the group broke up and went to tidy up their Centaur work while awaiting re-assignment. Within a day or two, most were re-assigned. The Product Development manager was assigned to investigating problems with the print cartridge on a machine that had already gone to market, making site visits to collect samples of the failed cartridge and to ascertain details of the circumstances of the failure from those using the machines. The lead draftsman was set to redesigning the latch on the cover of a existing model, a very modest task for someone of his experience and skill, but very much a provisional assignment.

What is remarkable about project cancellation is not so much the fact that such a high rate of cancellation takes place but that so little interest is shown in learning from the experience. Cancelled projects are consigned to history and business goes on as usual.

The prospect of cancellation was not, however, a constant pre-occupation. Certainly, they did not seem to think their work would inevitably be futile. Grudin, by contrast, reports a study of software engineers who were reluctant to undertake or invest serious effort in some of their work because they felt it was likely to be cancelled. Though they were well aware of the prospect of cancellation, our engineers tended to disregard this in their day to day lives. In addition, they showed a concern for the fate of the project as a whole and not just their part.

COMMITMENT TO PROJECTS.

We did occasionally encounter engineers who were indifferent to or even alienated from the project they were currently involved in. But, for the most part, when it occurred it was understandable. One, for example, was more concerned with the new project he was scheduled to join in a week or two and resented the way difficulties on his current project had kept him involved with it beyond the point at which he had originally been scheduled to move on. The work he was having to do was not really of interest to him. Such isolated cases of disaffection contrasted with the more general sense of involvement with the current project and its fate. Indeed, the prospect of a schedule slippage or of a particularly serious problem, indeed the overall fate of a project, were viewed as collective concerns.

The Mersey project displayed a good example of this. Jeff, the Project Manager, called a meeting of all the project staff (over 200 of them) to explain the project's schedule slippage. This was due to problems with the integration of the two software sub-systems. He went on to reassure them that this was not so serious as it looked. In his view, it was a software problem and so, once solved, could be implemented easily and quickly. The meeting was an open one, so that any of the project members could attend if they wished. The majority did. The engineers were committed to the project and concerned about its fate.

Whilst everyone was expected to be committed to the success of their project, and whilst this commitment was patently felt , they could, nevertheless, switch their allegiances rapidly. The participants in Centaur were certainly entitled to be disappointed at its cancellation. Their Project Manager acknowledged that they cared about Centaur and this was to their credit. However, he also called upon them to exhibit an appropriately "mature" attitude, to put their disappointment behind them and move onto other projects. The expectation was thus one of a transferable loyalty. Loyalty would be invested in the current project, but which could be shared with or transferred if need be. This does not mean the loyalty was shallow. People could be quite nostalgic for previous projects. Thames engineers for instance who had survived the downsizing, would hold Thames reunion evenings. Others would have memorabilia of past projects on their desks, and were especially proud to have participated in projects whose product reached the market..

Given the expectation of transferable loyalty and the high level of commitment which everyone demonstrated, the combination of a matrix management system and the rotation of engineers from project to project allowed some managers the opportunity not to "play entirely fairly". Because resources were always under pressure, they were thought sometimes to keep their engineers longer than was really necessary, thus preventing them from moving on to other projects, or to require them to give their projects more time than was strictly allocated. Such tactics often caused conflicts with other project managers and departmental managers.

These conflicts of loyalties are, of course, only to be expected within a system of cross cutting responsibilities and authority. Moreover, the push from managers for individual engineers to giv top priority to "their" project is simply the obverse of the requirement to display loyalty and commitment. Managers want their projects to succeed and do everything they can to make sure this happens, including bring pressure to bear on individuals. As is to be expected, these tactics were subject to certain normative constraints. Bullying and browbeating were totally unacceptable. Instead, the Òbest managersÓ seemed to be able to get people to give them more time through charm and humour. Managers could be quite open, not to say brazen about the extent to which they put their own projects first and expected their team to do the same, but it would be treated indulgently because of who they were and the way that they did it.

AGGRESSIVE SCHEDULING

One of the "managerial disciplines" imposed upon projects was the routine use of "aggressive schedules". Schedules would be set which, even if they were adhered to and everything went "right first time" would be extremely difficult to sustain. The philosophy behind the imposition of such schedules seemed to be the fear that if less tight schedules were set, engineers would relax and "drift", taking as much times as they were offered rather than the minimum necessary.

The point, though, was not to manage against the schedule as to set what was termed a "stretch goal". Much the same was true for managing within the financial budgets for projects. They were set as "goals" and pretty much everyone expected they would not meet them. This expectation did not mean they should not try to do so though. Engineers were expected to strive to meet the stretch goal even though no-one really expected them to do so. As a consequence, re-scheduling was a fairly common practice.

[This *engineering Calvinism* is worth spending some time on. It clearly interacts with the rubric of *continuous improvement*.]

As we have mentioned in our general discussion of the projects, Centaur in particular was the subject of very aggressive scheduling. It had to be designed, developed, tested and launched in little over a year. The deadline had been set by the marketing group's definition of the "buying window" utilised by the target marketplace (ie academic institutions in the US). The tightness of the schedule meant that everything just had to go "right first time". No slippages could be allowed for and only one prototype could be built. This combination was a very serious engineering challenge. If you add to this the fact that decisions about downstream planning and expenditure had to be taken before the normal check points had been passed, then the tensions regarding the project's "manageability" become all to clear. Then there was the unit manufacturing cost "problem". The size of the marketplace ruled out the possibility of getting a high enough production run to reduce the UMC to the $400 level marketing required. In all likelihood, it would be three times that figure. No wonder those involved with it dubbed Centaur "The Project from Hell".

Scheduling on the Archer project was nowhere near As tight as on Centaur. Here slippage became an intrinsic part of the project because of a number of organisational constraints unforeseen when the project was being planned. As the project involved "europeanising" a Japanese device, it was necessary to interact with Japanese engineers. However, unlike their managers, these engineers seldom spoke English. This vastly complicated and slowed down the exchange of engineering information. In addition, the project had to maintain the rated speed of the original device, which imposed some considerable engineering difficulties. Finally, as we have seen, it was taken as an opportunity to introduce new software development tools which had to be learned "on the fly". Code production using these tools was slower than it would otherwise have been.

CONCLUSION

In this chapter we have been attempting to explore the organisational situatedess of industrial software design and development work, and how the engineers orient to this in doing their work. In the next chapter we take up a related theme which is that engineering work is often about the organisation of work and we examine the ways in which engineers organise their work in order to be able to do it.

7.0 Engineering Culture

EVERYDAY ENGINEERS

Throughout this book, our emphasis has been on engineering as work. In this chapter, we attempt a summary description of the 'culture' which we found amongst the engineers we studied. By 'culture' we want to attend to those things which they very much took-for-granted and treated as the most normal, natural and unremarkable things in the world. These were the things which as a matter of course they expected of themselves and each other. The spirit with which they went about their daily work is one which treats it in a matter of fact, prosaic, disciplined and cooperative way. Ours is a study of ordinary, everyday engineers doing ordinary, everyday engineering work.

[CONTRAST, PERHAPS, WITH BUCCIARELLI, AND HIS "TWO WORLDS" VERSION OF ENGINEERS, AS A PROBLEMATICAL MATTER OF MOVING BETWEEN ÔTHE WORLDÕ OF ABSTRACTION AND PRACTICALITY, WITH OUR VERSION OF THESE PEOPLE JUST MOVING ON FROM ONE TASK TO ANOTHER, ATTENDING NOW TO QUESTIONS OF HOW TO ORGANISE THE WORK, AND NOW TO THE WORK ITSELF, INTERFACING THE CALCULABLE AND THE INCALCULABLE IN A PRACTICAL MANNER, WITH IT NOT BEING A MATTER OF INTERFACING TWO DISPARATE WORLDS BUT OF THE VARIABLE PRACTICALITIES AND DIFFICULTIES OF INTERFACING THE CALCULABLE WITH THE NOT-CALCULABLE - THIS CAN BE MORE-OR-LESS TROUBLESOME, BUT IT IS, AFTER ALL, ONLY ANOTHER ENGINEERING PROBLEM.

PUT THIS THE GENERAL INTRODUCTORY STUFF ON APPROACHES TO THE DESIGN IN CH1?]

We recognise that characterising people's outlooks and their actions and interactions is a complex, delicate, and therefore difficult task. Such an exercise is, of necessity, a considerably simplifying and coarsening matter, and there is a limit to how well one can sketch the standpoint of even a relatively small group of people. The complexity and delicacy results from the necessity to generalise across a diversity of individuals and seeking to specify a single standpoint for a collection of people who certainly do not agree on everything and have more or less subtle points of difference even with those to whom they are closest in outlook. It also results from the fact that the attitudes of such individuals are complex and conditional. It is all to easy to reduce these to caricature by leaving out the elaborate qualifications relative to circumstance which are essential for the proper understanding of anyone's attitudes. Thus, although we deem it important to convey an understanding of the orientations of the engineers and how they undertake engineering as an everyday matter, our description must be read with these reservations in mind. Our description is a sociological sketch, whose aim is to familiarise those interested in design and development work but who have not experienced or witnessed it under production conditions. We do not claim to be making a rigorous analysis of engineer's attitudes, circumstances, practices and methods, merely attempting to portray how the everyday engineer appeared to us. We are putting together a type, one which is constructed from our observation of the things that, day by day, the engineers said and did. Ours is a rough synoptic view (often) of the manner in which the engineer's approached things,

THE ENGINEER AS FOOT SOLDIER.

Pride-in-the-job.

The engineers we studied took their work very seriously. They took pride in it, and in the organisation for which they worked. They aspired to high quality engineering and were confident that they often achieved it. They enjoyed the work they did. It was the kind of work with which they felt happiest, and they spent a great deal of their time entirely, in Goffman's terms, engrossed in that work. There was, however, no sense of 'mission' to their activities. They were neither the advocates of any large (or even modest) cause, nor were they the instigators of any innovators with far reaching consequences. Far from looking upon themselves as the protagonists of an exemplary, aggressive and all conquering, engineering mentality, they were, rather, attuned to the specialised character of their what they did and, associatively, to their own limitations and the modest status of their work.

They spent long hours at t work. Although ten or eleven hour days were not unusual, they did not complain nor seek to evade the work. Indeed, any evasion was a very noticeable occurrence because it was so rare. One particular individual had gained some notoriety as one who could be hard to find during the working day; he would not be at his desk, nor in any other obvious place. It was commonly assumed, when he was not to be seen, that he was, "goofing off". However, he was remarkable by this very fact. By and large, the engineers treated each other (to their face, and behind their backs) as fully committed professionals.

Certainly for these engineers, photocopying and office printing is not a cutting edge technology. Thus they construed themselves as "only" photocopying engineers. But they conceived of themselves as "good" photocopying engineers. They might only be photocopier engineers, and even "humble mechanoids" (i.e. mechanical engineers) or "electroids" (electrical engineers), but they were good (photocopier) engineers who could take pride in their standard of work and in the quality of their products. They were proud of their attachment to the company, and judged their status primarily by reference to their competitors and relative to other sites in the company. Although they were feeling the intense competition of the photocopier market, they were satisfied that their products would stand comparison with their rivals. Their machines were perhaps more expensive than rival brands, but that was because they were often of better quality.

This view of themselves was reflected in their impression of how the Company saw them. They felt themselves to be viewed as an out-dated but still necessary part of the company, working on a technology which would soon be passing out of use.

Although they viewed themselves as good, they thought they were perhaps not the best. That accolade went to the Japanese of whom they were very respectful of and from whom they thought they could learn much. They themselves had no lesson to teach everyone, and were quite willing to entertain the possibility that others might have something to teach them - even the visiting sociologists could be invited to contribute something, anything , to improving the operation. Though they could acknowledge their limitations, and (mildly) regret their lack of grasp upon matters outside of their expertise, the engineers were nevertheless comfortable with themselves.

They also assessed themselves as less "state of the art" than their American counterparts and were thus surprised and heartened to hear the contrary from two of their number who returning from a visit to the US as a part of an international QIT (quality improvement team) reported back that they had found that their practice was often more advanced than that of the American end of the company. There were many simple, and basic, kinds of ™good practice› which they engaged in which the Americans had not been aware of.

Commitment and business like

They were serious about their work in the following sense: they treated the achievement of a high standard of performance as the requirement; they made efforts to achieve that standard; they shaped their work tasks in ways that, and at the pace that, they deemed necessary to ensure their best effort. They were neither idealistic nor cynical about that work.

The engineer's approach to their day to day affairs can only be described as businesslike. The engineerÕs characteristic working day would be a long and full one - they would be around the building from seven am until after six PM. They were, too, tireless in their activities. For example, on a sunny afternoon, which was very hot in the small room in which the software PMC had been meeting, after three hours of steadily working through the thick wad of sheets making up the problems list it came to 5pm. The researcher at least was delighted, it was time to stop work. Not so. The manager remarked that he was meeting his wife to go to the theatre and seven, which meant that he did not have to go home and so he could afford to spend the next hour getting through more of the software work; they were afterall, somewhat behind in their deliberations and this was perhaps a good idea, did they agree? The researcher prayed that they would have other, better things to do, but they readily agreed that another hour was a good idea. The engineers stayed until at least six and after.

Methodic.

The engineer's approach was steady and methodic. Their characteristic response to difficulties was to consider how to tackle them and to devise some plan of action, to formulate another meeting to focus on the particularly difficult or demanding problem. Thus, on Centaur, when the ™timing diagram› problem which we will discuss below became critical, an additional meeting was called, and all participants in the project were invited to attend. They were getting to the point at which it was seeming doubtful that the problems of timing the movements of the paper on the paper path could be resolved and it was certainly the point at which , if it was to be solved it would have to be solved within the very near future or the project would be entering its review with a ™critical› problem, which could prove fatal for it. The meeting was thus deemed to be a desperate measure, but the air of the meeting was not one of desperation, they addressed the problem methodically availing themselves of standard procedures we will describe below, not shortcutting them in their desperation and panic.

Experienced.

They were predominantly ™old hands›. Very many of them were in middle age and had been with the company - had been at this site - for twenty years and more, and they saw themselves as serving out their time with this company and at this site, should it survive that long. They were themselves veterans and survivors of many projects, and the survivors of recent and substantial ™downsizing›, with reductions being achieved through early retirement or reallocations. Insofar as they were eligible, they had declined those possibilities.

Enthusiasts.

They were interested in technology, but in a hobbyist, rather than any visionary sense - they would have hobbies which involved building things (such as model aeroplanes) or would read magazines about new technologies. They were especially interested in cars and some of them adorned their office walls - with advertising photographs of BMW cars. However, the discussions in which they engaged were ones which contemplated the engineering ingenuity in putting together new equipment rather than considerations of its social meaning or practical consequences. Their own efforts at innovation were commonly of the kind that could be encompassed by the Total Quality rhetoric of continuous improvement to the work that they did, and which could be submitted for the modest site competitions for new ideas.

Realists

They were photocopier engineers in transition. The technology was moving towards the development of distributed electronic printing systems, and some projects at the site were already at work on laser printing equipment The engineers with whom we worked were, however, concerned with ™mid-volume› machines but they saw that the move towards digital systems was on the horizon. However, these changes did not have any great significance to them. They meant that they would surely have to learn new things, for example, about laser printing, but their work practices were not being greatly reshaped by the first steps into that technology. Nor was it foreseen that within the near future this would make a great difference.

They could see that changes in the technology were ÒinevitableÓ but this did not indicate any metaphysically pedestrian conception of technology as an autonomous force but was simply their assessment of the advantages of such technology as technology, and its capacity to provide possibilities which, if offered, people would want, even demand. The need to keep up with or surpass their market rivals was also seen to provide considerable pressure for if they did not move in these directions, then other companies would do so. All things considered, in their circumstances, they did not see what else their company could do other than to move in a digital world.

There were some speculations about the future, about the role of technology, but these were relatively rare occurrences, touched off topics of conversation, triggered by some incidental comment, and largely focused upon what these things might mean for their company and, therefore, for themselves. Thus, it was often remarked that if they wanted a long term future for their site, they had to ™catch up› with the Japanese. However, the engineers were, as mentioned, prevailingly caught up in their work, were engrossed by one or another of the tasks which made up their workload, and if they were looking into the future it was in the main no further than the end of the next hour (and thus of the current meeting) or toward the end of the working day.

Steadiness.

There were few extremes of emotion on display. Predominantly, the engineers were interested in the work in hand and they treated the great majority of it as worthy of their time, attention and effort, and work demands which were legitimately made of them were to be carried out with care and competence, and to a high standard. The strongest emotions we witnessed were probably those of relief and disappointment, relief when a project pretty much made it through a critical review its members had feared it would fail, and disappointment when, subsequently, the same project was cancelled for budgetary reasons. Anger and annoyance were also occasionally manifest, though these tended to have fairly specifically focused upon particular situations or individuals, aroused by frustration or provocation in particular matters, rather than any generalised resentments.

WORKING LIFE: AN AGENDA OF BITS AND PIECES

Indeterminate work.

On any day the engineers' work load was likely to involve a multiplicity of (relatively) small problems which were remote from any kind of final outcome, and which were small steps towards an end which was, in temporal terms, quite distant. For much of their time the engineers were obviously in the midst of a project, with the purported completion date some way of, thus most of satisfactions to be derived from the work were not those to be celebrated - as they would be at the conclusion of any successful project - but were those which came from successfully completing pieces of work, from delivering things on time, in good shape, and as needed, or of feeling or being told that one had done a good job in doing so. In addition they experienced satisfactions which come from progressing through a workload, disposing of backlog, getting ahead of the game, closing out items or phases of work and tidying up after them, before moving on to next things.

Absorbed in the detail .

At any point in the working day the engineers were overwhelmingly likely to involved in doing their engineering work which mainly consisted of carrying out some detailed piece of project work. They would, commonly, be engrossed in such work, making it the focus of close and continuing attention. This routine feature of their work was highlighted on occasions when they would be present in work situations but not engaged with them, for example, when engineers would have to wait their turn in presentation meetings, and have to sit through other people›s presentations of their problems, proposed solutions and so forth, when these matters had no particular interest to them, and they were only there because they were scheduled to make their own presentations. Such occasions strongly contrasted with their routine work which required their close attention to detail.

Businesslike.

We found the way in which the engineers followed the vagaries of management practice a striking feature of their working life. For example, one engineer had pinned up on his desk a complaint from one of the ancient Romans about the way in which , in the army, the soldiers would get themselves comfortably organised, and then along would come a re-organisation and, they would be told, it was better now. This was, we took it, an ironic comment on management reorganisations of work, but at the same time, it seemed that the engineers did not particularly resent these changes in management approach. Rather, they would abide by them (more or less, more or less enthusiastically) whilst they were in force and would (though they might not see much point to the reorganisation) adapt to rearrangements and shortly be conducting the new regime in the same way. The quote from the Roman had a resigned aspect to it, and it was, perhaps, this tone which was taken by the engineers towards management changes and shifts of direction. Perhaps the effect is that the managerial strategies very often do not make much difference to the substance of their activities.

Nonetheless, the engineers were businesslike in the Total Quality Way. They would work in a continuous, end to end, steadily organised way, over the lunch hour, and from the start to the end of the working day. There were often few spaces between the different activities, as one meeting would follow on another, a result of the Quality policy that meetings should both begin and end on time. This policy meant that the meeting would end promptly at its scheduled conclusion and the engineer would make haste to the next meeting, which was scheduled to begin almost immediately, and where arrival on schedule was another quality procedure. Meetings did not, of course, begin immediately on schedule and not everyone would be there at the start, but nonetheless, they would commence not too far behind schedule and there would be some but little, and often muted, occasions for personal exchanges, gossip etc. prior to the start of the meeting. Even these exchanges were characteristically low key and perfunctory, and invariably brief, and they would quickly turn to the business at hand, which, again, was characteristically conducted in steady eye-to-the-clock manner with the work being got through with few digressions.

The convention of "off line" discussion was also widely and stringently adhered to. The discussion of a topic of business could be developed to some extent, but if it threatened to become a very time consuming discussion or it began to touch on matters outside of the strict relevance of the business in hand it would be declared something to be discussed `Õoff line› i.e. at another time and place by the relevant parties.

Problem centred.

A crude division can be made between two main kinds of work the engineers did. One kind involved dealing with the project's problems. These were the technical problems which had to be resolved if the machine was to work properly. For example, getting the interface to display the correct error message was one such problem, in fact one whole family of problems. Another was preventing the occasional "beading" of toner powder and the distribution of the beads through the machine and onto the print .

Logistics.

The other kind of problem involved dealing with problems of the project, with, effectively, its logistics. Thus the engineers would seek to ensure that the project›s necessary work was being done; that it would be completed in correct order; that it would meet schedules or minimise schedule slippage and that the schedule of prototype testing could be effectuated by providing sufficient access to prototype machines for all parties with legitimate claims to access and so on. We do not, of course, want to suggest that these different kinds of problems were kept rigidly isolated from one another. The engineers were continually alert to implications of each for the other, and of the import that dealing with a particular engineering matter could have for the planned organisation and objectives of the project, or,conversely, for implications from the organisation of the work to the solution of particular engineering problems.

There was a good deal of looking forward, attempting to anticipate how long it would take to deal with a particular problem or carry out a particular task, to look for consequences of achieving a particular outcome or doing a task in a particular way, particularly for ™knock› on consequences of particular decisions/outcomes, with consideration as to whether these will engender or eliminate, postpone or delay subsequent activities, for the temporal implications of decisions were frequently predominant, and sometimes overriding. Attempting to provide answers to questions of ™how long?›; ™by when?; ™can it be done quicker?› and ™if this is done instead of that what will be the consequences?› took up a great deal of the engineers time.

Schedule driven.

The engineers were busy people. It was organisational policy to keep them busy. They though they were busy, but they were not rushed . The pace of activity we observed seldom approached the frantic.

There were times, however, such as the approach of a project review, when work would acquire a more hurried aspect , and there would be a distinct sense of getting things done or ready before or in time for the review, but even this would be tend to be done at a measured pace. There was little rushing around or getting excited, little sense of emergency action being taken. It was rather more a matter of shifting effort around, assigning tasks which must be done prior to a review at the expense of other work, rather than speeding up the pace at which work could be done. preparing for a project review also involved doing some tasks more sketchily or skimpily than they might otherwise be done in order to get them (nominally) finished to meet a target data than, again, working at any more intense or hasty pace. Much of the work could not, presumably, be done any quicker. The work was being done as fast as it realistically could be, given the tractability of the materials being worked, the character of the unavoidable minimum of processes involved in carrying it through, and the optimal pacing of effective operations. There was pervasive searching for ways of getting the work done quicker, something characteristic of all phases of the work and not just of its more ™driven› phases, but for many of these matters the engineers were already doing them as economically as they knew how.

The engineers were busy and had full days because they had their hands full. It was, as we have suggested, organisational policy to keep them busy, to provide them with workloads that were at least enough to occupy the full working day, if not more. The engineers, as a result, had little time to spare, and their engrossment in any one activity, we noted above, had to be limited by an awareness that attention would shortly have to be transferred to some other task or problem. The engineers had their own daily schedules to keep to, for a large component of any day›s work would be attendance at meetings, and, as we mentioned above, there was a strongly enforced policy of promptness, prompt arrival at and prompt commencement of meetings, which, again as we mentioned, were also to close at or very close to their scheduled end.

The engineer's work tasks which did not involve them in going to meetings were ones which characteristically were allocated along with a date by which they were to be completed. These dates were commonly tight ones, ones and were often a compromise between the date by which their completion was needed or at least desired, and the earliest realistic (as far as those establishing the time were concerned) date by which an engineer (almost certainly with other things to do) could hope to complete them. An engineer had little time to spare, either with respect to a particular task, or with the days work, or with the full body of outstanding work.

Open to inspection.

An engineer's work was always somebody else's business, with others asking after or calling for reports upon the character of the work being done and/or its rate of progress. These enquiries could take on a number of characteristics. i) They could be into the way in which an engineer was solving a problem the way in which the problem was being tackled was a basis for assessing whether it would (preferably shortly) be solved. ii) They could be about whether or not an engineer was working on a problem because that could have consequences for what the enquirer would do. iii) They could be about the prioritisation of any engineer's tasks-in-hand because making sure that some tasks had got started so that beginning on them would be early enough to ensure they could be done within the time.

If tasks were being worked on, then there was also always the possibility of other questions being asked such as how they were working out, were they proving to doable as was expected, in the ways they were anticipated to be done, or were they turning out to be tougher, more time consuming, engendering unexpected problems? If they were working out, then how quickly were they going - were they, so far as could be told, on schedule? What could be done to facilitate, help out with or expedite them.

Up against the clock.

For any particular task, there was characteristically, no time to spare. Any new had to be fitted in with the numerous other outstanding tasks in an engineers workload, and often had to compete with them for time and attention, thus if a task was to be given priority and sustained application, then this would be at the expense of something else. There was no time to spare, either, in the sense that the deadlines for the completion of tasks were set at or as close to the minimal conceivable time for carrying them out. There was no time to spare in the engineer's working day either, for the number of tasks to be worked on during the day, together with the number of meetings to be attended and other things to be done, was sufficiently heavy to ensure that without consistent effort the day's work would not get done.

Falling behind was constantly to be contended with, and was commonplace; being up with or ahead of one's workload was a conceivable occurrence, but an uncommon one. The major effort was expended upon attempts to avoid falling even further behind. Getting behind was not, however, treated punitively for it was usually accepted by managers that engineers were falling behind despite their best efforts, that things do take longer, prove more difficult than expected and go wrong in ways that were not and could not have been foreseen. Attention characteristically turned to the question of what, if anything, could be done about it?

PROJECT FATES

Living with cancellation.

The very first thing to notice about design and development work is the acceptance of the overwhelming probability of failure, of the likelihood that projects will be aborted some way short of their successful completion. There were apocryphal tales about engineers who had worked for the company for over twenty years without ever participating in a project which ™went to market.› The possession of an ™appropriate› attitude toward the likely cancellation of projects was considered important, and it was emphasised that the abandonment of a project was to be responded to as an expectable exigency of the work, one which was to be calmly accepted.

This attitude was not, of course, necessarily subscribed to. One engineering draughtsman was particularly disturbed by this, and was reluctant to join projects because of the risk that they would be cancelled. He had been persuaded to join the Centaur project only on the basis of assurances that this project would not, could not, be cancelled. When it was eventually cancelled he was infuriated and at the meeting called to announce the cancellation was vociferous in his complaints, and was the occasion for a generalised comment to the assembled project team that one must be "adult" in recognising that cancellation of projects is in the nature of project work. One of the company's managers would also rail against the acceptance of the high rate of cancellation which was, in his view, immensely wasteful. As these instances make plain, however, whatever the view that individual's took of the probability of cancellation, nonetheless the strong probability of such an occurrence was universally recognised.

The recognition that cancellation was a considerable likelihood did not, however, occasion a cynicism with respect to the project›s work, nor to any restriction of effort on the ground that, given the likelihood of eventual cancellation, it was anyway futile. Grudin reports such cynical orientation in his studies of software engineers, where the undertaking of work for use by ™downstream› participants in the project was regarded as a waste of time since the likelihood of cancellation meant that the current work that engineers were engaged in would never be used. Our, researches did not, however, encounter this attitude. The participants in projects generally worked with determination, and the likelihood of cancellation was not something which was raised in a generalised way. The threat of cancellation was something attended to in relation to the specifics of the project, to the appearance of difficult, perhaps intractable problems which, with the approach of a review, would be contemplated as a possible outcome, and assessments of how great a risk there was contemplated.

There was a prevailing sense of commitment to the projects, the participants felt personally involved in its fate and that they would do what they could to ensure it succeeded, continuing to make efforts even in the face of situations which might be considered hopeless. For example, the participants on Centaur were assiduous in assembling the materials they had put together, particularly the components of the prototype, after the project›s cancellation, in the hope/expectation that the project might be resuscitated at a later date, and for a brief, though equally ill fated, period it was.

No Recriminations.

The organisation's policy was to contain the ramifications of cancellation. Participants from a cancelled project were, if they were not laid off, quickly redeployed to other projects and work, and there was little exploration of the causes of project failure or inclination to blame anyone. This was concurrent with the orientation, mentioned above, to treat cancellation as a normal occurrence of project work, such that those who moved from a project simply went from one piece of work to another. There was no apparent tension between the committed involvement with a project we noted above and the abrupt switch to another project; there might be disappointment that a project was cancelled, but this was very quickly to be put behind one and involvement in a new project embraced. Engineers might, however, be given a transitional assignment which might be regarded less than enthusiastically. For example the reassignment of Centuar›s lead designer to the re-design of a latch on another machine was treated (by him and others) as involving him with a task well below his competence.

Normal natural troubles

It must be borne in mind that not everything went wrong, and that things did not go wrong all the time . Far from it. Many things went right and, of course, the work got done and by and large projects made forward motion. Also, although things did go wrong they were not things which necessarily threw the project in disorder, which gave an air of chaos to the proceedings, but were, instead, the very stuff of the engineer's work, were the kinds of troubles which the engineer's expected to encounter and which it was just another part of their job to contend with. These were ™only to be expected› problems, the kinds of problems which had been seen often enough before, which had not been expected but which, when they occurred, were of the sort that were ™only to be expected›. The occurrence of the problems was not bewildering to the engineers, for they could diagnose the source of those problems adequately enough. In the main these would turn out to be the procedures and practices being employed, or the ways, characteristics and relationships of persons involved or the intractability of the materials and phenomena being engineered. There were endless possibilities for things to go wrong, more than could be looked out for in advance or planned against. It was not that their work was something to be undertaken which might be thrown of course by the occurrence of problems, but it was, rather, work which was involved in responding to problems as they occurred and the challenge for the engineers was to know what to do when a problem occurred, to find, if they possibly could, some solution for it.

For example, although it is not by any means a sign of anyone's incompetence, it is a normal natural trouble that things turn out to be much more difficult to do than they had seemed. Thus, in the case of the Archer project, which was conceived to be an unusually easy and unproblematic project, so much so that it would have difficulty attracting self-respecting engineers because it merely involved customising a machine produced by the company's Japanese subsidiary and selling extremely well in the Asian market. One of the reasons that it was so successful was the fact that the Asian marketing teams had been able to use a distinctive feature of the machine which was that it was very fast, indeed the fastest copier in its class on the market, to good effect. The marketing department involved in Archer required that the re-engineered machine also retain the speed feature so that they could mount a similar campaign to their Japanese counterparts. In setting up the project there was no reason to question the priority which was given to the machine's comparatively high speed because already possessed this project. When the project was initiated, however, it became apparent that retaining the high speed feature was by no means uncomplicated for the engineers found that in redesign parts of the machine, particularly the user interface so that it displayed European symbols instead of Japanese ones, and employed icons meaningful to European cultures rather than the Japanese, they had inexplicably impaired the speed of the machine. The engineering of even a slight speed advantage is a complex and delicate matter, and the rewriting of the machine›s software in a way which would not dissipate that small but crucial edge was much greater than had been expected.

The Centaur project contrasts with that of Archer. While Archer was at the outset deemed to be a "Mickey Mouse" project Centaur, although a modest project, was recognised, from the beginning, as one that would be very difficult to do. Normal natural troubles would assume the mantle of disabling problems on Centaur. One of the major reasons for this was the time-scale on which Centaur was undertaken meant that even if the scheduling and other requirements could conceivably be satisfied, the project would still be hard to complete on schedule. Indeed the schedule was so tight that it allowed no opportunities for ™iteration›, for doing things over. This meant that the engineering had to proceed under the stringent and difficult to achieve requirement of ™right-first- time›. Right-first-time does not allow for iterative design nor for the development of prototypes, the first version is to be produced as the final version of the software. However, right-first-time conflicts with the requirement to work fast because of the time-scale set for the development. Right-first-time characteristically requires that more time is taken over the ™first time› than would otherwise be the case. Centaur, however, did not have the luxury of any time and everything depended on getting the first and only software release right and doing so in a hurry.

From the very outset of the project, it was unlikely that Centaur would be able to meet the schedule, even if things went right first time which it was unlikely to. The reason for this was that the schedule itself contained unresolved conflicts, particularly between the timing of design, review and manufacturing timetables. Thus, the working out of a design and the development of the software release took what was considered an irreducible amount of time, and it was only when a substantial version had been delivered that a review could be held and a decision whether to proceed to manufacture could be made. At the same time, because of the unusually short nature of the project, the initiation of the manufacturing required lead time, required procurement and tooling preparations, and the point at which those must be initiated if the launch deadline was also to be met.

The engineers considered projects from the point of view of what we will call "give". Thus, for Centaur, there was little room for give, and the launch deadline could not give at all. The whole rationale for the project was shaped around its meeting that launch date, and there was no room for rescheduling in the project should the development start to fall behind. However, at least on first sight, there was also no given in the design and manufacturing timetable. This meant that on the projected time-scales the design would not be completed by the time that manufacturing would have to begin to meet the launch date. Indeed, the review of the software development that, if successful would place trigger the release of funds for the manufacturing to begin, could not be held early enough to enable the release of money for the procurement and tooling activities preparatory to manufacturing. The only give that could be expected, that would be essential would be on the ™unit manufacturing cost› (or UMC) where, because of the small production run, the cost at which the product could possibly be manufactured was a multiple of that at which it was to be marketed. Thus, the managers and engineers were doubtful, from the very start, that they could succeed with the project. However, this prospect did not deter them: they would discover if the problems were indeed insuperable .

PROBLEM SOLVING AS A WAY OF LIFE.

We mentioned that the most noticeable thing about the engineering projects we studied was that they were carried out under the threat of cancellation. The second most noticeable issue was that they involved problem solving. Thomas Kuhn's notion of ™normal science› as ™puzzle solving› is relevant here. The problems which scientists face under ™normal science› are, according to Kuhn, ones which are like puzzles: it is known that there is a solution, and indeed, it is known how to work out the solution. There are ways of solving it, the methods are known, and it is just a matter of applying the methods and arriving at the solution, though what the solution is will be known until the puzzle solving has been. Many of the problems which the engineers encounter have this character, and their concern is very much with getting a solution to the problem in hand, to finding the time, assembling the resources to allow work on the problem.

However, although the vast majority of engineering work has this cast to it, there are problems which are stubborn, persistent and dubiously resolvable. These are problems which have no (satisfactory) solution, which recurrently arise, and which lack any general solution to be applied. The engineers do not, however, view these sorts of problems as problems in hand on this project, but as generalised problems which seek a generalised solution. The most striking example of this type of problem that we found was that of the ™ninety percent finished› instance in connection with engineering drawings.

The ™ninety percent finished› problem is involved in estimating how long a collection of tasks will take to do so as to control the tendency of work to run over schedule. Thus, in the classic situation, the work is ninety percent finished in ninety percent of the time allowed, but it proves that the work is ™ninety percent finished› only in respect of the proportion of the number of tasks completion i.e. ninety percent of the identified tasks have been done. However, the outstanding ten percent of the tasks are the more difficult, time consuming tasks, and they are the ones which are not going to be complete in ten percent of the time. Thus although ninety percent of the work has been done in ninety percent of the time the project will still overshoot its deadline because it is too late to take corrective action and allocate more than ten percent of the time to the remaining ten percent of the problems. The production of engineering drawings was considered a task which was likely to overrun its schedule, because, of course, the production of such drawings characteristically did overrun.

The ™ninety percent finished› problem is not that the engineers deviate from the schedule, but is that only discover they have done so after they have done so, and at a time when it is ™too late› to recover the situation. The classic ™mythical man month› problem is associated with this problem, in the sense that the standard solution to the scheduling problem is to add staff to the project. But this does not necessarily expedite matters and may even further delay the completion of the outstanding work. New staff are not familiar with the project and the intricacies of its tasks, and have to be ™brought up to speed›. This means that they are not contributing to the project work, and that their instruction in the project›s problems takes the established staff away from their regular work.

The concern is, then, to detect the problem at an early stage and to allow early corrective measures to be taken before it gets out of hand such as putting in overtime on the jobs causing the problem, bringing in extra staff in a controlled manner the cost of which can then recovered before its deadline is reached.

This ™ninety percent› problem is a good example of the fact that it is the detection of things going wrong which is often desired. Things will go wrong, but these, in themselves, are not the problem. The problem is, rather, that things will go wrong and that the project team will not be aware that they have gone wrong, nor will they be aware of how wrong they have gone, finding this out only some time after the mistakes have been made and have compounded into more serious problems or have been deeply incorporated into the work that has been done. If the mistakes are found shortly after they are made it is possible to take corrective action to resolve problems and recover schedules. Also, if the fact that something is going wrong is identified at the point at which it starts to go wrong, attempts can be made to restore work to the scheduled track. It is often much less difficult and much less expensive to correct them if they are identified before other and subsequent decisions are made and much more work on the product is done for the correction of the problem may then involve redoing not only of work on the problem itself, but also on many other aspects of the design or product which are affected by the mistake.

We have mentioned the ™mythical man month› problem, but is should be noted that the managers and engineers were not necessarily aware of what are, within the research area of the design world, well known problems. The ™mythical man month› problem is well known in the design community because of Brook›s popular book. Nonetheless although well know to the academic community that worries about such things we observed an experienced and well respected project manager fall foul of precisely this problem. Software problems were becoming serious on (which project) which risked what would be a further schedule slip, and a bid was made by the engineers for extra staff. The project manager was willing to take this bid higher up the management line and he made a plea at one of the company›s senior management meetings in Germany for extra resources, to argue that the successful completion of the project on schedule was vital to the company and that extra resources in the form of software engineers was essential to this. He was successful in his pleading and returned to the site to make a triumphant announcement to his software engineers of his success, only to be taken aback by their unwillingness to accept the help.

The reason for the engineers reservations was that the engineers expected the help to be drafted in from the site's complement of software engineers who were familiar with the project›s software and its problems. The engineers that the manager had been able to secure, however, were to be brought in from one of the company's US sites and had not previously been involved with the project. The engineers on the project did not want to work with the Americans because bringing them up to speed would hold their own work back The project manager, however, insisted that they must use these engineers because he had embarrassed himself enough in asking for them in the first place, and did not intend to turn down what he had given. The software engineers were subsequently told that they had better work out some way of successfully using this additional staff. After all they were expert in the software development and there must be things they could do which would help even though they did not know the project›s particular conditions.

That this is a generic problem of software development was not something of which the project manager was aware - it is, of course, not even a software problem, but is another version of the general point that it is quicker to do it myself than explain it to you. The software engineers had, however, taken it for granted that when asking for extra staff the manager would have taken the problem into account.

WORKING UNDER PRESSURE.

As the case of Centaur suggests, there was "pressure" on the engineers. Pressure took the following forms: i) getting through tasks more slowly than was necessary to keep their workload within the limits of what the could foreseeable do; ii) having already fallen behind in their workload and being unable to discern ways in which they could catch up; iii) running into problems that, after investigation and time spent attempting to solve them, proved to be less-than-tractable and beginning to wonder if the problem was soluble and iv) seeing that the project was getting into difficulties and feeling the pressure of approaching, for example, a review where, as just mentioned, there might be an outstanding ™critical› problem or where there would be other features which might leave the work undone under review.

In such cases, there would be a sense of urgency about things, and there would be ˜redoubled efforts— or ˜refocused efforts—. The engineers would drop other work everything and focus upon the big problem(s) and attempts would be made to expedite tasks by finding quicker ways of doing them, and by sacrificing the care and scruple with which they were done to speed in doing them. Thus, the sense of, for example, a ™project in trouble› would pervade its activities, and there would be concern and anxiety expressed at meetings and in informal conversations. Pressure did not, however normally affect the business like and calm way in which the work was gone about though, not surprisingly, morale might be friable.

RELATIONSHIPS AT WORK

Goodwill.

This was a standard resource of the working relationships. The relations between the individuals in projects, and between members of projects and others were characteristically ™procedurally proper›: they dealt with each other in terms of the formal requirements of their positions, and were properly respectful of each other's provinces of responsibility and competence. They operated a policy ™concurrence› which was routinely enforced to limit ™transgressions› of ™proper› dealings with one another. Thus, for example, the policy of ™concurrence› would occasion notifications were boundaries might be exceeded or where responsibilities and competencies might overlap. These engineers had often known each other for a long time, and relationships amongst them were generally affable. The fact that their relationships stood upon such an amicable basis meant that they could readily ask more of each other than they might formally be entitled to, though, as we shall observe elsewhere, they were could equally well and amicably decline such requests.

While there were formal procedure used in the organisation of the relationships to one another, the engineers also invoked informal methods to organise their working relationships. Thus ™favours› were often sought and granted. For example, the software managers would often find themselves subject to demands from the hardware engineers for early releases of software that hardware could deal with its problems, such as testing a machine. This pressure would come in the form of solicitations of help, in terms of expositions of the way in which the shortage of the software was a handicap to the mechanical work, and as requests for favours, as something where the requester knew they were asking for much more than they were entitled for, but felt that they could do so out of familiarity/friendship etc.

Troubles.

Although goodwill was a resource that engineers used in the organisation of their work, relations at work could also create troubles for their work. For example, there were animosities between the project manager of Mersey and the head of the software design team in the US, who would regularly exchange acrimonious memos. The friction between them was widely treated as the cause of project difficulties for each refused to recognise the validity of each other›s complaints and findings, just would not be reasonable about these things.

On another one of the projects one manager was somewhat feared because of his tendency to play the devil›s advocate, and was seen as coming to meetings merely to raise problems and create difficulties for people who did not want to explore difficulties for their own sake but who had work of their own to get on with. His participation was viewed with resentment by others. For example, a point was reached where the Thames IOT software engineers were particularly irritated by some criticisms he was reported as making of their procedures, and they were intensely looking forward to a proposed meeting with him in order to give him as hard a time as they possibly could. Unfortunately, for them he cancelled the meeting at the last minute. That same manager was also regarded as awkward and obstructive by the Thames manager, and there would be occasions on which the latter would insert a ™rant› against him into project meetings, or would report back that there had been a ™frank discussion› between the two of them.

Management.

Project managers varied in their approach to the engineers, and the approach they took considerably impacted the engineers working life. For example, one of them, Big Mike, a larger than life character, who managed Centaur was notorious for an over-the-top commitment to his project, for demanding commitment above and beyond the call of duty from his team members. A classic example of his attitude and its consequences for those who worked for him was a three week, three cornered struggle between Big Mike, his software manager, Stewart, and Stewart›s wife over Stewart›s holiday. The holiday had been arranged and Stewart›s wife was determined to go on it, but Big Mike thought that Stewart should not leave the project›s work at this delicate time. It was, of course, always an inconvenient time, and Mike would spend much time trying to bully, cajole or otherwise convince Stewart that the holiday should be cancelled/postponed, and at the end of the working day, Stewart would go home with a new proposal to put to his wife who remained resolute. Steward eventually went on the holiday. The tone of Big Mike's position was that he was disappointed in Stewart, was disappointed that anyone could put their own domestic and leisure concerns before the needs of the project. This was always done, of course, in a slightly ambiguous way, somewhere between a joke and something that was quite serious.

Managing your manager.

Engineers have to contend with, even mange their mangers. On the Archer project, the software manager, Ahmad, who was also departmental manager of software on the site, was regarded as a difficult and inept individual, someone who could not be dealt with in a rational way, who was too insecure about his own position and too concerned with how problems might reflect upon himself to take an interest in the real problems of projects. The engineers found him difficult to deal with, with the result that they would avoid, as far as possible, having to deal with him, and would seek to shape their dealings in such ways as to get what they wanted by indirection. Thus they would shape up problems they needed him to deal with in ways would avoid abrading his sensibilities and which would avoid any mention of matters which might threaten his sense of security. They preferred, however, to avoid dealing with him at all, and would try to solve problems themselves rather than turn to him for help. Managing Ahmad was an addition to the work load of his subordinates, ensuring that problems which would benefit from managerial intervention had to be solved by less efficacious means, and that other problems had to be dealt with in elaborate, evasive or concealed ways which would protect his self-esteem, keeping from him the extent of difficulties, the extent to which the difficulties were his fault, and any suggestion that the might be his responsibility.

CONCLUSION

Thus, the site was much the same from day to day: the engineers commonly, engaged in either working on problems at their desks, or on their machines; down in the labs or readying themselves for or taking part in one or other of the numerous meetings in which, over the course of a week, they were likely to be involved; sometimes in offices with managers, either talking about problems or engaged in.

In this chapter we have been attempting to give a sense, through a sociological sketch, of the orientations and the working life, of everyday engineers, as they worked day-in and day-out on the design and development projects they were involved in. From inside this working life engineers presented a very different face to that which is portrayed in the popular stereotypes and some sociological treatments of technology. In the following chapters we will explore in more detail how they did their work taking up particular themes for attention.