Title: Janus: the multiple faces of engineering design

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# Janus: the multiple faces of engineering design

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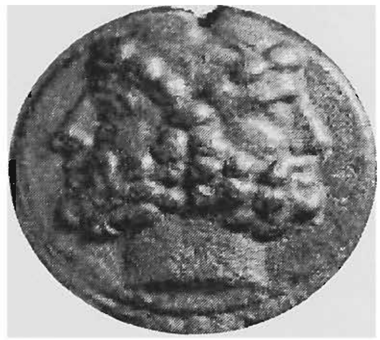
# Janus



# The Multiple Faces of Engineering Design

A Thesis Submitted in fulfilment of the requirements for the award of the degree

PhD

From

UNIVERSITY OF WOLLONGONG

By


Ross Wotherspoon
BE Mech (Hons), MBA (Merit)

Department of Management


2001

## CERTIFICATION

I, Ross D. Wotherspoon, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Department of Management, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Ross D. Wotherspoon

5 September 2001

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## List of Abbreviations

| | |
|---|---|
| 5MTPA | Five Million Tonne Per Annum |
| BHP Pty Ltd | Broken Hill Propriety Limited Company |
| BHP | Broken Hill Propriety Limited Company – Steelworks Port Kembla |
| BOS | Basic Oxygen Steelmaking |
| LK | Lime Kiln |
| PLC | Programmable Logic Controller |
| WTP | Water Treatment Plant |

## Abstract


This study is a sociological exploration of the work of engineering design. The data for this research were generated from a two-year ethnographic study of three engineering design projects within an Australian iron and steel producing company. This study provides an account of the activities undertaken, by engineers and others, during the design of human computer interfaces for process control.

The study takes a symbolic interactionist perspective and acknowledges its criticisms. The study draws on Strauss's social worlds/arena theory, and Clarke's subsequent conceptualisation of the theory in an organisational context, to provide a broad set of sensitising concepts focussed on the interactive aspects of the construction of meaning amongst the social collectives involved in the process of engineering design.

The findings of this study are organised around five interlinked and over lapping themes – *trajectories of technology and work, design boundaries, engineering and operator social worlds, arenas in the process of design,* and *routine and non routine action.* These themes reflect emergent concepts identified through the constant interplay between observation and analysis.

The accounts given describe design negotiations riven through with ideologies of engineers, plant operators, and others, as individuals and as members of social collectives, such as occupational groups. I have come to understand these negotiations can be seen as battlefields with winners, losers, and only sometimes agreeable truces.

These battles are conducted according to what appear to be predetermined rules of engagement that reflect - and define - who has power and over what elements of the battle that power can be exercised. The outcomes of these battles are design specifications that guide the 'trajectory' of a technology from an initial concept toward its final shape.

This study is intended to provide a needed addition to the literature - detail on how individuals and groups go about creating new technological artefacts in an industrial design context. My hope is to assist both academics and practitioners in improving the process of engineering design.

## Acknowledgments

This study has been made possible through the collaborative efforts of the workers and management of BHP Steel, the BHP Institute for Steel Processing and Products (ISPP), the University of Wollongong Department of Management, and the Australian Research Council.

The BHP ISPP was established in 1995 and consolidated a long history of collaboration between the University of Wollongong and BHP Steel. The institute is multi-disciplinary and concentrates on focussed academic research. The institute derives much of its project funding from competitive government funding schemes, creating a triangular alliance between government, industry, and university.

This study has been conducted under the auspices of ISPP 'Management of Innovation and Organisation Change' Program. This program is typified by in depth, long term ethnographic and action research studies that aim to contribute to academic research on innovation, technological change, and organisational learning.

Throughout the course of this study I have had the pleasure of the supportive assistance of three wonderful supervisors - Richard Badham, Karin Garrety, and Will Rifkin. They have each freely given their time and knowledge, greeting every one of my new ideas, directions, and tangents with genuine enthusiasm and rigorous academic debate. The final form of this dissertation is a testament to their combined input and guidance.

Special thanks go to Richard Badham for initially creating the industry and academic opportunities for this research to take place.

Finally, I am most indebted to my lovely wife Catherine and our two beautiful daughters, Jessica and Emily, whose gracious love, support, and sacrifice has made this dissertation possible.

## Preface

Prior to embarking on this study I had spent twelve years working as an engineer in the Australian iron and steel industry. I performed many roles during this period, starting as an engineering cadet and then moving through the professional ranks into management positions. These roles required the performance of a variety of tasks, including technology design, project management, technology support, technology maintenance, and technology operation.

Many of the engineers whom I met during this period spoke at one time or another of their dreams of a 'technological utopia'. In these dreams, they envisaged industrial plants where the tasks of operators were usurped by the marvels of technology. The foibles and frailties of the human race were forgotten in the blaze of precision machine measurement, movement, and reasoning. Unfortunately for most of these engineers, when they awoke from their dreams, they faced a reality far removed from their utopia - a reality where machines broke down, technology failed, and in the end, human operators remained to pick up the pieces.

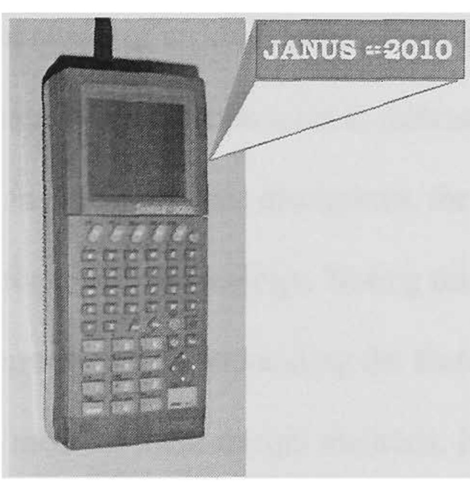
The idea for this study was born from my observations of one such engineer's search for his small slice of technological utopia. His particular quest involved the replacement of a manual, paper-based, warehouse inventory management system with hand-held computers, bar codes and readers, and radio frequency data links to a mainframe computer system. His quest was conceived at a trade-show where his eyes were drawn to the latest hand-held computer terminal, the Janus 2010, developed by Intermec.

Unfortunately, for the engineer in question, the reality he faced upon awaking from his project was one where the Janus technology remained locked in the cupboards of the operators, untouched and lifeless. The paper-based system endured and does so to this day. Although the technology performed within the requirements of the engineer's specifications, he was unable to overcome what seemed to be well founded and well managed operator resistance.

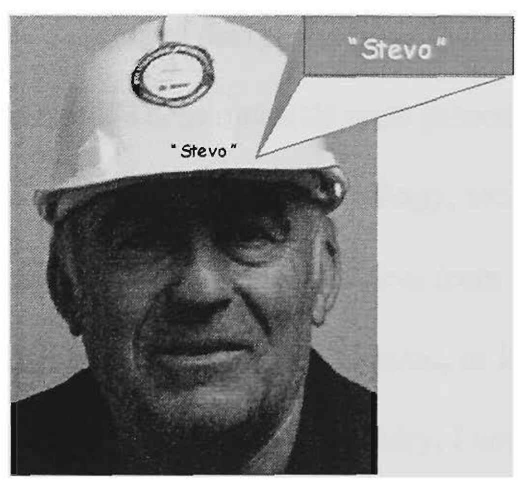
The ageing, predominantly migrant, workers were unable to read the small liquid crystal displays on the hand-held terminals whilst operating them in the dimly lit warehouse. Nor were they able to understand the complex training sessions. Further to this, these workers had for many years performed manual labour tasks in the plant. As a result, their large callused fingers were unable to accurately press the small keypad buttons. In addition, the workers appeared to perceive the Janus project as a threat to their continued employment due to an ongoing distrust between workers and the management.

Under the combined weight of these factors, the workers instigated what appeared to be a well organised campaign of overt and covert resistance. One of their more ingenious covert schemes involved the gradual removal of the bar code labels from the products. Inch-by-inch, day-by-day, the workers would secretly peel the edges of labels from the product. This ongoing process appeared to the engineer as an incompatibility between the adhesive and the product surface. For more then six months, specialist label consultants from 3M endeavoured to select an adhesive that would successfully bond the label to the product. Eventually, a shipment of products was dispatched directly to China with test labels attached. After two weeks in transit, and four weeks in a Chinese warehouse, it was reported that all labels remained completely intact. This result alerted the engineer to the covert scheme of label removal, though no punitive actions were ever taken.

Intermec's decision to name their hand held computer 'Janus' was perhaps more apt for this project than they might have imagined. Janus is the mythical Roman God of gates and doors, depicted with two faces looking in opposite directions. To the chagrin of the instigating engineer, the Janus project had a technological face and a social face, both of which required his equal consideration.




A Technological Face




A Social Face[1]

There is a multiplicity to these two faces of the Janus Project. The technological face can be seen as including the Janus 2010 hand held computer, bar code labels, bar code readers, systems of radio frequency links, mainframe computer system, and software, to name but a few. Likewise, the social face can be considered to include Stevo, the

[1] This photo and all other forms of collected field data presented in this dissertation have been done so with written permission of the human subjects involved.

engineer, and every other actor involved in the process of design and implementation, both overt and covert, and the social collectives that they may represent. Further to this, the technological faces are a reflection of the social processes through which they were created. In turn, these social processes are a reflection of the participants', as both individuals and representatives of their social collectives, interpretation of technological, social, cultural, political, and economic circumstances within which the Janus project was undertaken.

My goal when I first conceived of this study was to develop a design method that encompassed the multiple faces of engineering design. In pursuing this goal, I quickly became aware of an abundance of previously developed design methods that were purported by their proponents to address this need. These methods were presented in a wide range of academic disciplines, for example, engineering, psychology, sociology, and information technology. Noting this proliferation, I shifted my focus from 'methods development' to understanding the factors that influenced the deployment, or lack of deployment, of these design methods. In following this avenue of inquiry, I sought out studies that depicted the social processes of engineering design in the hope that they might illuminate relevant factors worth studying. This inquiry highlighted for me the dearth of literature describing in detail the social process of design. This 'gap' inspired the final focus of this study - the development of an understanding of the actions of humans engaged in the process of engineering design.

design. The *design studies* literature is a forum for development of theoretical aspects of design in many areas, including engineering, architecture, planning, and industrial design. The research within this field focuses on similar phenomena to my study, within a broad interest in theoretical aspects of design. However, design studies are carried out within a cognitive psychology framework not a sociological framework, focussing on individual problem solving rather than individual and collective negotiation and decision making. *Ethnographic studies of engineering design* are predominantly short-term, descriptive, and theory testing studies driven by sets of practical goals rather than, as I attempt here, the pursuit of an explanatory framework for the activities of engineering design.

Such an explanatory framework is introduced in the following empirical sections, which present the overlapping and interlinked themes that organise this study's account of the observed process of design.

# Part (B)

Part (A) of this dissertation – Chapters (1)-(3), introduced this study's interest in providing an account of a process of engineering design. It explained how this account has been developed through an ethnographic study of three engineering design projects within an Australian iron and steel producing company. Part (B) – Chapters (4)-(8), presents the empirical findings of this study. These findings have been organised around five interlinked and overlapping themes – *trajectories of technology and work, design boundaries, engineers and operators, arenas in the process of design,* and *routine and non routine action.* Chapter (9) draws these findings together in a condensed account and discusses the broader implications of the findings.

During the process of design, technologies change, evolve, and even mutate. Some authors, particularly those from traditional engineering and economic fields, focus their explanation of this process on the technology itself and the linear sequence of stages through which they see it as being developed. This study, in contrast, focuses on the changing social processes that occur around the technology during the course of design. Chapter (4) describes these changes in terms of three complex, iterative phases, which I am terming – *artefact seeding, artefact negotiation,* and *artefact accomplishment.* The 'trajectory' of the technology and the work of design are analysed in terms of these three phases. Chapter (5) focuses on the 'design boundaries' that influence trajectory of a technology. These design boundaries are sets of negotiated specifications that constrain and enable technology trajectories by representing specific variations or options that may or may not be pursued. The various actors and social collectives engaged in the negotiations that occur over these design boundaries are described in Chapter (6). One aspect of these negotiations, discussed in Chapter (7), is the emergence and diffusion of 'arenas' around contentious design boundary issues. A further aspect of these negotiations, illuminated in Chapter (8), is the use of 'routines' in ordering the exchanges amongst the actors and social collectives. But first we must understand the trajectories of technology and work.

# Chapter (4) – Trajectories of Technology and Work

## *4.1 Introduction*

The concept of *trajectories* provides a useful temporal dimension for studying the process of design. The term *technology trajectory* has been used to refer to the path by which a technology develops, be it how the bicycle has evolved over the past 200 years or how a new control system moves from conception to installation. Traditional engineering and economic perspectives on technology trajectories are that they are in some way 'natural', following a sequence of stages from inception to maturity. These traditional views are useful for management and planning, however, they are not representative of the social process of design, as has been highlighted by studies in social history and sociology of technology. My empirical data adds to this critique, showing that technology can usefully be recognised to be made up of sub components. Each of these sub components can be seen to develop via its own unique trajectory. These sub component trajectories, though, are interlinked so that the trajectory of the technology becomes an amalgam of its sub component trajectories.

These sub component trajectories are analysed in this study by a characterisation of phases of development. Each phase provides a temporal dimension, based on individual and collective action, for analysing trajectories without restricting them to a linear sequence. Junctions between these phases are marked by changes in the nature of interactions amongst actors and social collectives around the sub components as they progress through the process of design. Three phases - seeding, negotiation, and accomplishment are evident in the sub component trajectories in the 5MTPA Project.

In the context of this study as a whole, this chapter builds an interpretation of sub component trajectories for the overall project, that is derived from a symbolic interactionist perspective, employing ethnographic and grounded theory methods, as noted in Chapters (1) and (2). These sub component trajectories manifest themselves in unique ways due to the physical context within which this study has been undertaken, that is, human computer interface design in an Australian iron and steel industry, as described in Chapter (2). The concept of trajectories introduced in this chapter represents the first of five themes in my analysis. These themes are discussed and then illustrated by a series of representative scenes or events that I refer to as vignettes. Subsequent chapters address notions of design boundaries, social worlds, arenas, and routines, which will be shown to be linked to the trajectories described here. These concepts taken together form my account of the complex, negotiated, social process of design in the 5MTPA Project. First, though, one needs to understand trajectories.

## *4.2 Trajectory Theory*

Writers from various academic traditions over the years have theorised about the innovation process and nature of technology trajectories. One perspective is that technological innovation follows a natural path starting with pure research, progressing through to applied research, then development, followed by production, marketing, and finally maturity (Bijker 1992, p.17). A further refinement of this notion is that in industrial societies much of this technological innovation occurs within companies and industries rather than by individual inventors selling an idea in a market place. In these cases of *institutional innovation*, 'engineers and others are paid to design and create new technologies' (Kline 1985, p.43). This sort of institutionalised innovation is the particular focus of this thesis.

As mentioned in Chapter (3), some authors characterise the process of design as a sequence of activities, starting with need recognition, where the output of each stage serves as the input to the next stage. They see these stages as representing the trajectory by which a particular technology 'proceeds logically from the conceptual level through physical design and evaluation stages' (Czaja 1997, p.29).

The authors of an internally published BHP 'Design Control Procedure' (BHP 1997) seem to share similar views to those mentioned above. The authors of this procedure state that its purpose is to 'provide a common understanding of terms and processes used in design work…' (BHP 1997, p.2). One of the ways in which the authors attempt to provide this 'common understanding' is through a list of thirteen sequential steps, each feeding the next, that outline the purported BHP process of design (see Fig 4.1).

Please see print copy for image

**Figure 4.1 - Stages of Design - BHP Design Control Procedure (BHP 1997)**

The academic and industrial descriptions outlined above are claimed, by their authors, to represent the process of technical innovation or design. This representation undoubtedly contributes to our understanding of the process of design and provides a framework for managerial control. However, studies in the social history and sociology of technology (see MacKenzie 1985; Bijker 1987; Latour 1996) have highlighted the failure of these descriptions to fully explain the trajectories along which observed technologies have developed (Bijker 1992, p.17).

The economists Nelson and Winter (1982) and Dosi (1984) noted a discontinuity between the trajectories predicted by the linear models and the trajectories observed in real world settings. They attempted to redress this discontinuity by proposing an evolutionary approach to technological trajectories. Nelson and Winter argued that organisations should be seen as loosely structured clusters of routines - ways of doing things and ways of determining what to do. Following on from this, they argued that these routines were the organisational equivalent of personal skill. Each organisation is seen as having its own unique set of routines that are responsible for organisational choice. These routines automatically select between technological possibilities and are subsequently subjected to selection pressures from the environment (van der Belt 1987, p.137).

In an unrelated, yet nonetheless relevant field, Strauss, Fagerhaugh, Suczek, and Wiener (1985) performed a study of illness trajectories and hospital patients. In the study, Strauss et al were concerned with the work of medical practitioners in managing the course of an illness. Strauss built on this study and later provided the following definition of 'trajectory':

> (1) The course of any experienced phenomenon as it evolves over time (an engineering project, a chronic illness, dying, a social revolution, or national problems attending mass or "uncontrollable" immigration) and

> (2) the actions and interactions that contribute to the phenomenon's evolution (Strauss 1993, p.53).

Strauss argues that phenomena do not just automatically unfold, nor are they straightforwardly determined by social, economic, political, cultural or other circumstances. Rather, they are in part shaped by the interactions of concerned actors.

In this study, I consider that the trajectory of a technology (Nelson-Winter-Dosi) and the trajectory of the work of design (Strauss) are indelibly linked. Both concepts seek to capture outcomes of collective action and interaction amongst relevant actors and social collectives[1], and as such cannot be separated. In an example of this, Kevin Robinson, the BOS Project operations representative, discusses what seems to be a motive for some of his actions in the process of design.

> "My main aim is to make sure that there is no loss of functionality… I'm not interested in trying to make the new system better. I just wanna make sure it's no worse than what we have now."

Kevin's perspective and motivation will, firstly, influence the trajectory of the work of design, by guiding the ways in which he interacts with others and others with him. Secondly, it will influence the trajectory of the technology through its effects on the design negotiations that occur amongst the relevant actors and social collectives. Because of the inseparable nature of technology and the work of design I have chosen to

[1] I consider "relevant actors and social collectives" to be those with both the inclination and opportunity to influence the process of design.

continue to use the term "trajectory" in spite of its multiple, and sometimes diffuse, meanings.

In this section, I have discussed how some models of technology development, such as traditional economic and engineering models, focus on the technology and describe technological innovation as following a natural, linear path from inception to maturity. The Nelson-Winter-Dosi approach broke with economic tradition and proposed a more evolutionary model focussed on the technology and the organisation. Strauss et al present a contextually different, though theoretically relevant, notion that trajectories are an important component in the work of medical practitioners when treating illnesses. These models provide an overarching theoretical perspective on the process of design, however, they do not account for the social interactions that occur within the process of design. The following section begins to redress this limitation by examining in more detail, through a focus on sub components, the nature and make-up of the specific technology or artefact[2] being designed.

## Sub Components

The actors in my study seemed to follow a reductionist approach to engineering design. That is, the actors in the 5MTPA Project seemed to address each of the artefacts as though they consisted of a number of smaller sub components. In the ensuing vignette, Eric Haines, an electrical engineer on the WTP Project, demonstrates this reductionist

[2] In order to simplify the ensuing general discussion, I have elected to use the generic term 'artefact' to represent the various specific technologies under observation within my study.

approach as he explains some of the sub component levels, and relevant actors, in the WTP Project.

***Vignette - I'm responsible for the level 2 automation***

Eric's office seemed empty. There was no computer, no filing cabinet, no blinds, no pictures, no memorabilia, just an old wooden desk with a phone in the centre of a barren room. Eric explained that he had only recently returned to the steelmaking section after a prolonged secondment to the tin mill development project.

"So what will your role be now that you're on the WTP Project?" I asked.

"I'm going to be responsible for the level two automation stuff," replied Eric. "That means I'll be responsible for transferring all the relay logic into code for the PLC. Level three automation, that's the man-machine interface stuff, will be handled by Steve Gilroy. And the level one automation is the responsibility of Stewart Keenan from BHP Engineering. He's got to look after all the drawings. It's pretty easy. He just has to cut and paste the existing design circuits onto the new drawings. Then he adds the hardware that maintenance has selected."

In explaining his role within the WTP Project, Eric has indicated that there are three major sub components: (1) the circuits and hardware, (2) the PLC code, and (3) the man-machine interface. Further to this, each of these sub components is the responsibility of a separate actor: (1) Stewart, (2) Eric, and (3) Steve. Following on from this, the design of each of these sub components will reflect its own set of social, economic, political, and cultural factors, and its own set of concerned actors. Under the influence of these factors each sub component will evolve over time via its own unique but interlinked trajectory. An amalgamation of the trajectories of these many smaller sub components forms the technological trajectory of the main artefact.

This notion of multiple sub components seems to be reflected, although not explicitly stated, in Strauss et al's (1985) study of illness trajectories. In one of the examples cited by Strauss et al (1985, p.12), a patient, Mr. Einshtien, was hospitalised for possible congestive heart failure. Apparently, at the time, he was also suffering from anaemia, severe respiratory difficulties, and chronic neck pain. As with my example above, each of the relevant specialists was responsible for a sub component of Mr. Einshtien's illness. Further to this, the conditions and required treatments interacted in complex ways to form the overall illness trajectory of the patient. This example demonstrates that illness trajectories, as with technological trajectories, can be seen as an amalgamation of many smaller trajectories.

Each of the sub components of a technological artefact can be examined with respect to its own unique trajectory, and could, no doubt, be further broken down into even smaller sub sub components, each with their own distinct but overlapping and intertwined trajectories. However, it is not my desire to enumerate the existence of the numerous levels of sub, sub sub, and sub sub sub components. It is my intention to introduce the concept that sub components exist and that the main artefact's trajectory arises from the amalgamation of the numerous sub component trajectories. The following section introduces the notion that the social interactions around these trajectories can be characterised by phases.

## Trajectory Phasing

Strauss' (1993) discussion of trajectories introduces a number of concepts that he and his co-workers developed. One of these concepts, *trajectory phasing,* has proven particularly useful in characterising the interactions around sub components. Strauss defines trajectory phasing as:

> represent(ing) the researcher's conceptualisation of phases, in accordance with the changes in the interaction occurring over time "around" the phenomenon as it evolves. Analytically, these phases are properties of the sequence of interactions (Strauss 1993, p.54).

Through my analysis of the actions and interactions within the 5MTPA Project, I have identified three conceptual trajectory phases within the arena of design[3]: Phase (I) Artefact Seeding; Phase (II) Artefact Negotiation; Phase (III) Artefact Accomplishment. It is important to note that these phases do not represent chronological stages through which all sub components must pass in unison. Nor do they represent predictive factors through which the final form of a technology may be foretold. Rather, they represent changes in the interactions around sub components as they individually develop via their own trajectories. For example, one sub component may be located in the seeding phase, while simultaneously others are in the negotiation and accomplishment phases.

[3] An arena represents the interaction of groups and individuals around specific issues (Strauss 1993). In this section I use the term "arena of design" to represent the interactions that occur around the issue of technology design in the 5MTPA Project. The concept of arenas is explored in detail in Chapter (7).

Figure 4.2 presents sub component trajectories and trajectory phases (shown in bold) in an overarching conceptual map that represents my interpretation of the process of design. These phases are discussed in detail in the following sections.

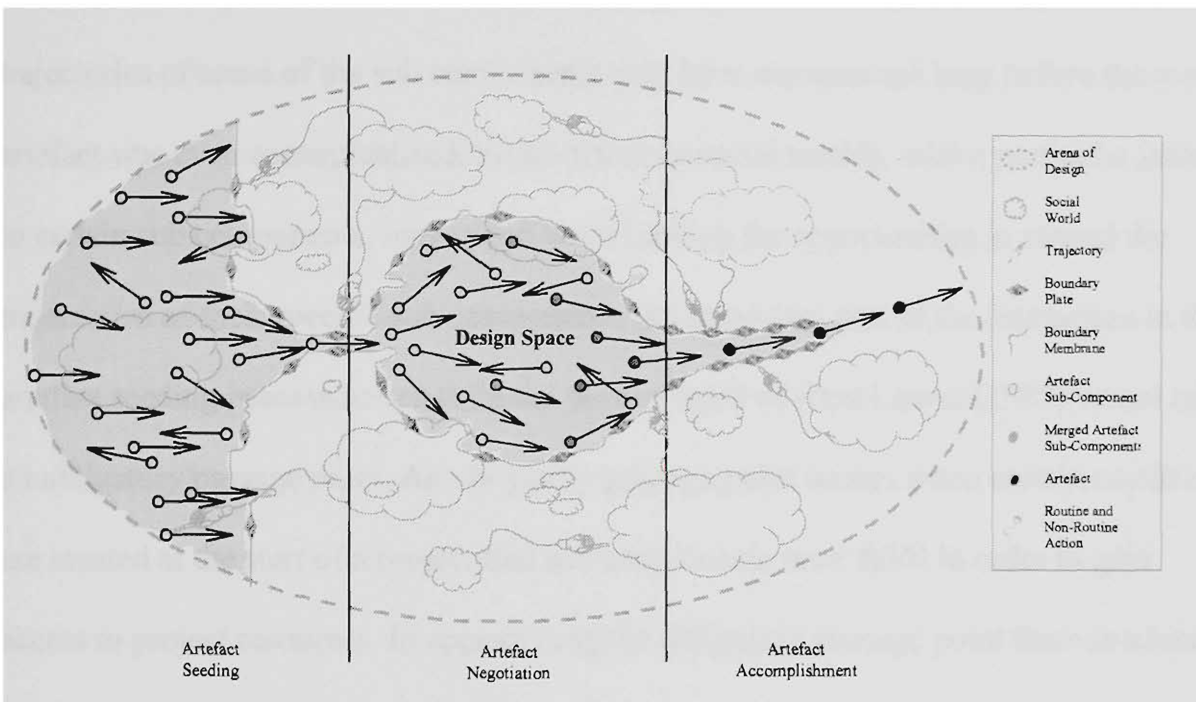



**Figure 4.2 - Sub Component Trajectories and Trajectory Phases**

### *4.3 Artefact Seeding*

*Artefact seeding* represents the first of my conceptual trajectory phases within the arena of design. In this phase, actors from different social worlds[4] negotiate, through action and interaction, which sub components will enter subsequent phases in the process of design and, if successful, be merged to form the final artefact. These negotiations may

[4] A "social world" can be defined as a group of actors with shared commitments to certain activities (Strauss 1993). This concept is explored in detail in Chapter (6).

also involve adaptation and modification of particular sub component characteristics to suit the final artefact's perceived requirements.

When examining the artefact seeding process in the 5MTPA Project, it appears that the trajectories of some of the sub components may have commenced long before the main artefact was even conceptualised. Some actors or social worlds, with a particular interest in certain sub components, may spend years looking for opportunities to extend the trajectories of their specific sub components. An important part of the interaction in the artefact seeding process seems to be the development of what Latour (1987) would call an obligatory passage point. An obligatory passage point occurs when certain conditions are created at the start of a project that sub components must fulfil in order to gain access to project resources. In approaching the obligatory passage point there is a kind of 'funnelling – reframing or mediating of the concerns and interests of multiple actors into a narrower passage point' (Star 1989, p.390). Those sub components unsuccessful in negotiating access through a particular project's obligatory passage point may be redirected by their sponsors toward other, potentially more suitable, projects.

In my map of the process of design, I have represented the obligatory passage point as a necking in of the design boundary[5]. This neck represents certain specifications that have been identified by the formal organisation as being imperative for trajectory continuation. The "formal organisation" in the 5MTPA Project seems to be a tripartite group: Daniel Grace, the 5MTPA Project Manager, Steve Bull, the 5MTPA Project Technical Manager, and Steve Gibson, the Steelmaking Plant Manager. In this case,

[5] "Design boundaries" are a set specifications that constrain and enable trajectories by representing specific variations or options that may or may not be pursued. This concept is explored in detail in Chapter (5).

these three have constructed the following obligatory passage point for the 5MTPA Project:

> The project will guarantee plant capacity to a long term sustainable 5.0 million tonnes per annum slab make[6] at high levels of quality control and product delivery performance. The capital expenditure focuses on improving plant reliability and reducing bottlenecks in the process stream from raw materials unloading and handling to slab dispatch. Improved safety, environment and operational security aspects are incorporated in the modified and enhanced items of plant (Russell 1998, p.6).

In order for a sub component to progress through the 5MTPA Project, the relevant actors and social worlds must ensure that their sub components comply, at least in appearance, with the obligatory passage point as defined by Daniel Grace, Steve Russel, and Steve Gibson. In this context, the obligatory passage point represents what the traditional engineering design authors, cited at the start of this chapter, would refer to as the first step of design, that is "needs recognition". The recognised need in this case is a "sustainable 5.0 million tonnes per annum slab make". In contrast to these traditional models, I would argue that "needs recognition", in the form of the obligatory passage point, occurs after the process of design commences, or, more specifically, at the end of the artefact seeding phase.

[6] The term "slab make" refers to the quantity of steel slabs produced in the steel plant.

The following vignette provides an example of the interactions occurring during this initial artefact seeding phase. In this case, Richard Illes, a BHP senior maintenance engineer, discusses how he was able to attract funding for a number of plant modifications under the auspices of the 5MTPA Project.

***Vignette – Don't tell those bastards about our scam***

It was Pat Funmer's farewell. The ex-servicemen's club on a Friday night was the engineers' favourite place for such gatherings. I stood at the austere marble and brass bar to order my first beer. The forests of empty beer glasses growing across each table a testament to the fact that the party was well under way. I gazed at the mirrored wall behind the bar and saw reflected the happy faces of a group of men farewelling a much-liked colleague. In spite of my engineering background, I felt a little displaced as the only university researcher amongst a group of BHP engineers.

I suspected that most of the men present tonight would have spent the day working together: meetings, reviews, personal discussions, phone calls, etc. Counter to this, I had spent a solitary day reviewing documentation on the twenty-seven sub-projects contained within the 5MTPA Project. However, many of the names of the engineers in the room tonight had appeared on the documentation for the projects. Finally, with a cold beer in my hand, I turned to join the party.

"How ya goin tige," rasped Richard in his deep gravelly voice as he smiled and walked up to greet me.

"Great thanks Richard," I replied. "Oh by the way I was reading about you today."

"Oh really!" Said Richard. "What was that?"

"Just about the $1.5 million you guys at Slab Handling got from the 5MTPA Project," I replied, suggesting that Richard had achieved a victory of sorts.

I smiled and quoted Richard's justification passage from the front page of the document. "To meet the additional output requirements of the 5MTPA Project it is necessary to enhance slab handling systems to overcome bottlenecks and plant reliability problems."

Richard leaned in and gave me a conspiratorial wink. "Don't tell those bastards about our scam. The guys have been trying for years to modify and update some of the equipment. We've got that Steve Russel and Steve Gibson bluffed into thinking these projects are essential under the pretext of plant throughput. You and me know they aren't, but don't you ever go telling them that."

This vignette illustrates one of the ways in which concerned actors or social worlds can progress their particular sub components. In this case, the hurdle is that Daniel Grace, Steve Bull, and Steve Gibson have constructed an obligatory passage point through which all 5MTPA Project sub components must pass. Facing this hurdle are Richard and "the guys", who have been trying for "years" to extend the trajectories of a number of sub components in which they have a particular interest. It appears that the 5MTPA Project represents an opportunity for them to do this. However, Richard and "the guys" must first ensure that their sub components appear to pass through the obligatory passage point presented by Daniel Grace, Steve Russel, and Steve Gibson. Richard seems to have been successful in this endeavour and the sub components are now part of the 5MTPA Project.

This process of artefact seeding seems to be the technological equivalent of March and Olson's (1983, p.286) 'garbage can' model of organisational redesign which relies on 'highly contextual combinations of people, choice, opportunities, problems and solutions'. In these terms, design projects can be portrayed as 'collections of solutions looking for problems, ideologies looking for soapboxes, pet projects looking for supporters, and people looking for jobs, reputations, or entertainment' (March 1983, p.286).

This section has discussed how the first of my conceptual trajectory phases – artefact seeding[7] is characterised by action and interaction amongst actors and social worlds endeavouring to merge and/or create artefact sub components that are suitable for the project's obligatory passage point. The end of this phase represents the start of what would traditionally be called "design" of the overarching technology, or what I refer to as 'artefact negotiation'.

[7] Because of the nature of artefact seeding the majority of activities occur prior to formal recognition of a design project. The cases that I examined in this study were selected from a list of approved, but at the time not started, design projects. This meant that my observations commenced after many of the artefact seeding phase activities were complete. As a result the account provided in this section has been based on examination of actor discourse, project documentation, and interviews, rather than direct observation of the actual process as it unfolded. Further research specifically tailored to the characteristics of this phenomena may help construct a more complete picture of the phase.

## 4.4 Artefact Negotiation

*Artefact negotiation* represents the second of my conceptual trajectory phases within the arena of design. In this phase, actors from different social worlds negotiate, through action and interaction, artefact design details. The phase commences as a myriad of loosely related sub components stream through the obligatory passage point. At this stage, the design boundaries are few and the options for development many. However, as each new detail of an artefact is negotiated, an additional design boundary is added. These negotiated design boundaries act to limit the range of possible choices available to relevant actors. As the sub components continue to progress through this phase, they develop more detail and stronger links with one another through mutually defined design boundaries. As these links strengthen they align the individual trajectories, and sub components begin to merge. The end of the negotiation phase is characterised by a merging of sub components into a single artefact that moves into the accomplishment phase.

In the 5MTPA Project anticipated trajectories appeared to be an important part of artefact negotiation in the work of design. Exploration of anticipated component trajectories includes calculating and carrying out numerous lines of work relevant to the numerous sub components. These anticipated component trajectories then form a kind of 'blueprint to guide and coordinate the many discrete and conflicting pieces of accomplished work'. This type of work is referred to by Strauss et al as 'articulation work' (Strauss 1985, p.151). Strauss et al developed their concept of 'articulation work' in research into illness treatment in the medical field. They also cite its relevance for 'industrial, engineering, legal, military, and other kinds of work' (Strauss 1985, p.152). However, they note some significant differences. They suggest that industrial processes are relatively rationalised in comparison with illness treatment. This distinction notwithstanding, the concept seems to have a strong resonance with the observed activities of actors within my study.

Part of the work of design that I observed appeared to involve the visualisation and eventual realisation of artefact and sub component trajectories. Actors involved in this work appear to use, amongst many other things, both the concept of trajectories and what I have identified as design boundaries as important inputs to this process. The design boundaries restrict the range of possible trajectories that an actor may attempt to realise. These restrictions influence the social interaction between relevant actors and the social worlds influence the trajectory of a given artefact.

In the following vignette, I recount a scene where Daniel Grace, the manager of the 5MTPA Project, seems to be engaged in trajectory work during the 'artefact negotiation' phase. In this example, as with the Strauss et al (1985, p.153) example of an illness trajectory being disrupted by a post-surgical infection, Daniel's technological trajectory is disrupted by an unexpected plant failure and the impending BOS vessel reline to which his project is attached. Daniel addresses this contingency by visualising, and subsequently investigating, two possible trajectories from which he can choose.

***Vignette - I got each of them to predict their likely outcomes***

I had rung Daniel on the previous day to arrange a time to get together to discuss some of the new developments in the BOS Project. Daniel explained to me over the phone that the BOS vessel had developed a refractory fault and was in need of urgent corrective actions and that the planned reline had been brought forward a month. As a result, the Flux PLC installation would also have to be brought forward a month or put back a year until the next reline.

"Like I said on the phone, the shutdown's been brought forward a month," said Daniel. "So we're working on our options at the moment. We can either put the installation off for another year, or we can try and rush everything through and get it done during the twenty-one day window in this reline. If we put it off, that will stall the project, cost us money, and cause all kinds of hassles. If we pull it forward but don't get it right, Production will really get the shits, and that would be an even bigger problem. So I've been putting together some numbers for doing it now. I've put it to Max (Max Davies, the BOS Superintendent) that we have a ninety percent chance of success with the twenty-one day window and a ninety-eight percent chance of success with the twenty-one day window plus two weeks."

"How did you come up with the percentages?" I asked.

"I went around and talked to each of my project guys separately," replied Daniel. "I met them face to face and got each of them to predict what their likely outcomes would be. I then combined this information into an overall percentage rate for success."

In this vignette, Daniel creates two anticipated component trajectories along which he sees the artefact has the potential to travel. With the first path, "installation postponement", Daniel has associated a number of potential outcomes, "cost" increases and other general "hassles". With the second path, "installation", Daniel has associated another set of potential outcomes, "not getting it right" and "Production will really get the shits". The primary outcome that seems to concern Daniel is failure to complete the installation phase of the project on time. In an attempt to further understand this particular concern, Daniel has undertaken a number of activities. Firstly, Daniel has personally interviewed the key actors from his team and synthesised their opinions of the potential paths. Secondly, Daniel has discussed these potential paths with Max Davies in what seems to be an attempt to gauge his reaction and probable repercussions should the installation time overrun the scheduled plant shutdown.

As demonstrated by the previous vignette negotiations over design boundaries do not occur within the simple constraints of the participants' current environment. Rather, they include both past experiences and possible future circumstances. Trajectory work is one way in which actors are able to bring these past experiences and future circumstances to bear on the negotiations that occur within their current environments.

The following vignette provides another example of the concept of trajectories in use by designers. In this case, Ralph Hopkins, Senior Engineer on the BOS Project, discusses a future trajectory that represents a potential outcome that he wishes to avoid. By adding detailed information to the trajectory, Ralph is able to, firstly, communicate to others the undesired outcome, and secondly, arrange activities to ensure the outcome is not realised.

***Vignette – We've got to make sure we avoid that trap***

The final issue on the agenda of the BOS Project commissioning meeting had just been covered. The room was filling with the murmur of general conversation as the participants were standing in readiness to leave. I resisted the urge to follow, instead I sat and casually reviewed my field notes from the meeting. I had learned some time ago that some of the "back room" planning that occurred between actors took place in these post-meeting situations. So I continued to sit and read and wait.

The room became still, and I looked up to see that only Ralph Hopkins and Steve DeRosa remained. My presence seemed to cause them little concern as they stood at the end of the table discussing the shutdown.

"Everything seems to be going well," said Ralph. "But there's more to commissioning the Flux desk than just getting it operational. We've got to make sure we manage the opinions and impressions of the production managers. I remember when we blew in the new OG system. We had all the managers there to watch the first heat, you know; it was the big event. Anyway the system crashed and we couldn't get it back up and because of that one problem the managers walked away with the impression that we had done a bad job. So, we've got to make sure we avoid that trap with the flux desk and get it operational before we show it to the production managers."

In this vignette, Ralph seems to be drawing on past experience to envision a trajectory that he wishes to avoid. The discussion between Ralph and Steve is centred around what actions need to be taken in the present to avoid an identified and undesired future path, one that leaves a bad impression on the production managers.

The actors in the previous two vignettes seem to use trajectories in the work of design in two ways. Firstly, they use *trajectory projections* (Strauss 1993, p.53) to create a vision of the expected course of interaction that they perceive as being required to shape action with regard to an artefact. Secondly, they develop *trajectory schemes* (Strauss 1993, p.53) or plans designed to shape the interactions as desired, given the content of the trajectory projection. This shaping of interactions is an important influence on the negotiations that occur amongst the various actors and social worlds over design boundaries, and, ultimately, the final form taken by a technology.

In this section I have introduced the second of my conceptual trajectory phases – artefact negotiation – where the trajectory work of the actors includes calculating and carrying out numerous lines of work relevant to the artefact's numerous sub components. These numerous lines of work and various sub components eventually merge in the production of the physical technology. This process of merging is discussed in the following section, 'artefact accomplishment'.

## 4.5 Artefact Accomplishment

*Artefact accomplishment* represents the third of my conceptual trajectory phases within the arena of design. In this phase, actors from different social worlds negotiate, through action and interaction, the final physical form of the artefact. At the start of the phase all of the sub components are merged into a final amalgam under the pressure of overall design boundaries. This newly merged, penultimate artefact continues through a moulding process until completion of the accomplishment phase, where a final physical artefact emerges.

In a similar conceptual framework, Bijker (1995b) proposes a social constructivist model of the technological innovation process that concludes with "closure" and "stabilisation". Although Bijker sees these concepts as being two aspects of the same process, he treats them separately. Bijker states that,

> Closure leads to a decrease of interpretative flexibility – to one artefact becoming dominant and others ceasing to exist. As part of the same movement, the dominant artefact will develop an increasing stabilisation within one (and possibly more) relevant social groups (Bijker 1995b, p.87).

Bijker's explanation of the concepts of closure and stabilisation in the social constructivist model has proved useful in my examination of the process of design in the 5MTPA Project.

Before addressing the usefulness of these concepts, it is worth revisiting some of the differences between the two phenomena of interest, that is, technological innovation and institutional innovation. The social constructivist approach addressed by Bijker and others was formulated with respect to general technological innovation occurring within society. I am focussed on institutional innovation occurring within the notional boundaries of a single organisation and at the request of that organisation. This is an important difference to highlight because the social constructivist model of technological innovation portrays multiple artefacts developing simultaneously in competition with one another. Counter to this, the institutional innovation process that I observed in my study involved the development of single artefacts in an environment devoid of competition to perform the given duty. That is, BHP would not have five competing designs for a single duty, though it may have five groups competing for funds to develop artefacts with different purposes. This means that, unlike Bijker's model, during the process of closure in the projects that I was observing, there was no single dominant artefact emerging from a host of competing artefacts with similar duties. In spite of this, my data suggest that the concepts of closure and stabilisation seem appropriate, even if the specific details do not. In an attempt to address these parallels and differences, I have developed two concepts that are similar in meaning, but different in content, to those of Bijker's model, these are – *artefact accomplishment* and *closure*.

In terms of my observations of the 5MTPA Project, *artefact accomplishment* occurs when the design boundaries squeeze together so tightly that they effectively limit any further digression of the artefact in the process of design. Reaching the state of artefact accomplishment is heralded by the emergence of the final physical artefact. *Closure* is intimately entwined with artefact accomplishment in that the imminent emergence of the physical artefact triggers the social activities of closure. Closure represents a general agreement between the relevant actors that the physical artefact reflects their negotiated design boundaries. The actors within the 5MTPA Project seemed to employ a number of closure mechanisms. Two of the closure mechanisms that I observed were part of an official BHP standard procedure (BHP 1997) for the "Control of the Process of Design" mentioned at the start of this chapter.

The first of the closure mechanisms from the official procedure that I would like to discuss is the "Design Review Authorisation" (see Fig 4.1, step 11). This is a process by which "all involved parties approve the design". This closure mechanism seems to be triggered when the design boundaries tighten around the abstract artefact and emergence of a physical artefact is imminent. The procedure defines "involved parties" as being "the engineering coordinator, any specialists attending the design review, the discipline engineer, and the customer" (BHP 1997, p.4). To enact this closure mechanism these relevant actors meet and formally approve the design. This formal agreement is symbolised when each party signs the approval document. It seems that once this document has been signed, production of the physical artefact can commence based upon the negotiated design boundaries.

In the following vignette, Steve DeRosa, the BOS Project Engineering Coordinator, discusses a list of requests for interface modification arising from operator training on the simulation system that occurred after the design review authorisation had been completed. The physical setting that I describe below suggests the complexity of the technology being developed.

***Vignette – We don't intend to do anything.***

I rang Steve DeRosa to see if I could arrange to attend some of the new Flux interface training sessions.

"Yeah, sure," said Steve. "That won't be a problem. We are running all the operators through with full day sessions at Australian Automation. So all we need to do is pick one of those dates that suits you."

When my suitable date arrived, I headed off for my day of training and observation. I entered the small training room at Australian Automation and saw first two neat computer terminals positioned side by side at the front of the room. After absorbing this initial detail, I turned to survey the remainder of the room. My eyes were startled by what was at the back of the room. I was confronted by a mass of jumbled, colour-coded wires that looked like the insides of the tortured carcass of a spacecraft from a Star Wars movie. This was later explained to be the PLC simulator, which provided the two neat computers at the front of the room with all the real field data for our training purposes.

One of the many things that I observed during my day of training at Australian Automation was the operators uncovering what they considered to be design flaws within the new system. These flaws were all recorded in detail by the trainer for the future reference of the design engineers.

The following day I bumped into Steve in the design office.

"So how did your training day go?" Steve asked.

"Oh it was great, the prawns for lunch were a nice touch," I replied.

"Yeah" replied Steve smiling. "We make sure we feed the guys well to try to encourage them to go to the training."

"Actually, one thing I wanted to ask. How are you dealing with all these last minute faults the guys are identifying during the training?" I said.

"We don't intend to do anything," Steve replied. "They reviewed and signed off on the design as it is. Any changes they want from now on they will have to pay for themselves once we've finished."

This vignette provides an example of how a closure mechanism, such as the "Design Review Authorisation," can tightly couple the physical artefact that emerges to the negotiated design boundaries. Steve does not question the validity of the faults that the operators have identified during the training sessions. He does, however, question his responsibility for modifying the artefact in response to the identified faults. It seems that once this particular closure mechanism has been enacted the previously negotiated design boundaries become very difficult to change within the current process of design. This does not mean that the identified faults will not be remedied, rather that these modifications will occur outside the current process of design and outside the current set of negotiated design boundaries. As such, one can see that negotiated design boundaries not only define concrete specifications but also the extent of responsibility and accountability of each party to a design.

A second closure mechanism, from the official BHP standard procedure for the "Control of the Process of Design" (BHP 1997), that I would like to discuss is the "Post Commissioning Inspection", (see Fig 4.1, step 13). This process involves the "discipline engineer" carrying out "a post commissioning inspection to check that the design is functioning safely. ... is being used as intended, and is functioning correctly" (BHP 1997, p.20). This closure mechanism seems to be triggered after the physical artefact has been produced and allowed to settle into its intended environment. To enact this mechanism, the "discipline engineer" and the relevant users of the artefact congregate around the physical artefact in use in its intended environment. The assembled relevant actors observe and evaluate the physical artefact with respect to its negotiated design boundaries. If this evaluation proves favourable, and agreement is reached, then the final phase of the official process of design is complete.

The artefact accomplishment phase is characterised by the action and interaction amongst actors and social worlds to merge the sub components and produce the final physical artefact. This phase is accompanied by a series of closure mechanisms that seem to be designed to limit further design modifications within the current arena of design. However, this does not mean that the trajectory of the artefact will not continue into the future with modifications, repair or even replacement. It merely means that, with respect to the current arena of design, the trajectory is complete.

## 4.6 Summary

Designing technology is a complex and dynamic process. This process can be characterised by a number of phases, the junctions between which are marked, not by changes in the technology itself, but primarily by changes in the interactions amongst actors and social worlds. This definition does not force technology to fit some 'natural', or perhaps more aptly called 'un-natural', linear path of development. Rather, it allows the process of design to be examined in terms of the social forces that shape it.

Illustrations in this chapter show how technology develops via a process of amalgamating trajectories of sub components. The sub components are themselves shaped by interaction amongst relevant actors and their social worlds within the constraints of external technological, political, cultural, economic, and social circumstances.

The concept of 'trajectory' not only provides a macro, etic structure, it also helps explain certain elements of the discourse observed amongst the actors in the 5MTPA Project. The actors appear to use a trajectory concept, developing trajectory *projections* and trajectory *schemes* to guide their actions and interactions during the process of design. These projections and schemes influence and fuel negotiation about design boundaries. They assist certain actors in their attempts to shift design boundaries. Yet, conversely, design boundaries constrain trajectory projections and trajectory schemes. That is, the accumulated technical specifications and social agreements embodied in a design boundary act as a restrictive phenomenon. This mutual interplay or dialectic between design boundaries and trajectories provides a link between the social processes surrounding development and the final physical form of the technology.

The following chapter describes the development of the specifications that constitute design boundaries, and enable the physical technology to take its final form.

# Chapter (5) – Design Boundaries

## 5.1 Introduction

The term *design boundary* refers to the set of specifications that represent the outer limits of a design space and influence sub component trajectories. For example, the configuration of a bicycle is constrained and enabled by a set of design boundaries, one of which is that the number of wheels shall be two so that a bicycle may be steered by a combination of leaning and turning. Design boundaries can be understood to have two overlapping elements - boundary plates and boundary membranes. These two elements are distinguished from one another by how participants in the design process interact with them. They differ, for example, in how explicitly they are addressed and acknowledged.

The actors in the 5MTPA Project employed a number of methods for constructing design boundaries. These methods resemble, without being derived from, some of the common prescriptive design methodologies, for example, role-play, simulation, and prototyping, which were discussed in Chapter (3). The actors seem to choose amongst these methods based upon a combination of personal proclivities, their understanding of the situation, and the phase of the trajectory – whether seeding, negotiation, or accomplishment.

Design boundaries not only influence sub component trajectories, they also represent an opportunity for individuals and social collectives to act on hidden agendas. Actors exert power by defining certain elements of a design for others. As a result, institutional design does not follow a natural or sequential path from inception to maturity, a point noted in Chapter (2). Instead, there are myriads of sponsored sub components constantly being redirected toward new development opportunities. In the 5MTPA Project these opportunities came in the form of three, organisation-sponsored design projects: WTP, BOS, and LK. A sub component could enter these projects via the 5MTPA obligatory passage point as characterised in the preceding chapter. Once inside the design space sub components are more easily provided with the resources and opportunities to develop and grow. They then develop via unique but interlinked trajectories, setting and responding to design boundaries along the way. This chapter describes the outer limits of the design space, and illustrates how two types of design boundaries – boundary plates and boundary membranes – are constructed and manipulated.

## 5.2 Design Boundaries

*Design space* is a sociological construct used to represent the range of possible choices that actors can make with respect to an artefact being designed (Clark 1988; Thomas 1994). A limitation of the design space concept is that it does not provide an analytic framework for exploring interaction amongst actors, social worlds, and artefact trajectories. In response to this, I have developed a further construct, *design boundaries*, to represent and subsequently analyse interactions around the outer limits of the design space. A design boundary is a set of specifications that constrain and enable artefact trajectories by representing specific variations or options that may or may not be pursued. These design boundaries are the negotiated product of interactions amongst relevant actors and social worlds in conjunction with external technological, political, cultural, economic, and social circumstances. Design boundaries may include such things as budgets, time frames, user requirements, and technical specifications.

As noted in Chapter (4), the design boundaries at the start of a project are few and the options for development many. However, as each new detail of an artefact is negotiated an additional design boundary is added. These boundaries continue to grow in number throughout the process of design, constraining more and more of the design options until eventually, through the twin processes of *artefact accomplishment* and *closure,* a final physical artefact emerges from the process.

In this chapter, I focus on the more tangible aspects of the social processes related to design boundaries (Chapters (7) and (8) focus more specifically on the social processes themselves). I have identified two general types of design boundaries in the 5MTPA Project. The first type, boundary plate, is a relatively rigid outer limit that is generally recognised and understood by the relevant actors and social worlds. The second type, boundary membrane, is a flexible outer limit that is negotiated on a local level and may not be recognised by other relevant actors or social worlds (see Fig 5.1).

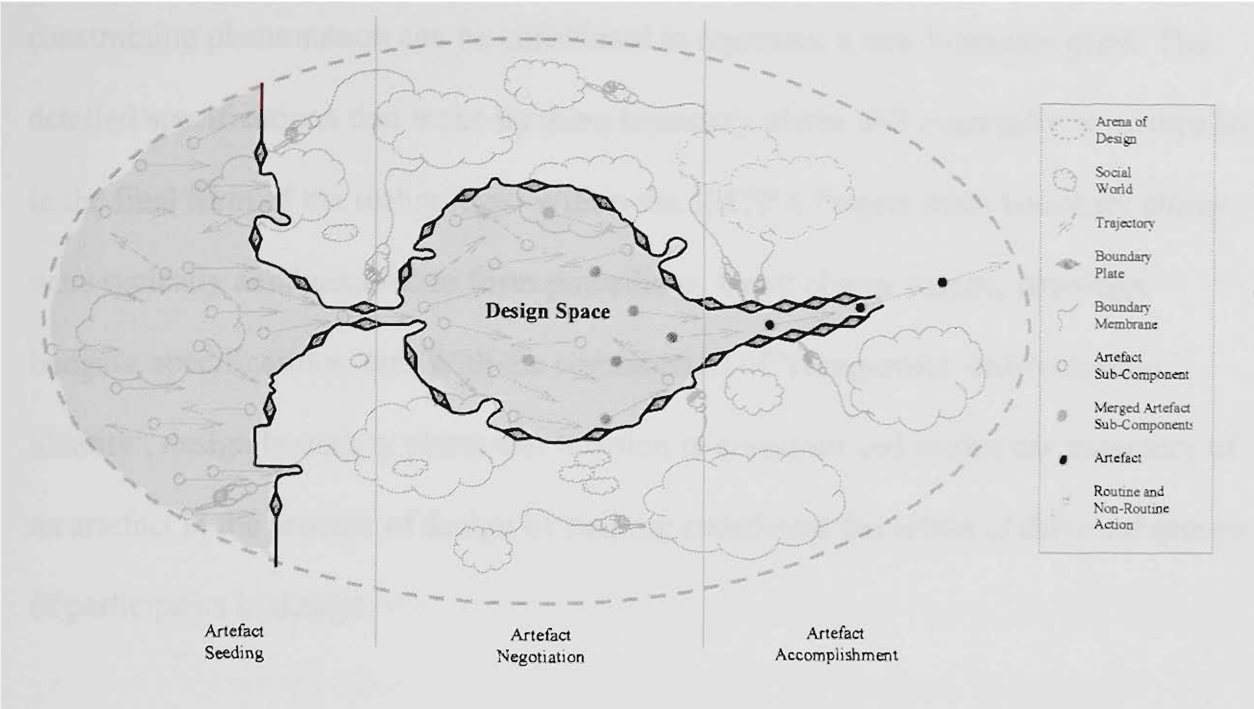



**Figure 5.1 - Design Boundary**

The diagram above presents my conceptual representation of boundary plates and boundary membranes (shown in bold). The thicker boundary plates are linked together by the thinner boundary membranes to form a continuous perimeter that defines the design space (shown in grey). In the following sections I explore in more detail the nature of these two types of design boundaries.

### 5.3 Boundary Plates

A design *boundary plate,* as noted earlier, is a relatively rigid outer limit to the design space. It is comparatively well recognised and commonly understood amongst the relevant actors and social worlds and is recognised as being a constraining phenomenon in the process of design. Each new negotiated detail of the artefact (the diameter of a hole, the colour of a screen icon, the length of a desk) that is commonly recognised as a constraining phenomenon can be considered to represent a new boundary plate. The detailed specifications that make up these boundary plates will eventually be embedded in the final form of the technology. Within the 5MTPA Project these boundary plates were typically amalgamated to form procedures, Gantt charts, rosters, drawings, budgets, specifications, etc. With the combination of 'recognition' and 'common identity', design boundary plates can function to constrain and enable the trajectory of an artefact in the process of design by helping coordinate the action of different groups of participants in design.

The work of Leigh Star and others on the concept of "boundary objects" seems useful for considering how the relevant actors and social worlds within the 5MTPA Project developed and maintained boundary plates and their amalgamated forms. According to Star and Griesemer, boundary objects are:

> objects which both inhabit several intersecting social worlds *and* satisfy the informational requirements of each of them. Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of several parties employing them, yet robust enough to maintain a common identity across sites. ... They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognisable... (Star 1989, p.393)

Design boundary plates, especially in the amalgamated form, can be considered to be boundary objects. One of the ways Star's boundary objects enable action is through their common identity across social worlds. Boundary plates also enable action through their common identity. However, unlike Star's boundary objects, boundary plates are seen to have a dual enabling/constraining nature, that is, they enable the process of design by constraining the trajectory of the artefact. One of the strengths of the concept of a boundary object, with respect to my research interests, lies in its ability to link the boundary plates with multiple and divergent actors, groups, meanings, and uses (Fujimura 1992).

The following vignette provides an example of how boundary plates can influence the process of design. In this case, Ralph Cowie, the WTP operations supervisor, is discussing some of the recent financial and time limitations that have been placed upon the WTP project. It seems that in this case the reduced budget and extended time frame are boundary plates that are restricting the options available for the development of the WTP Project.

***Vignette - It's simple, the more energy the better the result.***

Ralph shared a large partitionless office. A constant stream of men dressed in gritty grey woollen clothes, heavy boots, leather spats, and charred hard hats that resisted the heat and sparks of the plant were wandering in and out. These were the workers who handled the molten steel. I sat beside Ralph feeling rather vulnerable in my clean blue shirt and shiny black shoes, taking notes in my neat leather folder.

Ralph seemed totally unperturbed by the contrast.

"You gotta understand," said Ralph. "That the energy and resources available impact on the project and its outcomes. The quality of work is mediated by the amount of energy and resources you put into the project. It's simple, the more energy the better the result. The problem with the WTP project is we've limited resources and an extended timeframe."

The background to the situation described by Ralph in this vignette is a corporate tightening of general capital expenditure. As mentioned in Chapter (2), when Paul Anderson took over as the new BHP chairman in 1998 he directed a review of all capital expenditure in an attempt to reduce cash outflow. As part of this general capital review, all of the 5MTPA Projects were scrutinised. It appears that the relevant actors involved in this review selected the WTP project as a target for potential cost reductions. Although Ralph had no input into the construction of these boundary plates, he nonetheless recognised and responded to the constraints that they represented[1].

My observations of the 5MTPA Project revealed several typical types of boundary plates that actors seem to use, or refer to, as constraining activities and options during the process of design. Table 5.1 lists my labels for eight types of observed boundary plates, a brief description, and one of many examples of each that I recognised. (Note that this is not necessarily a comprehensive list of all of the project design boundary plates).

[1] In this situation Ralph has been forced to comply with changes to the outer limits of the WTP Project design space with respect to time and expenditure. The circumstances through which such modifications to boundary plates may be made, and the potential ramifications of dissension, are discussed in greater detail later in this chapter.

| Table 5.1 Observed Types of Design Boundary Plates | | |
|---|---|---|
| **Type** | **Description** | **Example** |
| Technical | Technological capabilities. | "I want to see everything on the screen!" said Leo. "Just like I've got now with the mimic panel."<br><br>"Yeah that would be nice," replied Steve. "But you've got to understand, we are constrained by the technology that we have. They just don't make screens big enough to fit on all the information you want." |
| Financial | Financial resources. | "The 5MTPA Project was originally approved for $98M," said Daniel. "But with the cutbacks that's now been reduced by $13M to only $75M. That means some of the projects have to change. So I'm redirecting funds and personnel to make sure we meet the new budget." |
| Time | The time available to complete given tasks. This includes either too much or too little time. | "Another constraint that's worth mentioning is time," said David. "Projects are often rushed and the first thing to go is the time you should spend with operators. We end up making most of the choices for them." |
| Industrial | Industrial relations issues between management and workers. | "This is the first step towards a single control room," said Ralph. "Technically we will have the capabilities, but we won't do anything physically until we're ready to take on the operators industrially." |
| Physical | Physical limitations of relevant plant and equipment. | "I was looking inside the panel the other day," said Eric. "There is hardly any space left. I wanted to install the new 27R relay but there's no way it'll fit. There are just too many wires in there and the 27R is too big." |

| | | |
|---|---|---|
| Access | Operational plant access limitations. | "We have to be careful how we design it," said Eric. "The goal is zero impact on production from the changeover. That means we can't just shut down the plant and change it over however we want." |
| Status | Plant and/or project status. | "If Timbo (the superintendent) were driving this project, things would be different," said Ralph. "The project would have a much higher status and things would be done a lot differently." |
| Goals | Original project approval aims and goals. Typically represented by the project's obligatory passage point. | "One of the major goals of this project is operational security," said Bill. "That means we're building in as much redundancy as we can. If anything fails, we want to have at least one backup." |

The table above provides a list of types of boundary plates that can be used to represent the outer limits of a design space. This typology characterises the ways in which actors gain useful information about the relative rigidity, nature, and background of specific boundary plates. In turn, some actors seem to use this information as a source of power during creation and/or modification of boundary plates, for example, citing a tight schedule as a reason to select one design option over another. In this sense, power is derived from the 'actor's capacity' to use boundary plates 'to define major elements of the artefact for other actors' (Clarke 1991, p.144). This process will be addressed further in the closing stages of this chapter.

In this section, I have introduced the notion that boundary plates constrain and enable artefact trajectories by representing specific variations or options that may or may not be pursued. Further to this, boundary plates are the products of interactions amongst relevant actors and social worlds in conjunction with external technological, political, cultural, economic, and social circumstances. For example, the depressed world steel market in 1998, and BHP's accompanying poor economic performance, influenced the 5MTPA Project through Paul Anderson's direction for a general review and rationalisation of all BHP capital expenditure. I have also introduced in this section a typology of boundary plates with an initial eight categories. Section 5.6 of this chapter continues the discussion about boundary plates by reviewing some aspects of their use in the 5MTPA Project. In the following section, I shift the focus from the relatively palpable and concrete boundary plates to their brethren, the more abstract boundary membranes.

### 5.4 Boundary Membranes

My concept of a boundary membrane, as with the astronomical concept of a black hole, relies primarily on indirect evidence. Although astronomers cannot see black holes, they postulate that they exist because of the observable, but otherwise inexplicable, variations in the orbits of certain planets. In a similar way, I have been able to directly observe variations in sub component trajectories that are not explainable in terms of my boundary plate concept. In response to this, I have developed the notion of a *boundary membrane,* which fits between, and links together, the boundary plates to form a continuous outer boundary around the design space. Having said this, the distinction between plates and membranes is not a strict binary classification; rather the two concepts blur together at the points of junction.

A boundary membrane, as noted earlier, is a flexible outer limit to the design space that is negotiated on a local level and may not be recognised by other relevant actors or social worlds. They are typically undocumented and maintained through discrete personal interactions amongst relevant actors and social worlds. Such things as individual preferences, social world traits[2], and routines[3] guide these local interactions. Their undocumented and local nature contributes to the fact that they may not be recognised by other actors or social worlds.

The following two vignettes provide examples of boundary membranes influencing the trajectories of a number of sub components. In the first vignette, Ralph Hopkins, the BOS Project Manager, discusses several personal preferences that seem to be influencing the process of design.

***Vignette – I'm trying to restrict that.***

Ralph's office was close to mine in Engineering's temporary project sheds located beside the Steelmaking plant. It was slightly amusing to me that that these 'temporary' sheds had not been moved from their current location for more then ten years. The location seemed relatively clean and quiet. That was until the occasional diesel locomotive rumbled past. The walls would shake and the windows would darken with the hulking presence of a loaded locomotive dragging hundreds of tonnes of glowing red steel slabs within inches of the building. Conversations would stop, heads would

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[2] I have defined a 'social world trait' as a representation of the commitments and ideologies of a social world. For example, the 'engineer' social world in the 5MTPA Project seemed to exhibit a trait that I referred to as 'high tech', that is, its members displayed a passion for new gadgets and new technologies. This concept is explored in detail in Chapter (6).

[3] A 'routine' can be defined as a standard pattern of action. These patterns enable goal directed action to occur without the need to invent new approaches each time a person or collective acts (Strauss 1993). This concept is further explored in Chapters (7) and (8).

turn, and I would be gently reminded of the size and power of the equipment within the steel industry.

Just such a train rumbled past as I was preparing for my discussion with Ralph. When the quiet returned, I gathered my notepad and pen and wandered off down the corridor toward Ralph's office.

After Ralph ushered me in, we sat and began casually discussing a variety of aspects of the BOS Project.

At one point in the conversation, Ralph said, "You know how it is with operators. They want push buttons for everything. So I'm trying to restrict that. I want to use more software and less hardware."

"What's the problem with buttons and hardware?" I asked.

"It restricts you too much," replied Ralph. "Once hardware controls are installed you have very little scope for improvement. For example, I have seen plants overseas that have only one control room for three furnaces. We have three identical control rooms to control three furnaces all side by side. I want to make sure that the technology we're installing has the ability to go to just the one control room, too, should we ever want to."

In this vignette, Ralph expresses his desire to use "more software and less hardware" in the new BOS control room. He states that his motivation to do this is based on the flexibility of software and the potential to control three furnaces with one control room. In this situation, Ralph's preferences are not generally recognised by others, nor do they directly appear in any of associated documentation. However, they still influence trajectory of the BOS control room.

In a related vignette, Craig and Terry, both BOS operators, discuss a number of their personal preferences that seem to directly conflict with those of Ralph.

***Vignette – It just seems so complex and easy to stuff up.***

I was sitting beside the stainless steel tea trolley at the back of the control room for the No3. BOS Vessel. The trolley would have seemed more at home in a hospital ward than a steel plant control room. Inside the spout of the scratched and dented stainless steel teapot was a dark tarnish that could only have been deposited through years of dedicated service. In all my visits to the control room, I had never seen who brought the trolley or who wheeled it away. To me, it seemed like a mysterious supply of strong, perpetually hot tea.

I returned my attention to Craig and Terry, the afternoon shift operators. They were both busy with the initial stages of blowing the heat. However, soon the 275 tonne pot of bubbling, frothing, exploding molten steel would calm, and they could return to their tea, and I could return to my questioning.

Craig returned to his tea first leaving Terry to control the heat on his own.

"So how much impact is the new Flux PLC going to have on your job," I asked.

"Well, a fair bit," replied Craig. "The flux system probably takes up about thirty percent of our time. I'm certainly not looking forward to them taking away our flux desk and replacing it with a computer."

Terry returned to his tea and added, "Yeah, I'm not at all impressed with computers. I'd much prefer to just push buttons. You know, no one can tamper with buttons, but computers, who knows! I remember when they installed a new computer in here a couple of years ago. Someone put a screen saver on it. The screen saver came on, and I had no idea how to turn it off. It just seems so complex and easy to stuff up."

In this vignette, Craig and Terry both express a desire for less software and more hardware. They state that they would "much prefer to just push buttons." This general desire appears to be in conflict with the preferences expressed by Ralph in the previous vignette. In this situation, Craig and Terry's desires for less software can act to limit the impact of Ralph's desires for more software and visa versa. The result is a boundary membrane that loosely represents the outer limits of the design space with respect to the levels of hardware and software contained within the final artefact. The factors that cause these outer limits are not documented, nor are they openly discussed amongst the relevant actors or social worlds within the project. Nonetheless, they affect options that may or may not be pursued with respect to hardware and software in the BOS Project.

Whilst the opposing views outlined in the two previous vignettes remain in balance, and out of the general public view within the BOS Project, they retain the status of a boundary membrane. However, should Ralph, Craig, or Terry attempt to go beyond these outer limits it is likely that an issue of contention will arise. If this were to happen, an arena may form around the issue[4] and a debate regarding software versus hardware may ensue. The outcome of this debate will be a further refinement of the outer limits of the design space and the probable creation of a new boundary plate.

In this section, I have provided a brief discussion of my notion that boundary membranes influence the trajectories of sub components. Further to this, the notion provides a conceptualisation of how boundary plates may be joined to form the continuous boundary that encompasses the design space. Because of the nebulous and individualistic nature of boundary membranes, I do not intend to examine them in as much detail in this study as I do boundary plates. That investigation will have to wait, despite the potential importance of membrane dynamics, for a future study specifically designed to examine this diaphanous phenomenon. The following section discusses the more tangible dynamics that I observed in the construction of boundary plates.

## 5.5 Boundary Plate Construction

In the 5MTPA Project, two salient aspects of boundary plate construction that emerged from the data were, firstly, the conceptual *materials* from which they are constructed, and secondly, the *methods* that were used by actors during the process of construction.

[4] The formation of arenas of interaction amongst individuals and social worlds around contentious issues is explored in greater detail in Chapter (7).

It seems that numbers are the most prolific *materials* used for the construction of boundary plates. There appear to be several reasons why numbers are so widely used. Firstly, the majority of actors seem to recognise and understand numbers. Secondly, this recognition of numbers allows for transfer between disparate groups within the process of design. Thirdly, the actors seem to generally assign a level of immutability to numbers. Finally, many characteristics of a technical artefact seem to lend themselves to numerical definition.

Individual boundary plates, in amalgamated forms, became visible to me as numerically constructed specifications, engineering drawings, budgets, Gantt charts, and rosters. Part of the rigid nature and common understanding of boundary plates, and their amalgamated forms, seems to come from the numerical nature of the materials from which they were constructed. The main disadvantage of using numbers appears to be that, due to their rigid nature, they do not readily lend themselves to defining the softer useability aspects of design.

The *methods* used by the actors for boundary plate construction seemed to be contingent upon the actors, the situation, and the trajectory phase. I have identified two general categories of methods that seemed to be used by the actors in the construction of boundary plates: *personal construction* and *team construction. Personal construction* occurs when an individual constructs a boundary plate in solitude. The process of personal construction typically occurred when individuals were alone in their particular workspace, for example, at their desk, drawing board, computer terminal, or operator station. The individuals usually sat alone and modelled, sketched, analysed, calculated, wrote, etc. All these tasks seem to be performed in order to potentially add some detail to the artefact under design. It is very difficult for me as an observer, without some visible cue, to understand what the actual thought processes are in calculating and designing with respect to the boundary plates under construction[5]. Suffice it to say, that after some time working alone, the individuals seem to possess a series of new boundary plates, such as pump flow rates, screen colours, or font size, which they present to other relevant actors involved in the process of design. The presentation may be performed implicitly through the inclusion of the newly created boundary plate within a boundary object, such as a drawing or specification. Alternately, it may be performed explicitly through a formal review process. Should an issue arise during the presentation then it is likely that an arena will form and *group construction* of the boundary plate will commence[6].

*Group construction* of boundary plates appears to occur in any location where two or more individuals can communicate and collaborate with one another, for example, offices, conference rooms, plants, control rooms, or phone links. The following vignette provides an example of what I see as group construction of boundary plates. In the scene, a group of engineers are meeting at Automation Australia's off-site premises to discuss the BOS Project. During the meeting, a number of options for artefact details are discussed. It seems that when agreement is reached on which option to select the details are documented and a boundary plate is constructed.

[5] Cognitive psychologists under the guise of 'design' have studied this process of personal construction of what I am calling boundary plates. This type of research is often carried out within laboratory settings where the participants are video taped and asked to verbalise their thought processes during completion of assigned design tasks. This area of literature was reviewed earlier in Chapter (3).

[6] The formation of arenas is discussed in detail in Chapter (7).

***Vignette – I'll just re-format the whole numbers.***

Three serious looking men sat around an imitation wood table in a hot windowless room. The Contractor's premises were modern, stark and cheaply constructed. Steve DeRosa, the young Company engineer given charge of his first project, was studying his worn diary, stopping to glance at his watch at regular intervals. Placing my pen on the page, I carefully record the scene in my notebook for future reference.

David Riley, the owner of the Contracting firm, enters the room; tall, bearded, seeming to command attention through presence alone. He casually settled into the remaining seat.

Steve appears to take this as a cue to start and looks at the two men across the table. "Let's get started… The reason I've called this meeting today is that Kevin has been talking to you guys from IT, asking you to do certain things. I haven't been informed of all Kevin's requests and wanted to call everyone together to clear up all the issues."

David's face creases, ever so slightly, with what looked like a knowing grin.

"I want to sort out exactly what information will be handled by the systems and when it will be handled. This will include the BBC (BOS Blowing Computer), the Macroview, the field devices, and all the logic behind them."

Steve pauses briefly to review notes recorded in his diary before continuing. "Let's start with this rumour I've heard about operators complaining about our display of whole numbers."

"Yes," replied Ray. "Kevin came to us with a complaint about the numbers being displayed incrementally on the screen as 5.7, 5.8, 5.9 then 6. He said the operators would prefer the whole numbers displayed with a decimal point and zero, so 6.0 not 6. If they see just a 6, they will get confused."

At this point, the room erupted with laughter.

Shaking his head, Steve replied, "Where do we get these operators?!"

The laughter erupts again. As the noise dies down, David interjects some seriousness, "Actually we can accommodate that request. I'll just re-format the whole numbers to be displayed with decimal points."

Steve mumbles acceptance and makes a note in the official meeting minutes then moves to the next agenda item on his diary list.

In this vignette, a group of engineers met to discuss several different artefact details and, where possible, construct the relevant boundary plates. The engineers discuss the way certain field measurements will be displayed on the operator interface screen in the BOS control room. The operators have expressed a desire for consistency of numerical display. After some light banter, agreement is reached when David suggests he can accommodate the request through reformatting the display. It seems that those present at the meeting represent the key actors on concluding the issue of numerical display because once they have reached apparent agreement, Steve stops to document the resolution then moves smoothly to the next topic. The combination of key actor agreement and documentation can be understood to elevate the resolution to the status of a boundary plate.

The preceding vignette exemplifies a group construction method for a boundary plate method that I refer to as *real time social negotiation,* that is, where the actors meet to discuss and resolve issues regarding specific artefact details. This method was commonly used throughout the process of design.

I have identified a further four common methods for group construction – *exemplar, artefact role play, time travel,* and *simplification,* each of which are discussed in the following sections. These methods are not part of BHP's official Design Control Procedure[7]. Rather, they seem to represent routines[8] used in the process of design with the specific result of defining boundary plates.

## Exemplar Styles

The early stages of an artefact's journey though the process of design can be hampered by a lack of detail. Although the conditions for passing through the design boundary

[7] This procedure was described at the start of Chapter (4) and represents BHP's explanation of how design 'should' be performed.

[8] As mentioned earlier in this chapter, routines are standard patterns of action and are discussed in greater detail in Chapters (7) and (8).

neck[9] at the start of trajectory phase (II) may have been met, they provide little concrete design guidance for the relevant actors and social worlds. One of the hindrances to design progress during this stage is that the artefact has the least amount of detail and hence seems difficult for the actors to visualise in terms of its physical characteristics and potential influence on the workplace. Furthermore, with the details so scant, actors cannot be sure that what they are visualising matches what other actors are visualising. In an attempt to counter this difficulty, actors appear to use a number of group methods for boundary plate construction based on a variety of *exemplar styles*. These exemplar styles serve as patterns or archetypes around which designs can be discussed and developed. The following paragraphs characterise and illustrate with vignettes some of these observed exemplar styles.

The first exemplar style is the rough and ready *start point* method. With this approach, an actor supplies a set of provisional boundary plates for an artefact as a start point for the process of design. In doing so, the actor creates an artificially high level of detail that, while containing significant inaccuracies, provides a basis for mutual visualisation and discussion. In the following vignette, Steve Gilroy, a process engineer responsible for designing graphical user interfaces, discusses how he starts his component of the process of design for the WTP Project. He specifically refers to one of his approaches, which I had observed him use on several occasions, for interacting with the WTP operators in the early stages of the process of screen design.

9 The design boundary neck is a set of conditions defined at the start of a project that represent an obligatory passage point through which all sub components must pass in order to gain access to the resources available within the project's design space. This concept was discussed in Chapter (4).

***Vignette – You have to design it wrong before you can design it right.***

"The problem is the guys just won't take the first step," said Steve shaking his head. "You know, they're great at telling me what they don't want. But ask them what they do want, and they're a blank! So I just make up a screen knowing it's probably all wrong but then the guys can sit around and tell you why it's wrong. Then you can design it right. If I gave them a blank screen and asked them what they wanted, there is no way they'd give me any answers. So I just design a screen as best I can knowing I'll change it once the guys see it."

In approaching the early stages of artefact design in this way, Steve seems able to circumvent some of the usual issues that arise from a lack of artefact detail. Steve provides the operators with a set of assembled building blocks that they have permission to disassemble and then reassemble into design boundary plates.

A second exemplar style is the *sketch* method. With this approach an actor engages directly with other actors involved in the process of design and collaboratively uses pen and paper to add visual detail to the artefact. The sketch seems to allow all of the participating actors to visualise similar artefact detail and hence engage in richer discussion and artefact development. In the following vignette, Steve Gilroy is visiting Leo Tims and Frank Stanic, two WTP operators, in the WTP control room.

***Vignette - We could lay the screen out something like this.***

Steve had explained to me earlier that the purpose of his visit to the WTP was to question Leo and Frank about how they controlled the plant. Steve said he wanted to know what they thought about the plant, and then he would use the information gained as part of the detail for designing the new interface screens.

After questioning Leo and Frank for some time, Steve seemed to become excited. He hurriedly grabbed a pen and paper and began sketching.

"You know, we could lay the screen out something like this," said Steve as he drew a series of layered boxes and started filling them with icons and labels.

"Yeah that's OK," replied Leo as he watched Steve sketch. "But I don't want to keep jumping screens." Leo pointed to the first box and said, "I want more information on this one so I don't have to jump around so much."

Steve, Leo, and Frank continued sketching, discussing, and revising the screen layout drawings for another ten minutes before returning to Steve's original line of questioning.

By using the sketch exemplar approach, Steve seems able to facilitate the interaction between Leo, Frank, and himself. The sketches appear to serve as a common visual prompt around which Steve is able to focus the discussion.

A third exemplar style is the *site visit* method. This approach is similar to the rough and ready start point method in that it instantly provides a high level of artefact detail during the very early stages in the process of design. However, in this case, the instant detail is provided by another functioning artefact of similar configuration. In the following vignette, Steve DeRosa, the BOS Project Engineering Coordinator, recounts how he took a group of BOS operators to another facility in the Tin Mill to see its new operator interface in operation.

***Vignette - But at least they could tell us what they didn't want.***

"I got all the guys together and took them over to visit the Tin Mill," said Steve. "They just spent $300 million over there fixing the place up. They got a couple of new control rooms and operator interfaces. So I took the guys over for a look at the screen layouts. They didn't like them at all. They were totally different from what they wanted. But at least once they had seen them they could tell us what they didn't want."

By approaching the early stages of artefact design in this way, Steve seems able to add a lot of initial detail with very little effort. Furthermore, he also seems able to start the process of screen design with all of the actors sharing a similar familiarity with the artefact. This mutual visualisation forms a base for subsequent design discussions.

These three common exemplar styles: *start point, site visit,* and *sketch,* seemed to be used primarily during the early stages of the artefact negotiation phase. Their use appears to be in response to a lack of artefact detail that needs to be filled to continue the design progress. As this detail is slowly accumulated, the relevant boundary plates can be constructed and the artefact proceeds along in its developing trajectory. In the later stages of the artefact negotiation phase, additional construction methods for boundary plates are employed.

## Artefact Role Play

One of the more salient methods that I observed actors using to facilitate group construction of boundary plates was that of *artefact role play*. This method seemed to be used by actors as details accumulated as the artefact moved into the middle and later stages of artefact negotiation phase. During role-play, actors seem to take on the identity and characteristics of an abstract, inanimate sub component of the artefact under design. In using the method, the actors did not discuss the specific artefact detail that needed to be addressed, then by consensus, decide that role-play was the most appropriate method. Rather, they seemed to slip in and out of character without signalling any awareness that they were employing a predetermined strategy to do so. The following vignette involves a scene from a formal design review meeting for the BOS Project where I observed the actors use the role-play method to explore and further refine an artefact under design, namely the operator interface.

### *Vignette – What? I can't see your flag.*

The BOS design review meeting was held in what I have come to consider as a fairly typical engineering conference room. The walls were bare except for the broken line of dark greasy heel prints around the base and the occasional hand print mid way up. The chairs were an odd assortment of discarded office chairs. The conference table was a cheap laminate construction and seemed to have a perpetual layer of thin almost invisible grime that instantly attached itself to anything with which it came in contact.

Steve DeRosa, the BOS Project engineering coordinator and the electrical engineer responsible for the field device interfaces, was droning through the previous meeting minutes. David Riley, the software engineer responsible for writing the PLC code, and Ray, the IT specialist responsible for designing the mainframe interface, were both listening and answering any relevant questions in a seemingly mechanical fashion.

The meeting continued this way for some time until Steve raised the topic of the information transfer between the PLC, the field devices, and the mainframe. David and Ray sat slightly more erect and a new exchange of information began.

Steve looked at David saying, "My bin full limit is reached." He then flicked his wrist to indicate the limit had been triggered and said, "Then I send the signal through to you," and pointed to David.

"OK," David replied, "I get your signal and raise a flag." David raised his hand up into the air and looked to Ray.

"What? I can't see your flag," Ray replied. "OK, I'll make sure I add that."

They continued exploring the system in this way. At different stages of the role-play, they seemed to also shift time frames, then re-envision the system under the new constraints.

"OK, lets move to when the new ethernet bus has been installed but the other control rooms are still on the old system," said Steve.

They started sending signals and responding to one another under these potential future conditions. Finally, after thirty minutes of role-play, they returned to their review of the previous meeting's minutes, and in doing so, resumed their more succinct, mechanistic responses.

In this vignette, it appears that each of the individuals has taken on the persona of the specific, inanimate sub components for which they have design responsibility. In doing so, they are able to model an abstract artefact in real time and explore its performance when subjected to possible real life situations. They seem to slip into this role-play mode without discussion or specific recognition of the shift. When engaged in role-play, the actors use a combination of voice and gesture to bring their specific items to life for the other actors present. In doing so, it seems they are able to check failure scenarios, system response logic, communication, and generally look for mismatches in the way sub-systems are designed well before they are combined into the final artefact. It seemed that in the portion of the scene recounted above, the actors discovered that the type of signal sent from the PLC (David) to the mainframe (Ray) under the stimulation of the "bin full" alarm (Steve) would not be recognised. Ray noted this fault on his pad and suggested that he would make the required changes.

A further method for group boundary plate construction that appears to be in use in the preceding vignette is that of *time travel*. Time travel seems to occur when actors use their imagination to examine the artefact under design at various agreed points in the past, present, and future. The actors move the artefact through time to an agreed point then stop and discuss its specific characteristics under those conditions. In the vignette, Steve moved the artefact through time to a particular point of interest. He defines this point for the other actors, then proceeds to examine it under these new conditions. In this case, time travel has allowed Steve, David, and Ray to examine the artefact's performance with the current bus and the future ethernet bus.

### Simplification Approaches

Artefacts gain more and more boundary plates as they progress toward the end of artefact negotiation phase and into artefact accomplishment phase. As this detail builds, it eventually becomes so voluminous that individuals appear unable to comprehend all of it unaided. At this point, they seem to find new ways to represent boundary plates in simpler terms. In this section, I discuss a number of methods that I observed individuals using to cope with the large quantities, and the complex nature, of design boundary plates. The methods discussed by no means represent a comprehensive list of approaches or even all observed approaches. They do, however, provide a number of exemplars of methods for understanding complex and abstract artefacts.

The first two approaches to simplification that I wish to discuss are the *mock up* and the *engineering drawing*. In these approaches, individuals use a physical representation of an abstract artefact being designed. This physical representation seems to serve as a prompt through which actors can create visual impressions of what the final artefact may look like. This image can then be used to discuss and add further detail to the artefact. In the following vignette, Kevin Robinson, the operational representative on the BOS Project, discusses his use of a mock up approach in the process of design.

***Vignette – Get the feel for what it would be like.***

I wondered to myself if I would ever hear Kevin utter more than a one-word response. I could not get him to say a thing! My repertoire of open-ended questions, usually yielding such a rich harvest, seemed to provoke a lifeless response today.

Finally, his phone rang. While Kevin listened and muttered his one-word replies into the phone, I looked around his office for a conversation lever. My eyes came to rest on a large sheet of plywood that stood against the wall in the corner of his office. The sheet had greasy handprints around the edges, crisscrossing black dividing lines, and was covered with an array of grimy worn yellow 'post-it' notes.

Kevin hung the phone up, then turned without a word and sat looking at me.

"Hey Kevin, what's that for?" I said whilst gesturing toward the plywood sheet in corner.

"That's my desk mock up," replied Kevin. He seemed slightly more enthusiastic as he continued his explanation. "None of the guys could understand the detailed drawings the engineers gave us to look at. So I just got a sheet of plywood the same size as the desktop and stuck on post-it note buttons. The guys could lay it on the existing desk and get the feel for what it would be like. You know, move the buttons around, imagine they were real, and generally get a feel for what would and wouldn't work for the new desk layout."

In this vignette, Kevin mentions two approaches to the simplification of artefact detail. The first approach, detail *engineering drawings*, is where engineers use symbols, codes, diagrams, and text to represent artefact detail. This method seems useful for individuals who understand this codification process, but could be confusing for those who do not. As Kevin mentions, "none of the guys could understand the detailed drawings." In the second approach, *mock up*, Kevin uses the operator's own language to create a paper and plywood model of the new desktop. This visual representation of the desk and buttons enables the other operators to "get the feel for what it would be like." Once the operators were satisfied with the desk layout, the engineers were given the mock up, and a boundary plate in the form of an engineering drawing was constructed. These two approaches are typical of methods that I observed actors using in what seems to be an attempt to simplify large quantities of complex artefact detail.

A third approach to simplification of artefact detail is that of *simulation*. In this approach, actors create virtual environments in which to test early versions of, at least partially functioning, artefacts. These virtual environments are based on actual plant design and plant conditions. They represent an early version of the stabilised artefact[10] that is produced at the end of a completed process of design. They are created in laboratories to safely examine the performance of the artefact under development before the final boundary plates are constructed. In the following vignette, Ralph Hopkins, the BOS Project Manager, discusses the use of simulation in the BOS Project. In this case,

[10] See Chapter (4) for a more detailed discussion of the concept of a stabilised artefact.

David Riley, the manager of Australian Automation, installed the software he had written onto a development system. This development system was then fed previously recorded field data and the performance and responses observed. That is, designers could see how effectively the new control system operated under simulated plant conditions.

***Vignette – In the end, it was great.***

"David suggested we create a simulation at the start of the project," said Ralph. "But I wasn't that keen on the idea. You know, there's a lot of cost and effort required to create one."

During a previous conversation with David Riley, I had learnt of Ralph's reluctance. However, David was such a firm believer in the approach that he decided to create one anyway.

"In the end, it was great though," said Ralph. "We were able to use the simulation for the factory acceptance tests and for all the operator training."

In this vignette, Ralph refers to an application of software simulation to an operating plant and the development of a new computer-based operator interface. The interface and the plant seem to contain too many details for any one individual to comprehend. By creating a virtual environment, the interface can be tested for performance before it is introduced to the operating plant environment. Further to this, the simulation can be used as a controlled, safe environment within which to train future users.

In this sub-section, I have provided an analysis of concrete manifestations of the social processes related to the construction of the outer limits of a design space. This involved examining how the actors and social worlds interacted with one another with respect to the construction of boundary plates. I noted how actors appear to prefer numerical materials for constructing boundary plates. Following on from this, I introduced the notion that boundary plates could be constructed by individuals or by groups. Finally, I linked the processual element of trajectories from Chapter (4) with the choice of boundary plate construction methods, where different methods were used at different phases of the trajectory. In doing this, I was able to postulate links between the structural conditions in the process of design and the construction method being employed.

On reflection, one can see that the methods that emerged bear a close resemblance to several prescriptive design methodologies mentioned in Chapter (2). For example, proponents of participatory ergonomics use an envisionment method similar to *artefact role play* and the HCI community use a prototype method akin to *mock ups*. Despite this similarity, a divide between these design method communities and the actors in the 5MTPA Project exists. To the best of my knowledge, the actors observed in my study had not been externally trained in these methods, nor had they explicitly developed or labelled these approaches as methodologies. Rather, they went about the work of design as best that they could, with the practical experience that they had, within the sequential BHP 'Design Control Procedure'. In the following section, I introduce the notion that hidden agendas and the unequal distribution of power are important aspects of design boundaries.

## 5.6 Power, Influence, and Design Boundaries

In the previous section in this chapter, I discussed at length my observations from the 5MTPA Project of actors and their materials and methods for design boundary construction. From the vignettes provided, one might mistakenly consider that the actions of the individuals constructing design boundary plates are altruistic, apolitical, and, in engineering terms, rationalistic. I have deliberately kept the focus on the practical aspects of design to develop an initial, functional foundation from which to extend my analysis into the more abstract social processes in the ensuing chapters. Having said this, I wish to conclude the chapter by discussing some aspects of power and influence surrounding design boundaries.

Defining the term *power* is not straightforward. It is a broad and vague concept that, although present in everyday life, has proved difficult to either define or to measure (Buchanan 1999, p.10). I do not wish to engage with the broad spectrum of debates and theories that are present in the literature regarding power. Rather, I wish to draw on several surface issues that seem pertinent to my account of the activities in the 5MTPA Project. Having said this, a useful starting point for the upcoming analysis is to use the following definition: *Power* 'concerns the capacity of an individual to exert their will over others' (Buchanan 1999, p.11). From an interactionist perspective, a major kind of power is the capacity to define a situation, or major elements of it, for other collective actors (Clarke 1991, p.144). In this sense, boundary plates do not just influence the trajectory of an artefact, they also represent an opportunity for actors to exert power by defining elements of the artefact for others.

In the following vignette, I recount an example of what seems to be a hidden agenda in the construction of a boundary plate. In this case, Ralph Hopkins, the BOS Project Manager, is discussing the impending reline shutdown for the No.3 BOS vessel.

***Vignette – Max has an extra week tucked up his sleeve.***

"It's the only opportunity we'll get to have the vessel down for the next two years," said Ralph. "So the project team are working flat out to make sure everything is ready."

"When does the shutdown actually take place?" I asked.

"Max Davies (the BOS production manager) and I have arranged the shutdown schedule," replied Ralph. "Starting from the second of February they have twenty-one days to get the old system ripped out and the new one in and functioning."

Ralph paused, as if thinking, before continuing.

"But between you and me, Max has an extra week tucked up his sleeve. He doesn't have to start filling orders for steel until the thirtieth. But we decided not to tell anyone. We want to keep the pressure on the project team to get it all done in the scheduled twenty-one days. Then, if they overrun, it won't matter because we'll still have that spare week."

In this vignette, Ralph and Max seem to have colluded to create, and document, a shutdown schedule, or a design boundary plate, for the BOS Project. The schedule has been created in order to deceive the remaining relevant actors into thinking they have a twenty-one day shutdown instead of the actual twenty-eight days. In doing this, they have exerted power over others by defining a major component of the situation, that is, the period of the shut down.

In this second vignette, I recount another example of what seems to be a hidden agenda in the construction of a boundary plate. In this case, during a discussion with Bill Woods, the WTP Project engineering coordinator, I overheard a telephone conversation between Bill and Colin More, the WTP Project manager.

***Vignette - Colin wants a number, any number, just so long as he gets it today.***

Bill had a small cubicle on the second floor of the engineering building. An automation hazard placard, covered with facts and figures, dominated the faded mauve fabric wall behind his desk. Pieces of paper protruded at irregular angles from the edges of the neat placard: order numbers, phone numbers, emergency contacts, control codes. Bill's desk was piled high with engineering drawings. Complex arrays of lines, numbers, symbols, and words stretched from edge to edge of each of the table-sized drawings.

I had been waiting for Bill to return from the plant for our scheduled meeting for more than twenty minutes. Finally he walked in apologising for his lateness. Apparently some issue down at the plant had held him up. As he sat at his desk and began talking, his phone rang.

Bill reached over, picked up the phone.

"Hello, Process Automation Department, Bill speaking."

Bill paused, as if listening then responded, "Hi Colin what's up?"

Bill swivelled his chair and turned away from me saying, "Nope, the estimate is not ready yet. I'm still working out the I/O requirements."

With his back to me Bill spoke into the phone saying, "Yes, I had heard that all capital projects were currently under review. And yes, I do understand that you have to allocate the funding before we lose it."

Bill leaned back into his chair, shoulders slumped, head down, and said, "OK, OK, I get the message. I'll make some guesstimates this afternoon and e-mail you before I go home today."

Bill remained motionless and said, "Bye Colin."

Bill hung up the phone and sat staring at the faded cubicle walls.

"That sounded kinda serious," I said.

Bill turned to face me.

"Yeah, that was Colin. He wants 'a number, any number', just so long as he gets it today," replied Bill. "I'll just have to make the best estimate I can for the I/O we'll need. Colin will approve the order first thing in the morning. Then the money will be spent, and they can't take it off us once we've spent it."

In this vignette, Bill and Colin seem to collude to create a boundary plate that represents the quantity of input/output required for the new WTP PLC. The boundary plate is created through Bill's expedient guesswork in order to spend the allocated funding before it is withdrawn. However, the origins and intentions of this boundary plate are hidden from the other actors in the project. When Colin receives Bill's written confirmation of the estimated input/output, it becomes an accepted design boundary plate and will eventually define for others what the system is capable of doing.

The previous two vignettes provided specific examples of the use of power in the construction of design boundary plates. In these examples, the actors seemed to be using their unchallenged capacity to define the specific design boundary plates. In doing so, they influence the actions of others without their knowledge or understanding. In this case, their 'unchallenged capacity' seems to stem from a combination of their 'expert status', and their organisationally-defined role with respect to the specific artefact detail in question.

Another form of power, sometimes referred to as 'legitimate' power or authority, is the institutional capacity to direct or control the behaviour of others for the promotion of collective goals, based on some ascertainable form of their knowledgeable consent (Buckley 1967, p.186). The key difference between the definition of 'power' presented here and that presented above is the 'knowledgeable consent' of the actors being influenced. The following vignette provides an example of how legitimate power can influence the process of constructing design boundary plates. In this case, Daniel Grace, the 5MTPA Project manager, discusses how he can potentially modify design boundary plates.

***Vignette - Basically I can change any number I want.***

It was my first meeting with Daniel in his new office. Although this was a bigger office than his last, he no longer had his own secretary by the door, and the teams of engineers that had once hovered nearby had been dispersed throughout the plant. The 5MTPA Project had undergone a corporate budget reduction and all the trimmings had been removed. Daniel said he had managed enough capital projects to have seen it all before. He seemed totally unfazed by these changes, perhaps even pleased to be managing a much tighter, leaner project.

I had arranged the meeting to discuss a number of issues, including some of the concerns that Ralph Hopkins, BOS Project Manager, had raised with respect to my involvement with his sub-project.

"Ralph said he was very happy to accommodate my research interests," I said. "But he said he had some concerns that my involvement might adversely affect his delivery or budget."

"That's not a problem," replied Daniel. "I can remove any barriers of cost, and time constraints can always be worked around.

"The trick is to understand which are the soft numbers and which are the hard ones," said Daniel. "For example, end dates can be soft or hard depending on the project. Soft end dates are flexible. You know, we can shift them around to suit our needs. Whereas hard end dates are pretty inflexible, but even then we can still influence them. In the end, it all comes down to the operators and whether they will get the shits with us for delaying the project.

"On the other hand, budgets are generally considered hard numbers. And I like it that way. My guys know that their budgets are firmly fixed. I mean, they can change costs, but if they do they know that they will experience a lot of pain. This pain deters them from trying to change their budgets unless they really need to.

"Basically I can change any number I want," said Daniel. "It just depends on how much pain I'm willing to bear."

In this vignette, Daniel seems to be describing his understanding of some of the ways in which his legitimate power can influence the construction and/or modification of numerically-based, design boundary plates. Daniel uses the terms *soft* and *hard* to describe the relative ease or difficulty with which numbers (design boundary plates) can be modified. It seems that his legitimate power to change design boundary plates, and in doing so direct the activities of others, is not carte blanche. Rather, the social organisation has developed methods for metering out 'pain' depending on the degree to which other social worlds are inconvenienced as a result of Daniel exercising his legitimate power.

In this section I have introduced the concepts of *power* and *legitimate power* and discussed them in terms of three specific examples. The purpose of doing this is to highlight the importance of power in the 5MTPA Project and to foreshadow the more detailed sociological analysis of actions around design boundaries addressed in Chapter (7). A comprehensive interactionist analysis of power within the arena of boundary plate construction and engagement with the literature regarding power is beyond the scope of my immediate focus.

## 5.7 Summary

The trajectory of an artefact can be seen as a synthesis of the trajectories of its sub components. The specifications that constrain and enable these trajectories are design boundaries, which represent specific variations or options that may or may not be pursued. Amalgamated specifications, such as engineering drawings and detailed designs, can be seen to be a type of boundary object that links multiple and divergent actors and social worlds with sub components and their progress through the process of design.

Observations described in this chapter have revealed differences between two constituent elements of a design boundary: the relatively rigid and generally recognised boundary plates, and the less widely perceived, diaphanous, boundary membranes. There are a number of different types of boundary plates, technical, financial, physical, etc, each of which have their own unique characteristics. These boundary plates may be constructed either by individuals or by groups, before being eventually introduced to, and recognised by, the broader social collectives involved in the process of design. Boundary plates are constructed by a number of identifiable methods, including exemplar, artefact role play, and simplification. Selection between these methods depends on the individuals involved, their view of the situation, and the trajectory phase, whether seeding, negotiation, or accomplishment. Membranes on the other hand, have proven to be flexible, undocumented, and individualistic sets of specifications that exist between the boundary plates. Together, they can be seen to form a continuous boundary encompassing the design space.

Design boundaries are not all constructed altruistically or apolitically. Rather, hidden agendas and unequal distribution of power influence the production of many of them. This chapter has deliberately focused on the palpable aspects of boundary plates rather than membranes as a base from which to analyse negotiations that can occur around boundary plates. Analysis of such negotiations continues in terms of individual and group traits and agendas in the next chapter.

# Chapter (6) – Social Worlds and Design

## 6.1 Introduction

It is commonly recognised that social collectives are an important consideration in any account of technology development. During the process of design actors and social collectives negotiate to create design boundaries that encompass variations and options that may or may not be pursued in producing the technology. Pinch and Bijker generated a model in which the technology being developed was influenced by an encompassing set of relevant and interested social groups. Strauss's social worlds/arena theory, and Clarke's subsequent conceptualisation of the theory in an organisational context, provide a broader set of concepts focussed more explicitly on the interactive aspects of the construction of meaning amongst the social collectives.

In this chapter, social worlds/arena theory is used to identify and explore characteristics of the social collectives within the 5MTPA Project. The term *trait* is used to refer to what the members of these social worlds deem as worthwhile and important. The differing traits identified for the predominant social worlds in the 5MTPA Project are examined and summarised in tabular form. This delineation helps in illustrating the 'migration' of individuals between social worlds, the switching of identities depending on the issue at hand, which itself provides evidence of the relevance of social worlds and traits to the actors in the 5MTPA Project.

The social worlds and traits identified here are put in context in the following chapter, which examines the role of arenas, where members of social worlds negotiate during the process of design. In turn, understanding arenas provides insight into discerning the 'rules of engagement' that pattern the interactions amongst social worlds in the process of design.

## 6.2 Social Collectives and the Process of Design

Identifying the actors and social collectives involved in design boundary negotiation is a major analytic task in constructing my account of the 5MPTA Project. However, my conceptual map of these social collectives needs to be placed first in the context of theory, specifically, Pinch and Bijker's relevant social groups notion and Strauss's social worlds/arenas theory.

### Relevant Social Groups

Pinch and Bijker (see Bijker 1987; Bijker 1992; Bijker 1995a; Bijker 1995b) have developed a model (Fig 6.1) of the social construction of technology that has as one of its central claims "... social groups are relevant for understanding the development of technology" (Bijker 1995b, p.45).

Please see print copy for image

**Figure 6.1 – Artefact and Relevant Social Groups (Bijker 1995b, p.47)**

Obviously, not all social groups will be of prime relevance to the development of a particular technology. Pinch and Bijker identify only social groups that are relevant to the actors involved in the technology development. These relevant social groups are defined as:

> Institutions or organisations (such as the military or some specific industrial company) as well as organised or unorganised groups of individuals. The key requirement is that all members of a certain social group share the same set of meanings attached to a specific artefact (Bijker 1987, p.30).

Pinch and Bijker point out that there is no 'cookbook recipe' that can be used to identify these groups or their members (Bijker 1987, p.50). However, having said this, Bijker

(1995b) feels it important to discuss their particular approach to empirical investigations, which has parallels with, and influence upon, my approach to the empirical investigations of groups in the 5MTPA Project.

The first aspect of the empirical research discussed by Bijker (1995b, p.46) is the method for identification of the relevant social groups. He advocates following two rules: "roll a snow ball" and "follow the actors". The "roll a snow ball" method involves interviewing a limited number of seemingly relevant actors and asking them, at the end of each interview, who else should be interviewed to get a complete picture. In doing this with each interviewee, the numbers of actors may increase rapidly, but after some time no new names are mentioned. In theory, at this point, what can be deemed a "complete" set of actors involved with the phenomenon have been identified. The "follow the actors" method uses this list of relevant actors as a starting point. The researcher then follows the actors to learn about the relevant social groups in more detail.

The context of my research differs from that of Pinch and Bijker in two main aspects. Firstly, I am researching industrial design and institutional innovation[1] and not general technological innovation within society as a whole. Secondly, the sets of relevant actors seem easier to identify within the organisational boundaries[2] of an industrial design project, such as the 5MTPA Project. In spite of these differences, my methods for identifying the relevant social groups appear to be similar to that of Pinch and Bijker.

[1] Institutional innovation occurs when companies pay workers to design and create specific new technologies. This concept was discussed in detail in Chapter (4).

[2] I have conceptualised a notional boundary existing around the 'BHP organisation'. This notional boundary is open to other interpretations. For example, workers at BHP may be employed via direct employment, permanent personal contract, temporary personal contract, or sub contract from other organisations.

The second aspect of the empirical research discussed by Bijker (1995b, p.48) is the theoretical relevance of actor-defined, relevant social groups. The problem with relevant social groups defined by the central actors is that those groups without the power to speak for themselves are left out of the account. Bijker argues, and I agree, that the problem of missing groups is mitigated if the conceptual framework is taken in the right spirit, that is as a collection of sensitising concepts that aims to provide the researcher with a set of heuristics with which to study technology development. For example, in my ethnographic study I did not observe the 'external technology suppliers' to engage directly in the social processes of design. As such, they do not directly appear in my account. This is not to say that they do not influence the trajectories of the various sub components through incorporation of their specific technologies. Rather, the influence that they have is mediated through actors who are more closely involved.

## Social Worlds/Arenas

Strauss's social worlds/arenas theory provides a useful means of exploring the aggregated aspects of social interaction around institutional innovation that is similar to that of Bijker's relevant social groups. Social worlds/arena theory is a broader concept, not specifically confined to collections of actors interested in technology. It also focuses more explicitly on the interactive aspects of the construction of meanings (rather than the construction of technology), both within and across social worlds, than does the concept of relevant social groups (Garrety 2000, p.105).

Strauss's social worlds/arenas theory is 'relativist, social constructionist, and focussed on collective actors of many types' including, but not limited to, formal organisations (Clarke 1991, p.129). Social worlds are defined as 'groups of people with shared commitments to certain activities, sharing resources of many kinds to achieve their goals, and building shared ideologies about how to go about their business' (Clarke 1991, p.131). In keeping with the interactionist focus on interaction and communication, social worlds are characterised as 'recognisable forms of collective action' rather then as 'fixed social structures' (Strauss 1993, p.233; Garrety 2000, p.105). The interaction amongst social worlds around specific issues represents an arena. Within these arenas, actions concerning issues are debated, fought out, negotiated, manipulated, and even coerced within and among the social worlds[3]. It can be individuals who do the acting, but for sociological purposes, they are located in some sort of social unit (Strauss 1993, p.226).

One of the strengths of social worlds theory in understanding collective action is its recognition of the relatively fluid boundaries characteristic of many social worlds (Strauss 1993, p.213). This fluidity is mirrored in empirical observations discussed later in this chapter of individuals moving between social worlds, of overlapping social worlds, of social worlds merging, and of social worlds splitting. In fact, Strauss argues that it is 'inevitable' that 'segmentation', or 'differentiation', of social worlds will occur (Strauss 1993, p.215). Strauss refers to the product of social world segmentation as subworlds. This segmentation results from the tendency for worlds to develop specialised concerns and interests within the larger community of common activities,

[3] Action within arenas that have formed around design boundaries is discussed in detail in Chapter (7).

which act to differentiate some members of the world from others (Kling and Gerson, 1978, cited in Strauss 1993, p.215).

Although social worlds theory was originally developed to help understand contemporary society, Clarke (1991) displays its equal usefulness for analysing both the array of organisational forms and phenomena and the diverse social processes that occur within and among them. Clarke provides a model as part of her conceptualisation of social worlds/arena theory in an inter-organisational context (see Fig 6.2).

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**Figure 6.2 - Social Worlds/Arena Model (Clarke 1991, p.123)**

This model is useful in that it ties together various concepts within an inter-organisational frame. However, Clarke's diagrammatic representation of her model depicts a more macro view of social worlds and arenas than was observed in this study. In her model, the main arena encompasses multiple organisations. The social worlds and subworlds are represented on an organisational scale and the negotiations are inter-organisational. Counter to this, my conceptualisation of the 5MTPA Project is that the main arena and predominant social worlds exist within a single organisational boundary and the negotiations are primarily intra-organisational. Figure 6.3 presents a notional arrangement of social worlds (shown in bold) within an overarching conceptual map that represents my interpretation of the process of design in the 5MTPA Project.

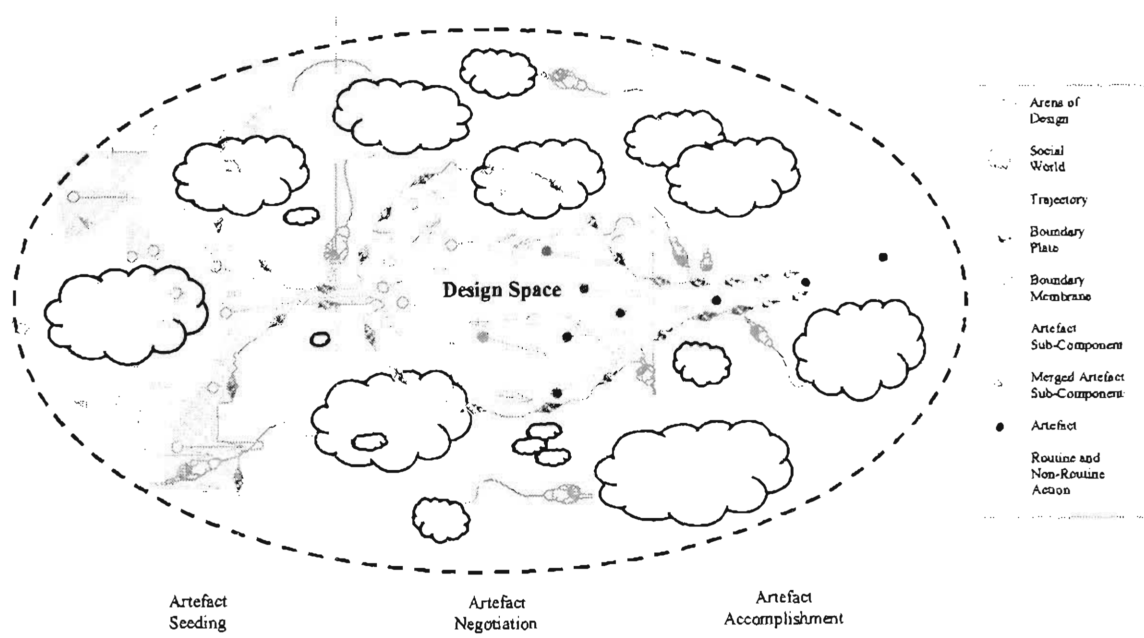


**Figure 6.3 - Social Worlds/Arena**

The usefulness of the concepts and theories of Bijker's *relevant social groups* and Strauss's *social worlds/arenas* is in their ability to provide a vocabulary and focus for my observations and subsequent analysis of the process of design in 5MTPA Project. They emphasise certain aspects of social life while de-emphasising others. They set the stage of sociological concern, both foreground and background, and they draw attention to particular actors (individuals or collectives) and their activities and interrelations. I intend to borrow from these theoretical traditions in the following sections where they open analytic doors to the complex nature of my empirical data (Clarke 1997, p.85).

### 6.3 The 5MTPA Project Social Worlds and Arenas

Individuals working on the 5MTPA Project seem to rarely refer to themselves or to those around them as individuals. Rather, I observed them refer to themselves and to others as members or non-members of a variety of groups. Further to this, these groups, more than individual personalities, seem an integral part of the action and interaction in the process of design.

In exploring this observation, one of my interests is in the way the actors use group labels as a sense-making tool in the process of design. It appears that these labels are attached to collections of individuals who are perceived to have a shared ideology - what is and is not important, and how things should and should not be done. In light of this, the social worlds that I have identified are groups of individuals who have been assigned a common label, either by themselves or by others, as a unifying sense-making concept. These labels influence the way individuals within the group are perceived, and related to, by others for whom the label has meaning. In defining groups in this way, I have not imposed the labelling concepts upon the setting, but have observed how participants apply the labels to themselves and others. Hughes (1971) provides a similar explanation for labelling in terms of "ethnic groups". From Hughes's perspective, an ethnic group is not one because of the degree of measurable or observable difference from other groups. It is an ethnic group, on the contrary, because the people in and the people out of it know that it is one; because both the *ins* and *outs* talk, feel, and act as if from separate groups (cited in Becker 1998, p.2).

The following vignette provides an example of how I have identified group labels and subsequent social worlds from my observations within the 5MTPA Project

***Vignette – Meet Ross, he is from the University***

It was my first interview on my first day in the field. I arrived early and sat in my car in the dusty, hot, gravel car park reviewing my strategy for the interview and making some final notes. At 1:50 pm, I stepped from my car and strode confidently across the car park ready for my 2:00 pm meeting with Steve. The cool air of the office rushed out to welcome me to my new world. As I entered, I looked around for some direction as to what to do next.

Recognising the first desk as that of a receptionist, I walked over and smiled, "Hi, I am looking for Steve Bull the Technical Manager on the five million tonne project."

The receptionist smiled back, "Have you signed the visitors book yet?"

The puzzled look on my face provided her with the required answer and she directed me to a table near the door I had just entered. I walked over to the table. Looking down at the book, I scanned across the top of the columns that lined the page. I was required to provide my name, my organisation, my BHP contact, my time of entry, my signature, and finally, upon leaving my time of departure. The secretary had explained that the book was a "safety measure and if there is an emergency, we will know you're here and make sure you are safely out of the building." I signed the book wondering how it would assist me in being rescued from a single story office building. I considered its usefulness limited and made a mental note to think some more about what other purposes the visitors book may have.

After signing the book, I was directed down the corridor to Steve's office. Upon reaching it, I glanced at my watch, 2:00 pm. Perfect timing, I thought and knocked gently on the frame of the open door.

Steve smiled and welcomed me with a handshake "Hi, Ross. Come in and take a seat."

As I entered, my eyes wandered around taking in Steve's office. What stood out to me were the shelves stocked with what I recognised as company manuals, procedures, and thick red folders filled with documentation from past, present, and future projects.

Steve and I sat and had a relaxed general chat about the 5MTPA Project. Eventually, I breached the subject of my visit and we proceeded to discuss my research interests. Steve listened intently as I used everyday terms to express my sociological interest in how designers actually design in real world projects and my desire to understand the social processes that make up and give design projects life. At the completion of my explanation, Steve responded with three statements that deflated my optimism about studying his project. Firstly, he said, "I am more interested in the technical side of making steel than in management and the softer social side." He followed this with, "You need to understand Ross that funding is very tight. We have already had it increased once and there is very little scope for you as far as money is concerned." Finally, he stated, "The 5MTPA Project is about delivering operational security to the plant. It's not about improving what the operators get. In fact, the operations people will probably not even notice any difference."

In spite of Steve's seemingly negative initial response, he proceeded to show me around the project office, introducing me to all the engineering team members. At each introduction, Steve would recount his interpretation of my research interests, "Ross is from the University and is researching how we manage the process of doing projects." We would then chat casually for a minute and Steve would move me on. After spending two hours with Steve, the interview was over. We had talked about my interests, we had talked about Steve's interests, we had talked about Steve's reservations, and we had toured the office and met the 5MTPA engineering team.

In this vignette, Steve seems to identify a number of relevant actors and social worlds. The first social world identified was that of the "5MTPA engineering team". Following this, Steve personally introduced me to each of the group members who were present. This introduction provided me with an indication of who Steve considered to be members and some initial insights into what these members felt was important and worthwhile. In this case, conforming to "budgetary constraints" and "operational security" seemed to be important concerns of the group. The second social world identified was that of the "operators". The interview gave very few details about the "operator" social world itself. However, Steve's comments did provide some insight into how the "5MTPA engineering team" thought about the "operators". It seems, at least in Steve's opinion, that the operator social world is unimportant to the goals of the 5MTPA engineering team and was not to be given anything from the project in the way of "improvements". The final social world identified by Steve was that of "University researchers," into which it seemed I had been placed.

The preceding interview represents the start of my trail for identifying the relevant actors and social worlds within the 5MTPA Project. By following this trail, I have been able to identify the interested and active individuals and social worlds, as well as the issues and apparent ideologies around which these interactions occurred. The relevance of these social worlds to the process of design can be explained using Strauss's concept of an arena. In this case, the issue around which these groups are interacting is the 5MTPA Project. More specifically, the debating, negotiating, manipulating, and coercing that was observed amongst the groups with respect to the design boundaries can, in part, be explained by the social worlds and their associated ideologies.

The following section provides the first piece of information that was gleaned from following my sociological trail, that is, the identification of the interested and active individuals and social worlds in the 5MTPA Project. The second piece of this puzzle, the apparent ideologies that influence negotiation amongst these social worlds, is addressed later in this chapter.

## Mapping the Actors, Social Worlds, and Arenas

Mapping the actors, social worlds, and arenas within the 5MTPA Project was one of the ways in which I attempted to understand the diverse social processes that occurred within the process of design. I followed the actors involved and observed their actions and discourses as the basis for forming my maps. I paid attention to what the actors said with respect to one another, noting when an actor referred to, or labelled, a group and in what ways they seemed to use the labels in the process of design.

The following vignette further illustrates the process that I used to identify and name the relevant social worlds.

***Vignette – The other mob***

I sat in the conference room with the other ten individuals attending the WTP project review meeting. I was casually dividing my attention between reading the previous meeting's minutes and watching those around me. Through the conversations, I was able to connect the faces around the table with the attendees listed on the previous minutes.

I turned the page and read the last line of the minutes "Next meeting: 9.30am 30/4/99", I glanced at my watch to check the current time, 9.40am. Colin More, the meeting convenor and chairperson, sat patiently and seemed to be waiting for the last stragglers to arrive.

Eric Haines broke the silence, "Come on Colin. Let's get started."

"I'm still waiting for Trevor," replied Colin.

"Trevor!!" shouted Eric. He then leaned back with a grin on his face and said, "He's a chemical engineer. That's the other mob. We don't talk to them anyway."

The room erupted in laughter at Eric's comment. As the laughter subsided, Colin commenced the meeting without Trevor.

This vignette depicts a representative field incident from which I was able to identify a number of relevant actors and social worlds. For example, at the meeting described in the vignette, the names, faces, and apparent responsibilities of ten actors relevant to the WTP Project were identified. Further to this, Eric Haines refers to Trevor Lord as a "chemical engineer", someone from "the other mob", someone that "we don't talk to". My interpretation of Eric's comments is that in some situations Trevor Lord may be perceived as belonging to a different social world to that of Eric. In this case, the social world has the label "chemical engineer".

When I analysed and coded segments of discourse, such as the previous vignette, I followed the actors' repeated use of labelling terms such as "operator", "engineer", and "chemical engineer". Such accounts of action and discourse, especially labelling terms, form the basis of how I have identified the social worlds that I list as relevant to the 5MTPA Project.

A potential anomaly that needs to be considered when using this method arises from the actor's motivation for using the label. Actors in the 5MTPA Project appear to use social world labels for two possible reasons. Firstly, as a *term of convenience,* and secondly, as a *sense-making tool.* In the situation where it is a term of convenience, the actors seem to use the labels as an easy way to represent multiple entities. For example, an actor may refer to a group of individual operators each by their own name or by the perhaps more convenient term "operators". On the other hand, when an actor uses the label as a sense-making tool, it seems to associate some set of pre-defined attributes to the individuals identified by the term. For the outsider, it is impossible to know, with any certainty, why actors choose to use the terms that they do. However, the fact that the label appears to have a recognised meaning to those to whom it is expressed implies that it will have an impact on the social interactions nonetheless.

The importance of the use of social world labels and the impact they can have in the 5MTPA Project is founded in the ways in which individuals make sense of social interaction. From a symbolic interactionist perspective, individuals engage in two notional forms of interaction, symbolic and non-symbolic. Symbolic interaction involves the interpretation of action; non-symbolic interaction occurs when an individual responds directly to an individual without interpreting the action (see Blumer 1969). The symbolic interpretation of an actor's use of a labelling term, which is of more interest here, does not depend on the intention, but on the meaning that the label has for those who respond to it. From this discussion, it seems that the potential anomaly arising from the unknown motivation for use of social world labels is mitigated by the notion that the meaning has two facets – the user's intention and the receiver's interpretation.

During the case studies I attended meetings, physically followed actors, interviewed actors, observed actors, and reviewed documentation. Based on analysis of this accumulated field data I have identified thirty-two central actors and twenty-seven social worlds that appear to come together and interact within the arena of the 5MTPA Project. Figure 6.4 presents the relevant actor names, organisational titles, and the projects with which they were involved. Table 6.1 provides a list and brief description of relevant social worlds.

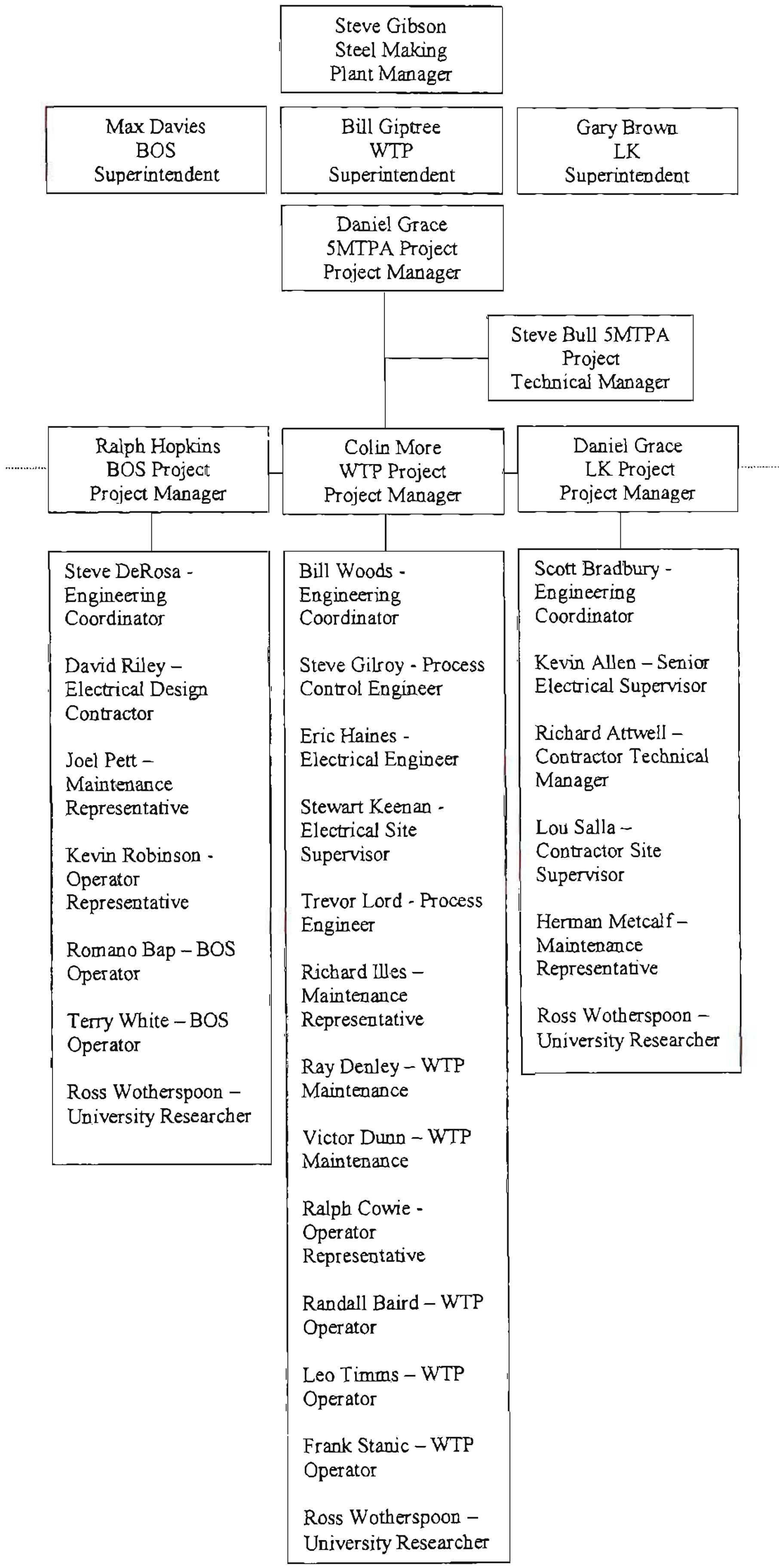


**Figure 6.4 – Relevant Actors in the 5MTPA Project**

| Table 6.1 – Observed Social Worlds of the 5MTPA Project | |
|---|---|
| **Name** | **Description** |
| BHP | Employees of BHP. |
| BHP Steel | Employees of BHP Steel. |
| BHP Engineering | Employees of BHP Engineering. |
| The University | Representatives of the University of Wollongong. |
| The Union | People with an affiliation to any one of the unions represented on the BHP site. |
| Customer | Consumers of BHP products and services, both internal and external. |
| Engineers | Primarily people with tertiary engineering qualifications and Engineering Department affiliation. |
| Engineering Management | Primarily people with tertiary engineering qualifications and managerial responsibilities within the Engineering Department. |
| Electrical Engineers | Primarily people with tertiary electrical engineering qualifications and Engineering Department affiliation. |
| Process Engineers | Primarily people with tertiary process engineering qualifications and Engineering Department affiliation. |
| Process Control Engineers | Primarily people with tertiary engineering qualifications specialising in process control and Engineering Department affiliation. |
| Maintenance | Maintenance Department employees. |
| Shift electricians | Maintenance Department employees with electrical skills working on shift. |
| Production | Production Department employees. |
| Production Management | Individuals with a managerial role and an affiliation to a Production Department. |
| Operators | Workers with a direct responsibility for producing a product within a Production Department. |

| | |
|---|---|
| BOS Operators | Workers with a direct responsibility for producing a product within BOS Department. |
| BOS Operators Shift One | Workers on the rotating roster "shift one" with a direct responsibility for producing a product within BOS Department. |
| BOS Operators Shift Two | Workers on the rotating roster "shift two" with a direct responsibility for producing a product within BOS Department. |
| BOS operators Shift Three | Workers on the rotating roster "shift three" with a direct responsibility for producing a product within BOS Department. |
| BOS Operators Shift Four | Workers on the rotating roster "shift four" with a direct responsibility for producing a product within BOS Department. |
| WTP Operators | Workers with a direct responsibility for producing a product within WTP Department. |
| Young Operators | Individuals in the earlier stages of their careers with a direct responsibility for producing a product within a Department. |
| Old operators | Individuals in the latter stages of their careers with a direct responsibility for producing a product within a Department. |
| Project People | People with a direct role within the 5MTPA Project. |
| Contractors | Externally employed actors under contract to BHP. |
| IT Guys | Information Technology Department employees. |

The twenty-seven social worlds identified within the arena of the 5MTPA Project do not exist as complete and separate entities; rather they overlap and overlay one another. Strauss recognises and stresses the importance of the "temporal dimension of arenas" (1993, p.231) and the "fluid boundaries" of social worlds (1993, p.213). One of the ways in which the fluidity of social world boundaries was observed in the 5MTPA

Project was through individuals alternating memberships amongst social worlds. This phenomenon is discussed toward the end of this chapter.

A further qualification of Table 6.1 is that, in Strauss's terms, my twenty-seven social worlds might be more appropriately termed sub worlds. That is, they exist as factions and sub divisions within the larger BHP social world. However, because of my micro focus and the extreme fluidity that I observed in terms of boundaries, a distinction between social worlds and subworlds did not add clarity to my account. In light of this, I have labelled each social collective as a social world.

In spite of the temporal dimension of arenas and the fluid nature of social world boundaries, I feel it is worthwhile to provide a snapshot of the social worlds within the 5MTPA Project (see Fig 6.5). It is important to note, however, that this snapshot represents only one of the many possible permutations of the social worlds. In the diagram, each of the social worlds is named and delineated by a wavy line to indicate the highly fluid nature of their boundaries. Likewise, the social world positions in the diagram reflect only one of many possible schemas for representing the social worlds with respect to one another. The usefulness of the diagram is in providing an impressionistic snapshot of where the social worlds may lie at any one moment, rather than in positioning the social worlds in objective slots.

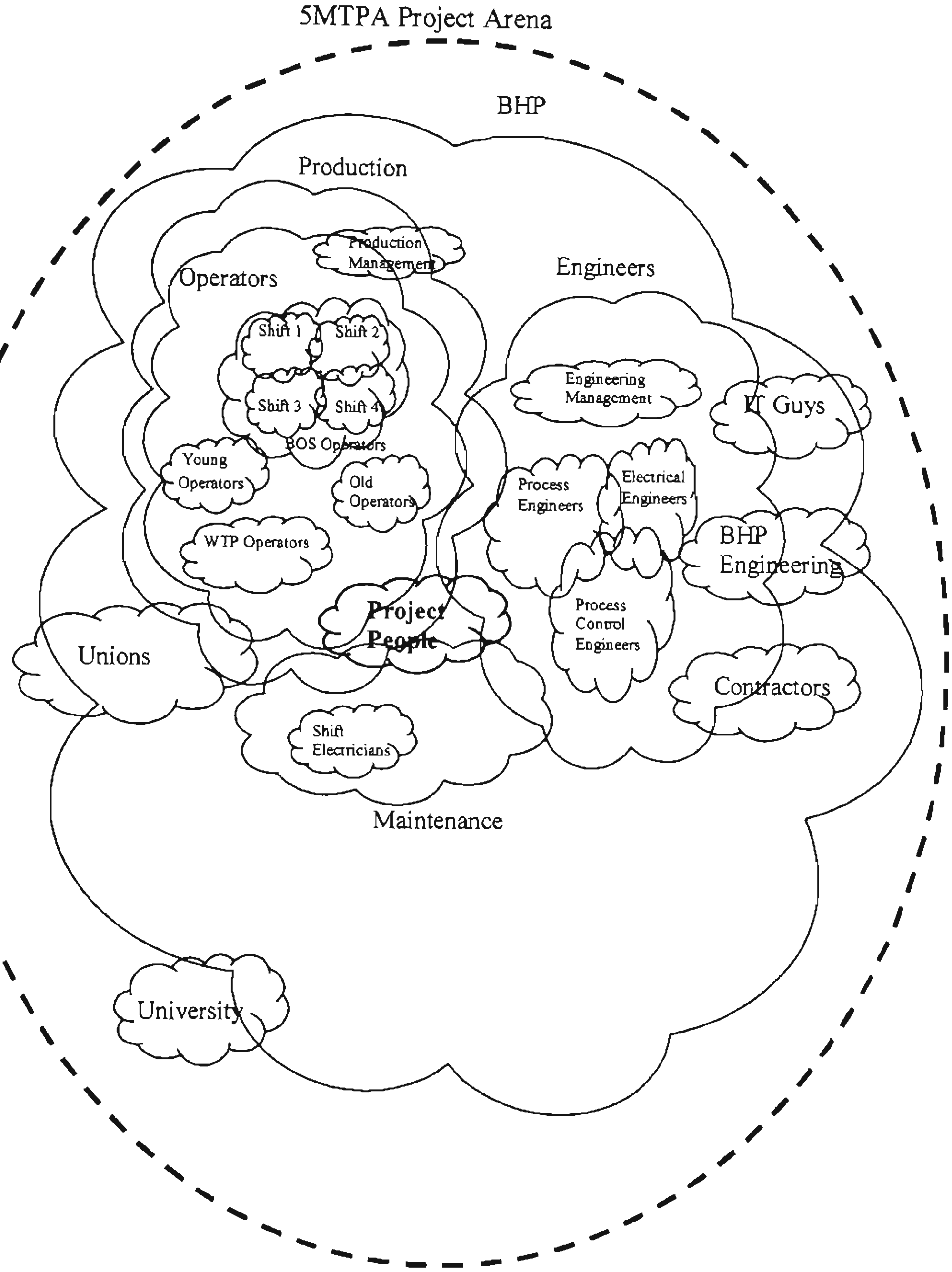


**Figure 6.5 - A Snapshot of the Social Worlds in the Arena of the 5MTPA Project**

In this section, I have defined the process of design within the 5MTPA Project as occurring within an arena populated by relevant actors and social worlds, as illustrated by the snapshot above. This information is built upon in the following section where these social worlds are discussed in terms of actor-identified characteristics.

## 6.4 Social World Characteristics

My interest in social worlds/arenas theory, in the context of the 5MTPA Project, is in the way that it focuses on how people organise themselves. It also addresses how they do this in the face of others trying to organise them and/or the broader structural situations in which they find themselves (Clarke 1991, p.135). The previous section included lists of those social worlds distinguished by the actors that I observed. My analysis of the collective, then, is based on what the actors themselves find meaningful.

In discussing what I feel is "meaningful" for the actors in the 5MTPA Project, I would like to review and contrast what Strauss and Clarke, both proponents of social worlds theory, argue are important characteristics of social worlds. Firstly, Strauss (1993, p.213) takes a more structural view than Clarke and argues that some of the significant properties of a social world include, "size, duration, origins, histories, rate of change, type and amount of resources, and relationships to technology and to state power". Counter to this, Clarke (1991, p.136), in an organisational context, takes a more cultural view and argues that some important questions about the characteristics of a social world are: "What are the commitments of the social world? How do members believe they should go about fulfilling them? What actions have been taken in the past and are anticipated in the future?" In asking these questions, Clarke is advocating studying social worlds where the units of analysis are the collective commitments and actions taken by participants.

Clarke's units of analysis have been used in my study because they reflect what the actors within 5MTPA Project term as both meaningful and important. That is, the actors speak more in Clarke's terms than in Strauss's. In the following vignette, Craig, a BOS operator, discusses a number of groups, or what I have called social worlds, and the characteristics he associates with them.

***Vignette – Our shift is the only good shift***

Craig was young, Terry was not, Craig and Terry are a team. They are more than *just* a team of two; they are responsible eight hours out of each twenty-four for a multimillion-dollar production process and for coordination of the ten other workers required to control the process. They are the BOS Controller and the Heater on shift four. They have serious jobs, in a serious control room, with serious consequences for errors.

Today shift four is the afternoon shift. They are rotated on a ten-day roster and have just taken control of the BOS from that day's day shift, shift three….

"Bloody management should do something about this!" Said Craig as he busied himself adjusting dials and resetting levels on the control desk. "It's ridiculous. Every shift and every operator on every shift has different ideas on how to best run the plant, you know, when to dump, what quantities to use, stuff like that. They are all just based on gut feeling, and each shift thinks its method is best. It's management's job to do something about this. They have to step in and make every shift operate the plant in the same way. You know, find one common best method and enforce it."

As Craig continued making adjustments, I began to wonder about the other three shifts. I had met them, and they seemed reasonable and competent workers to me. As I continued to wonder my mouth opened and I asked almost without intending to, "What are the other shifts like?"

"Our shift (shift four) is the only good shift to work on," replied Craig. "We take our jobs seriously. We look after the plant and try to run the place as well as we can [pause]. Shift one are lazy, shift three are stupid, and shift two are whingers [pause]. Well, I could work with shift two. They're not bad guys, but they just whinge about everything."

In this vignette, it would seem that Craig identifies a number of social worlds with whom he has associated certain characteristics. From Craig's perspective members of *management* are responsible for 'resolution' of issues, members of *shift one* are 'lazy', members of *shift two* are 'whingers', members of *shift three* are 'stupid', and finally members of *shift four* (a social world with which he associates himself) are 'good', 'serious', and 'look after the plant'. For Craig, these characteristics seem to be a representation of the different social world commitments and ideologies. Further to this, from Craig's suggestion that he would only work one of the other three shifts, it appears that these representations influence the way he behaves toward the other groups.

In light of what seems meaningful to Craig, and others, I have adopted the term *trait* to describe specific social world characteristics. In Craig's terms, these characteristics seem to be representations of a group's commitments and ideologies. It is important to note that these representations of commitments and ideologies may reflect the actions of the group members, or they may reflect non-members' perceptions of a member's actions. Defining traits in this manner leads to a bifurcation of the concept into 'member-defined traits' and 'non-member-defined traits', both of which play a role in an identifiable social ordering process.

Following on from this, the social world traits that I have identified in the 5MTPA Project have not been limited to those expected and enforced by the members alone. I have observed and recorded the disparate and diffuse statements and behaviours amongst the various actors and social worlds. This process of observation and analysis provides a set of member-defined social world traits and a set of non-member-defined social world traits.

The non-member-defined social world traits may not align with members' beliefs. However, they nonetheless represent an essential part of the ordering of social life in the 5MTPA Project. For example, in the vignette provided at the start of this discussion, Craig says "shift one are lazy, shift three are stupid, and shift two are whingers". This comment represents some of the traits that Craig, and by implication, other members of shift four, attribute to the other three shifts. They may not align with shift one, two, or three's internally-defined and enforced traits, but they definitely influence the ordering of social life amongst the groups by guiding how shift four members interact with, and think about, the other shifts.

The combination of Craig's discourse and the theoretical concepts of Strauss and Clarke is a useful expositor for some of the ways actors from the 5MTPA Project organise and cope with the activities of design. They seem to use social world traits to provide information about how they might be expected to act, how others might interpret those actions, and how they might expect others to act. This information appears to be used when the social worlds come together during the process of design to negotiate design boundaries. My account of the influence of social world traits on the negotiation of design boundaries is more fully discussed in Chapters (7) and (8). Here, I will delineate salient traits.

## 5MTPA Project Social World Traits

In this section, I add further empirical details to the concept of social world traits by examining traits specific to the predominant social worlds within the 5MTPA Project. I have identified these traits in the same manner that I identified the social worlds, that is, through the observation of activities and discourse of everyday events. I paid attention to two sources. Firstly, what the actors within the social world said and did with respect to their own social world. Secondly, what the actors from outside the social world said and did with respect to those inside the social world. In an attempt to further illustrate the trait identification process, I have included two vignettes that represent incidents akin to those that subsequently led me to name and define a social world trait.

### *Vignette – What my boss wants*

Steve DeRosa and I were walking to a general project meeting in the BOS. I had found the walk to and from meetings a useful time for gaining new insights. The meetings were places of intense social activity. On the way, the actors were verbally mulling over intended strategies and on returning they reflected on the successes or failures of implementation. These informal moments provided valuable lessons for the observer present.

Today was such a day. Steve was explaining to me how he was going to change the casual way he ran the BOS meetings in the future. "My boss wants a formally documented system. He wants formal meetings, with me acting as the formal chairman controlling everything, taking detailed minutes and action items. You know, the lot. He wants me to leave a fully documented audit trail."

It was easy to detect in Steve's tone of voice his distaste for what he was about to do. So taking this lead, I asked what his preferred methods would be.

Steve replied readily, "I would prefer to approach the design process as an *ad hoc* thing, working in a trusting team of engineers, operators and technicians. You know, doing everything verbally and trusting one another."

I nodded understandingly and we continued chatting and walking to the meeting.

***Vignette – I'll make you do it your way***

Steve Gilroy was in charge of designing the screens for the new operator interface being installed at the WTP. Part of his design approach was to spend time talking to operators on site in their control room. Steve's site visits entailed watching the operators work, asking how they visualised the plant, and discussing screen preferences and layouts. In an earlier discussion with Steve, I had asked if it was OK to accompany him on one of his site visits and he seemed more than pleased to comply.

On the day of the visit, I arranged to meet Steve in the control room at the WTP. To gain access to the plant, I had to pass electronic surveillance, automatic doors, swipe cards, and finally a deadly chlorine gas storage facility. Once inside the relative safety of the control room, Leo Tims, the operator, made sure that I was aware of the wind direction, chlorine alarm tones, and upwind emergency egress. After the safety introduction, I asked Leo about what his job entailed.

Leo replied, "It's primarily a monitoring job. We go backwards and forwards monitoring water levels, pump performance, acidity, filter pressures and the like."

Steve arrived toward the end of my introduction. Leo smiled at him saying, "I don't know why you even bother coming down here to ask me all these questions. You just ignore what I want anyway and do it your way." Leo looked to me and said, "He gets what he wants anyway, he always gets what he wants, and we get what's left over."

"I always listen to what you say, Leo, but I am constrained by technology," said Steve.

Steve proceeded to direct our attention to a series of interface issues he had listed down a page. Steve and Leo reviewed these issues over the next one and a half hours. Steve was busily taking notes and making sketches of screen layouts in his pad. When the list was completed, Leo said to Steve, "So you gonna provide me with a set of minutes from this discussion?"

"Uh, err, no," said Steve.

"Come on you engineers document everything, I'd like to see a list of what we agreed to today in writing," said Leo.

"Oh, okay, I guess I should," said Steve.

These two vignettes illustrate a trait of the engineer social world that I have termed *documentation*. I have defined the engineer trait "documentation" as their apparent desire to continually record detailed aspects of the design process. In the first vignette, Steve, the young engineer given charge of his first project, is learning the importance placed upon documentation by the engineer social world, "He wants me to leave a fully documented audit trail". Steve's more experienced boss (Ralph Hopkins) seems aware of the importance of this trait and endeavours to modify Steve's behaviour to bring it in line with that of the social world of which he is member. Steve reflects on his preferred mode of operation "doing everything verbally and trusting one another", however, he grudgingly accepts the engineer trait and complies. This example also demonstrates resistance that can be associated with conflict between group traits. The engineer group has another strong trait *efficiency* that frequently conflicts with *documentation*. In the second vignette, Leo, a member of the operator social world, appears to use the documentation trait as a lever to get Steve to write up the day's discussion. It seems that Leo has used his knowledge of the engineer social world's proclivity for documentation as source of power. In this case, reframing the situation for Steve in terms of what his expected behaviour as an engineer might be by saying, "Come on, you engineers document everything".

These vignettes, and associated analysis, display the way I have identified social world traits from actor's discourse and action within the 5MTPA Project. I have observed what the actors do and say when they are using group names in the process of design. I use these repeatedly observed behaviours and statements as the basis on which to name and define each trait. My premise is that these traits are representations of what the actors find meaningful in the organisation of social life in the 5MTPA Project.

During the twenty-four months of fieldwork, the thirty-two central actors followed were observed to refer to three primary social worlds, *engineers, WTP operators,* and *BOS operators*. Because these three social worlds featured so strongly in the social interaction, their traits could be observed and recorded in the most detail. For the practical purposes of completing my fieldwork, I have restricted my more detailed explanation of specific examples of traits to these three social worlds (see Tables 6.2, 6.3, 6.4). The contents of these tables will be drawn upon in the ensuing chapters as an important component in my explanatory account of the actions observed in the 5MTPA Project.

| Table 6.2 Observed Engineer Social World Traits | | |
|---|---|---|
| **Name** | **Description** | **Example** |
| Documentation | Use of formal systems and procedures for recording details of most aspects of the design process. These behaviours ranged from documenting phone calls through to documenting risk in multimillion-dollar projects. | "My boss wants a formally documented system," said Steve. "He wants formal meetings, with me acting as the formal chairman controlling everything, taking detailed minutes and action items. You know, the lot. He wants me to leave a fully documented audit trail." |
| Efficiency | Decisions are evaluated based on efficiency. New ideas are measured by their potential contribution to the "bottom line", that is, their ability to reduce cost and time. | "I thought the process was very useful on an overall level," said Steve. "You know, everyone got a lot out of it. But I was hoping for something that might save us some more project time as well." |
| Tangible Results | Activities that produce results, that can be measured, touched, and seen are preferred to activities that produce less tangible results. | "I'm sick of this f….g project!" exclaimed Steve. "All I ever do is chase everyone around, contractors, fabricators, operators. I'm an engineer, I want to design and build stuff, not chase my tail." |
| Positive Feedback | Preference for design activities that provide direct feedback with the potential to confirm self-worth and self-value. | "Everyone enjoys software and screen design," said Colin. "They get to find out what the operators want and try to deliver that. They like the fix-ups and re-writes, you know, getting the system so the operators love it." |
| Focus | Dislike for rushed multiple task situations in preference for time to think and work on a single task. | "As an engineer," said Bill. "I'd prefer to focus on just one job and get it right. But we rarely get that luxury; it's always two or more." |

| | | |
|---|---|---|
| New | Strong desires to participate in fresh and potentially superior projects and an associated aversion to standard or common projects. | "All the engineers were clambering over themselves to get on the 5MTPA Project," said Daniel. "We were the new project, and we were the ones with the money and resources." |
| Automation | A belief that the greater the mechanical and electrical control is over a system the less the system will be subject to variation. This is manifest in an ongoing quest to attain higher and higher levels of automation | "With the control system we're installing," said Ralph. "We could eventually automate everything and get rid of the operators altogether." |
| Control | Actively seek control over chaotic, uncontrolled, or poorly understood environments. If attempts to control environments fail, they are subsequently avoided. | "We had to push everything forward," said Ralph. "This meant that we lost some control, and there were lots of loose ends. I don't like loose ends; it makes it look like an untidy project." |
| Detail | Satisfaction derived from measuring, quantifying, and detailing the fine aspects of the design process. | "They've been slipping in the detailed stuff," said Ralph. "I mean, I went down on site, and they had two of the same drawings but with different revision numbers." |
| Logic | A preference for logical rational positions. Seeking ideas and concepts that follow formal demonstrable reason. | "Well let's approach this with logic," said Eric. "What about starting with the pumps and gravel filters?" |
| Rules | Followers and enforcers of rules, regulating concepts, and procedures. | "That's just not allowed!" exclaimed Steve. "We make the decisions at these meetings, and the guys do what we tell them. They don't make decision on site about changing things." |

| | | |
|---|---|---|
| High Tech | Passionate about new gadgets and technologies. The newer and the more advanced, the greater the expressed passion and interest. The newest technologies were observed to be favoured over older and perhaps more proven technologies. | "The old mimic panel is best," said Leo. "I can see everything at once, and it's instantaneous. But the engineers don't like them. They like the new high tech screens better." |
| Risk Aversion | Very strong aversion to risk that if realised could result in blame being attributed to them. On the other hand, they were observed to take little or no action if the risk or potential blame is borne by another group. | "We can't choose what colour to paint the door unless the production superintendent is here," said Steve.<br><br>"Oh, you engineers are hopeless! I'll make the decision to paint it blue and take any shit," replied Joel.<br><br>"Ok, blue it is" said Steve. |
| Uncertainty | Display an open dislike for future states beyond personal understanding or control. | "The engineers from the plant get all nervous towards the end of a project," said Daniel, a permanent project engineer. "They worry about what they will do next and where they'll be. But we don't. We live for projects and are not at all uncomfortable with the uncertainty." |
| Wasted Time | Avoidance of expending energy on activities that *they* deem "not useful". This may include activities considered useful by other social worlds. | "The guys at IT do good work," said Ralph. "But they are so bureaucratic. At the initial meetings, they had four or five high level managers and it's only a small project. Then there are all the levels of approval and associated paperwork. It just seems to be such a waste of time." |

| | | |
|---|---|---|
| Operator Error | Refer to operators as a source of error in plant operation, and that the more they could automate the plant, the less they would be exposed to these errors. | "The more we can automate, the more we can smooth the process," said Eric. "The idea is that if we can get rid of the operators we can get rid of most of the variances." |
| People Mess | Dislike of issues surrounding people that they could not control. I observed their preference for engaging with logical rational technologies as opposed to potentially illogical, irrational people. | "They are scared of the BOS operators," said David. "They don't want to involve them because they are never sure of how they will react or what they will do." |

**Table 6.3 Observed WTP Operator Social World Traits**

| **Name** | **Description** | **Example** |
|---|---|---|
| Trust Us | Expressed desire to take increased levels of accountability and responsibility with respect to control of plant and equipment. | "The onus should be on us," said Randall. "They should trust us with the responsibility that goes with running the plant." |
| Physicality | Actively pursue designs that included physical, hard-wired artefacts, such as lights and buttons, in preference to fully electronic graphical displays. | "I'm not at all keen on this new computerised system," said Leo. "I like the old hard-wired system. You know what's happening, you have a direct connection to the plant." |
| Reliability | A preference for simple, reliable, dependable plant systems over complex high tech systems. | "I prefer real buttons that you can push," said Leo. "You know that when you push it the contact inside will do exactly what I tell it." |
| Deskilling | A dislike of changes in plant and equipment that would reduce their skill requirements. | "There's no way I want them to take manual control away from us," said Randall. "It takes a lot of skill to use, but it's part of how we do our job." |

| | | |
|---|---|---|
| Low Power | Concerned with the limited power they had when it came to influencing changes to the WTP plant. | "There is no point me asking questions," said Randall. "I'm just an operator. I don't really know anything, and there is no point in me communicating. |

**Table 6.4 Observed BOS Operator Social World Traits**

| **Name** | **Description** | **Example** |
|---|---|---|
| Don't Trust Us | An internally expressed belief that they were not to be trusted. That they would always take the easiest option even if it were to the possible detriment of the plant or the product. | "Everyone knows that you can't trust us to do the right thing," said Terry. "So make sure the new system has interlocks so we can't run both vibros at once." |
| Zero Sum Game | A desire during the design process to keep things as close as possible to what they currently have. | "I'm not interested in trying to make things better," said Kevin. "My main aim is to make sure that things get no worse than they already are." |
| Whinge | Complain about almost all plant changes instigated by the engineers. Further to this engineers dismiss the BOS operator complaints as "the way they do things." | "We've all had input into how the new desk was designed," said Kevin. "But once they install it, everyone will whinge that it's not what they wanted anyway." |
| The Good Life | A preference for making work life as easy as possible and pursuing plant and equipment designs that produced low responsibility jobs and few challenges. | "I'm looking forward to the new system," said Romano. "It's more automated and more complex. So we have to do less when it's working, and if it breaks down, it's so complex we'll just have to put our feet up and wait for someone else to fix it." |
| Physicality | Aspirations for designs that included physical, hard-wired artefacts, such as lights and buttons, in preference to fully electronic graphical displays. | "I prefer buttons on a desk to computers," said Terry. "No one can tamper with a button, but with a computer, anyone can muck them up." |

| | | |
|---|---|---|
| Reliability | A preference for simple, reliable, dependable plant systems over complex high tech systems. | "What I want from the new system is reliability," said Kevin. "I want it to be simple enough so that I can still operate the plant even if the computers crash." |
| High Power | Power frequently exerted through threats of industrial action with respect to influencing changes to the plant. | "There was talk about them trying to reduce manning with the new system," said Romano. "There is no way that that's gonna happen while we're around." |
| Low Tech Respect | Low respect for technology in general. | "We can currently toggle the switch back and forth if a chute jams," said Terry. "But with the crappy computer, we won't be able to. I guess we'll have to just smash the screen with a hammer instead." |

In this section, I have introduced the notion that social worlds have identifiable traits and subsequently described social world traits in detail. Further to this, I have suggested that these traits are important because they influence negotiations amongst the social worlds during the process of design. This argument will be further developed in Chapters (7) and (8). The following section discusses some of the ways in which traits were relevant to the actors in terms of change in social world membership.

### 6.5 Social World Migration

As mentioned earlier in this chapter, the boundaries around social worlds are fluid, with individuals alternating amongst, and participating within, multiple social worlds. This multiple social world membership means that individuals may associate themselves, or be associated by others, with more then one set of social world traits. These variations will produce an accompanying change in the way negotiations are conducted and eventually the final shape of the artefact itself. In light of this, understanding the patterns and uses of social world migration will provide useful information on the social processes that occur during the activities of design.

In the following vignette, Steve DeRosa, the BOS Project engineering coordinator, seems to be allocated membership to three different social worlds. Firstly, Steve seems to associate himself with the social world, *engineer*.

> "Once the project starts I won't have time to ask the operators what they really want. It's the *engineers*' responsibility to pick the best way forward. We have to deliver the project on time and on budget."

Secondly, Kevin Robinson, the operations representative for the BOS Project, associates Steve with the social world *electrical engineers*.

> "The *electrical engineer* (Steve DeRosa) provides the drawings. We mark up the changes we want and then he modifies them."

Finally, Steve associates himself with the social world *BHP*.

> "I've been trying to encourage Australian Automation to make a claim against us. *BHP* is a large company and should shoulder most of the

responsibility. We aren't even going to notice if we pay them a bit extra, whereas they are going to feel it a lot if we don't."

These three examples seem to depict Steve as being a member of three separate and overlapping social worlds, *engineers*, *electrical engineers*, and *BHP*. The memberships have been assigned by Steve, internally, and by Kevin, externally. In light of this, I have proposed a five-element schema for categorising my observations of migration of members amongst social worlds - *transmuting, staying, transposing, hiding,* and *pushed*[4]. In the following sections, I review each of these schema elements and discuss some of the ways in which individuals used their group memberships to suit particular circumstances in the process of design.

## Transmuting

*Transmuting* occurs when individuals move from one social world to another. The impetus for movement between social worlds seems to be an attempt by actors to find traits or routines[5] that they feel best suit the situation at hand. The social worlds among which individuals may transmute are restricted to those for which their membership is generally accepted. In the following vignette, Steve DeRosa, the BOS Project engineering coordinator, seems to use the transmuting technique to position himself within the larger BHP social world and thus reduce the dissonance between his desired actions and the traits of the engineering social world.

[4] These terms are mine, not those used in BHP.

[5] A 'routine' can be defined as a standard pattern of action. These patterns enable goal directed action to occur without the need to invent new approaches each time a person or collective acts (Strauss 1993). This concept is further explored in Chapters (7) and (8).

***Vignette – BHP is not even going to know if we pay them a bit extra***

Australian Automation had successfully completed the initial BOS Flux interface designs. However, during the factory acceptance tests, a number of significant functionality problems became apparent. Although the source of the problems seemed to be within BHP, the contractual agreement was such that the responsibility rested with Australian Automation. David Riley, the manager of Australian Automation, accepted, without argument, the financial and physical liability of rewriting the software to overcome the problems.

Steve DeRosa was unhappy that Australian Automation was taking the full impact of the problems.

"It cost Australian Automation fifteen days to rewrite the software," said Steve. "I've been trying to encourage them to make a 'contract extras' claim against us. As an engineer, I should be trying to minimise my extras. But Australian Automation is a small company and BHP is a big company. BHP is not even going to know if we pay them a bit extra, whereas Australian Automation will feel it a lot if we don't."

In this vignette, Steve seems to align himself with two social worlds – the engineer social world and the BHP social world. As a member of the engineer social world, Steve seems restricted by the social worlds traits and routines with respect to providing Australian Automation financial compensation for the lost fifteen days. However, it appears that when Steve thinks of himself as a member of the much larger BHP social world he is able to adopt a new set of traits and routines that provide leeway for compensation. It is possible for Steve to 'transmute' between these two social words because he considers himself, as do others, to be a member of both.

## Staying

*Staying* occurs when individuals attempt to retain membership of a social world after others have generally accepted them as no longer being a member of that particular social world. Two typical reasons observed for members losing current social world memberships, and gaining new ones, were promotion and transfer. The impetus for an individual to attempt to retain social world membership seems to stem from either sentimentality or utility. Sentimental *staying* is based on the individual's enjoyment of social world membership. On the other hand, utility *staying* is based on the usefulness of retained membership. In the following vignette, Steve DeRosa reflects on the behaviour of Max Davies, the BOS superintendent, and his attempt at retaining membership of the BOS operator social world.

### *Vignette – He's one of the boys*

Steve DeRosa was explaining to me some of the factors that he saw as restraining the BOS Project.

"The new system is a half and half system," said Steve. "What I mean is, we are half-using computers and networks, and half-using direct wired push buttons. The buttons may be more reliable, but they are totally inflexible. You can't do a thing with them.

Whereas the computers and networks are much more flexible and intelligent. But there is no way we can get that through their thick heads."

Steve paused as if he were composing what to say next.

"And the superintendent, Max Davies, is no help," continued Steve. "He has no vision. He is an ex-operator who worked his way up through the ranks. He's one of the boys. He wants to give the boys whatever they want."

In this vignette, Steve seems disappointed that, from his perspective, the process of design is being restricted by Max's close association with the operators and his perceived lack of vision. However, in my observations, one of Max's strengths as a superintendent is his ability to work with his operators. This strength seems to be based on Max's attempt to retain membership (in terms of traits and affiliations) of the BOS operator's social world in spite of the commonly held view that he is now a member of the production management social world.

## Transposing

*Transposing* occurs when an individual imagines himself or herself as a member of another social world. The social worlds used in the transposing process are those for which the individual would not have generally accepted membership. As such, they can only experience membership through an imaginary environment. The impetus for *transposing* oneself seems to be to experience certain situations from the perspective of another social world. In the following vignette, David Riley, the manager of Australian

Automation, recounts two previous design projects. In doing so, he provides examples of situations where it seems he used the method of *transposing* in order to increase his understanding of other social worlds. This increased understanding assisted David in the process of design.

***Vignette – The way the Operators think***

"We did two interesting jobs last year," said David. "One at the K-Pack oil refinery and the other at the Southern Star Cement works. The two interfaces we designed were totally different. After spending time with the operators at K-Pack, I was able to figure out how they thought. Once I could imagine what it was like to be an operator there, I could design an interface to suit. Those guys thought about the plant as a system of flows and controls. So I designed the interface to match. I did a similar thing at Southern Star. The guys there thought about the plant totally differently. They saw a physical plant, so I designed an interface that looked just like the plant. I mean, if you looked out the window at the real plant, you saw exactly what was on the interface screen."

In this vignette, David recounts time spent observing members of the K-Pack and Southern Star operator social worlds. It seems that through his observations David was able to understand some of each of the social world traits. For example, David was able understand that the K-Pack operator social world used a mental map of the plant based on "flows and controls", whereas the Southern Star operator social world used one based on a "physical plant". With this understanding of social world traits, David is able to "imagine what it was like to be an operator there". By transposing himself, David is able to experience certain situations from the perspective of another social world. This experience is subsequently used by David in the process of design for creating an interface that he feels will best suit K-Pack and Southern Star operators.

## Hiding

*Hiding* occurs when individuals choose to mask or conceal themselves behind certain social world traits or routines. The social worlds used in the process of *hiding* are those to which the individual has generally accepted membership. The impetus for *hiding* seems to be the ease with which certain expedient actions may be legitimated as common practice by identifying oneself with a group that typically has the traits on which the actor wishes to draw. That is, the actor elicits expectations based on the generally accepted traits and routines that are assigned to an individual in conjunction with social world membership. For example, in the following vignette, I observed Steve Gilroy, a process control engineer on the WTP Project, using what seemed to be accepted engineering social world traits and routines to justify his actions to Leo Tims, a WTP operator.

### *Vignette – We can't just up and change them!*

Steve and Leo were discussing preliminary screen designs for the new WTP operator interface. I was attending the meeting as a non-participating observer. The design meeting was held in the WTP control room. This seemed to be a preferred site for these types of meetings as it provided real props and artefacts around which they could envision the new interface.

"OK, so we'll have controls for all the pumps and valves on one screen for each section of the plant. Then an overview screen that you can drill down to each control screen from," said Steve.

Steve started sketching the layout on a pad for Leo to see.

"Yeah, that should work," said Leo.

"What about the colours?" asked Steve.

"Well, we should keep them the same as the current mimic panel and control desk," replied Leo.

Steve seemed reluctant to use the current WTP colour standards, preferring instead those of the engineering standard. They began to argue about which colours would be best for which plant states of nature, for example, on, off, idle, and alarm. The argument continued back and forth for some time before Steve finally brought it to cessation with the following statement.

"Look it doesn't matter what we think. The colours we have to use are clearly defined in the engineering standards. We can't just up and change them because it's what you like!"

In this vignette, Steve seems to *hide* behind a number of the engineer social world traits, for example, *rules, wasted time,* and *efficiency* (see Table 6.2). In doing this, he is able to take actions to move the design process forward, in his preferred direction, with the weight of the entire engineering social world's "standards" behind him. In response, it seems Leo is unable to provide further sufficient arguments so he grudgingly submits.

## Pushed

The previous four elements in my schema dealt with voluntary movement amongst social worlds based on the actions of the migrating individuals. In my observations of the 5MTPA Project, it seems that in certain situations individuals may be pushed into, or involuntarily assigned memberships of, social worlds with which they do not have shared commitments. This observation differs from the definitions of social worlds provided in the literature where membership is voluntary amongst individuals with "shared commitments to certain activities" (Clarke 1991, p.131).

The following vignette provides an example where I was involuntarily pushed into membership of a social world to which I did not feel I belonged.

### *Vignette – Can you fix this?*

I entered the No.3 BOS Vessel control room midway through dayshift. Two men were bent over the large stainless steel control desk pushing buttons, clicking computer icons, reading displays, and talking on the public address system. They were busy performing the tasks required to control the melting and refining of a combination of molten iron and solid steel scrap. I walked over to the desk and in a moment of calm introduced myself.

"Hi, I'm Ross," I said as I extended my hand in greeting. "I'm from the university. Would it be okay if I hung around, watched you work, asked a few questions, and took some notes?"

I had developed the habit of keeping my introductions short. My official research proposal and consent form had been previously presented to all employees during off-shift meetings, and I refrained from covering the potentially boring detail a second time.

The younger of the two men responded by leaning over, taking my outstretched hand, and saying, "Joe. Sure, no probs."

The second man also leaned over and said, "Romano. What da ya wanna know?"

"I'm just interested in what you do," I replied. "You know, how you control the plant. I'll just sit and watch and ask questions and if you get too busy to answer, just say so."

For the next two hours, I watched, asked questions, listened to answers, and took notes. When I felt I had enough, I thanked them both and started packing up my notebook and pen.

Romano stopped me, pointed to some read outs on the screen and said, "Oh, before you go, Ross, can you change the way this info is displayed?"

I was startled by the request and shook my head explaining I was a social science researcher without the knowledge or authority to change the system. I realised Joe and Romano thought that I was an engineer. They had placed me in a social world they labelled *engineer*, associating with me all the meanings that engineers had for them, including the technical ability to fix their computer problems. The fact that I entered the room without wishing to be associated with the *engineer* social world had little initial effect on Joe and Romano's perceptions of which social world I belonged to. This vignette serves to demonstrate that, unlike the social worlds described in the literature, my conceptualisation of social worlds within the 5MTPA Project includes both voluntary and involuntary membership.

In this section, I have provided specific examples of some situations in which individuals migrate amongst social worlds. This migration affects the process of design through altering the traits associated with the individual and, hence, how they are perceived and responded to during negotiations throughout the process of design. These illustrations also support my conceptualisation of social worlds as being internally relevant to the actors within the 5MTPA Project as opposed to a banal set of externally imposed categories.

### 6.6 Summary

This chapter has drawn on Strauss's social worlds/arena theory to examine the social collectives that engage in the negotiation of design boundaries. This examination identified thirty-two individuals who were interested and active in the 5MPTA Project. The repeated appearance in the discourse of these actors of 'us and them' categories helped identify twenty-seven social collectives, or social worlds, that were meaningful to the participants. These social worlds possess identifiable characteristics, or traits, that provide information to members and non-members about what actions or behaviours might or might not be expected during the negotiation of design boundaries. Continued observations of the actors and social worlds indicated that, in the negotiation of design boundaries, three social worlds predominated - engineers, WTP operators, and BOS operators. The observed traits of these social worlds were presented here in tabular form for reference in the coming chapters. The migration processes through which individuals identify with a series of social worlds suggest avenues for the influence of social worlds and traits on the final shape of an artefact.

The detailed information presented in this chapter, regarding social worlds and their traits, provides an empirical base from which it is possible to further develop an account of the 5MTPA Project in terms of the interactions and patterns of action amongst actors and social worlds around design boundaries.

# Chapter (7) – Arenas in the Process of Design

## *7.1 Introduction*

In Roman times, an *arena* was an enclosure for gladiatorial combat amongst rival individuals and teams. This concept of an arena can be transposed into the process of design, where the physical enclosure becomes a socially constructed space, the gladiatorial individuals and teams become actors and social worlds, and the ensuing battles are not fought out to the death for spectator entertainment but for alignment of sub component trajectories with social world ideologies. That is, the operators want a control panel that reflects their values, and the engineers want features that reflect a different set of values.

The usefulness of this concept of arena is that it provides a dynamic analytic framework within which it is possible to study the interplay of technology trajectories, design boundaries, and social worlds. The battles that occur within these design arenas involve negotiation and cooperation where, as Strauss explains, the actors and social worlds transfer amongst themselves information, skills, and resources. As with Roman gladiators, the participants do not randomly engage in battle. Rather they follow predetermined strategies and employ standard patterns of action. These patterns of action, here called 'routines', provide an analytic framework through which it is possible to understand the thrusts, parries, and feints of the participants that, as described in the chapter to follow, are the detailed elements of the complex design process through which technology is shaped.

The use of the arena concept combines themes from the previous two chapters. That is, negotiations in these arenas produce a set of design boundaries that restrict or guide the amalgamated trajectories of a technologies sub components. These negotiations evince and are informed by social world traits that represent the expected behaviours and ideological orientations of the participating actors.

## 7.2 Arenas in the Process of Design

According to Strauss (1993), social worlds with an interest in a particular issue often form an 'arena' around that issue. The arena is a social space in which these issues are debated, fought out, negotiated, and even coerced amongst the social worlds. Strauss states that these arenas can be very small or very large and they can arise around issues both internal and external to the participating social worlds. As the issues around which the arenas have been formed are resolved, the social worlds disengage, and the arena dissolves. The largest and longest lasting arena in the 5MTPA Project has been the project itself. Within this arena the social worlds have come together to interact with one another about the artefacts being designed. As Strauss points out, within each arena smaller arenas are likely to arise over every issue that is not quickly settled (Strauss 1993, p.226). This was the case within the arena of the 5MTPA Project, where many small arenas arose over specific issues and were then dissolved, as the issues were resolved. The issues at the centre of these smaller arenas were typically related to either sub component trajectories, and the negotiation of the design boundaries that guide them, or the routines[1] through which the social worlds performed the work of design.

My use of Strauss's arena theory in this chapter is focussed on design boundaries (arenas that form around routines will be addressed in Chapter (8)). In Chapter (5), I introduced the notion that design boundaries were sets of specifications that acted as to constrain and enable the trajectories of an artefact and its sub components. Further to this, these design boundaries are the negotiated product of interactions amongst relevant actors and social worlds. When a social world initially recognises a contentious issue, with respect to construction of a design boundary, they draw other relevant social worlds into the debate and an arena forms. This arena exists while the relevant social worlds negotiate with respect to the design boundary issue and it will persist until some sort of arrangement between the social worlds regarding a course of action is reached. This arrangement may or may not satisfy the relevant actors and social worlds. Arenas are not utopian environments. They are battlefields, with winners, losers, and only sometimes agreeable truces.

The following vignette provides a specific example of a design boundary issue, within the WTP Project, around which an arena formed.

[1] A 'routine' can be defined as a standard pattern of action. These patterns enable goal-directed action to occur without the need to invent new approaches each time a person or collective acts (Strauss 1993). This concept is discussed further later in this chapter.

***Vignette – Yep, we won that one***

I was looking at the 'industrial size' keyboard in the WTP control room. I could see a small hole in its upper right hand side. I craned my neck, looking closer to see exactly what the hole was.

"That's the keyboard lock you're looking at," said Leo.

I looked up smiling. I had not realised Leo was watching me.

"What's it for?" I asked.

"You can use it to lock the keyboard. With it locked, no one can use it. Here let me show you," said Leo.

As Leo showed me how the key worked, he explained the trouble he had getting the operators access to the key. The engineers originally had the key and refused to give it to the operators. They claimed that the operators had no need to lock the keyboard. Counter to this argument, the operators claimed that it was a feature of the new system to which they wanted access. Eventually, the operators were given a key and a standard procedure for its use was created. Leo was finishing his story of the key when Steve, one of the engineers, walked into the control room.

Leo looked at Steve and smiled saying, "Yep, we won that one didn't we. It was a little victory for us operators over you engineers."

On the surface, it appears that the issue of contention around which this arena was formed, was that of the 'keyboard lock'. The WTP operators identified the issue and initiated the debate regarding key access. The two social worlds, engineers and WTP operators, came together and, in this case, resolved the issue by providing the WTP operators with a key and a written procedure for its use. Having said this, I would contend that the WTP operators have instigated the arena around the 'keyboard lock' as an opportunity to engage in a more subtle and ongoing arena. At the centre of this second arena is the WTP operator's fight for greater recognition and influence over their plant and the process of design[2].

Figure 7.1 illustrates a notional arena (shown in bold) within the 5MTPA Project. In this arena, two social worlds have come together to negotiate, debate, and perhaps coerce one another with respect to the design boundary highlighted.

[2] The notion that the WTP operators were fighting for increased levels of accountability and responsibility was first introduced in Chapter (6), where it was listed as one of their social worlds observable traits, see Table 6.3.

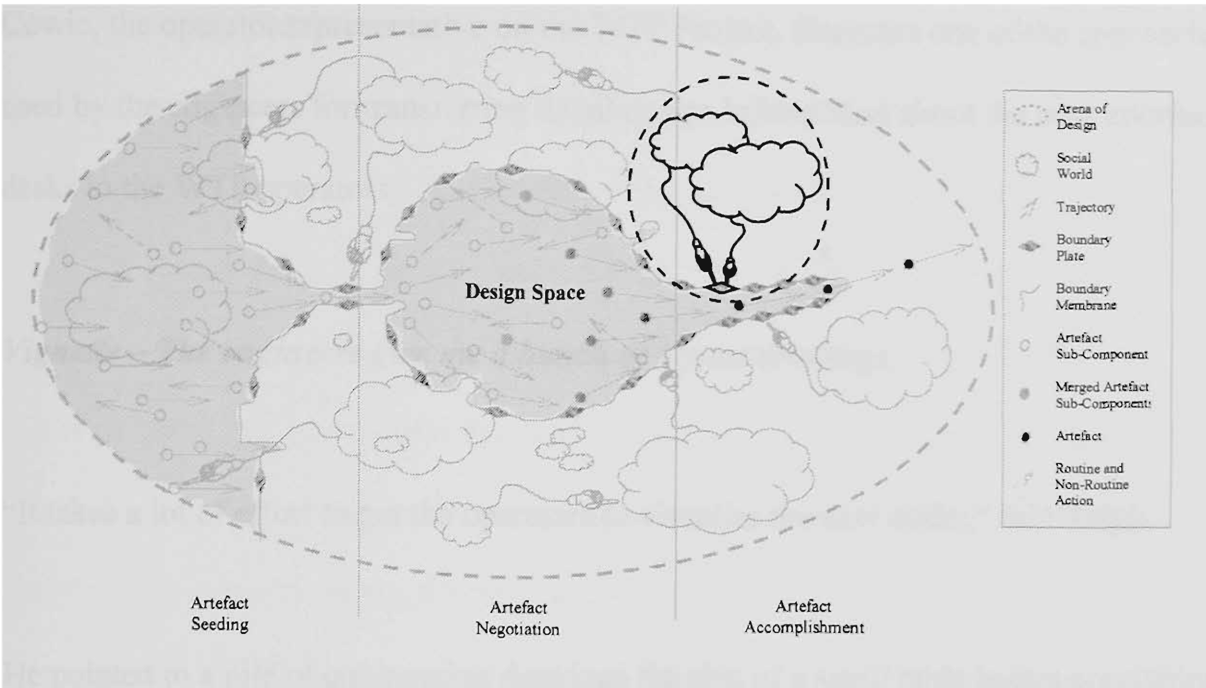


**Figure 7.1 -A 'Design Boundary' Arena**

When social worlds come together in an arena, they negotiate and sometimes battle about the issue at the centre. In doing so, they transfer, to one another 'information, skills, and resources' regarding the contentious issue (Strauss 1993, p.217). Identifying the processes by which they do this, and examining their use within the design boundary arenas, adds further detail to my interpretation of the activities observed in the 5MTPA Project. In light of this, the following sections describe the transfer of information, skills, and resources.

## Information Transfer

The transfer of information amongst social worlds within an arena is not a clear and straightforward process. Personal preferences, social world traits, and hidden agendas are but a few of the factors that influence this process. In the following vignette, Ralph

Cowie, the operator representative on the WTP Project, discusses one of the approaches used by the engineers for transferring detail design information about the new interface desks to the WTP operators.

***Vignette – The engineers give me a bunch of layout drawings***

"It takes a lot of effort to get the operators to visualise the new desks," said Ralph.

He pointed to a pile of engineering drawings the size of a small table before continuing.

"The engineers give me a bunch of layout drawings for the operators to comment on. I normally have to take the drawings down to the WTP and explain them to the operators. I then give them time to think about it before I gather up the drawings and their final comments so I can feed that back to engineering."

In the vignette, Ralph indicates that, in spite of the fact that the operators cannot readily understand 'layout drawings', the engineers have a preference for transferring information to the operators through them. It seems to me that the engineers' selected mode for transferring information to the operators is influenced by the engineers' commitments and beliefs, or in my terms, social world traits. In the specific case cited by Ralph, I would postulate that three specific engineer traits[3], which have little to do with receiver cognition, have influenced the engineers' choice of 'layout drawings' as the transfer method. The first trait that I see as influencing this choice is *documentation.* This trait refers to the engineer's frequent use of formal systems and procedures for

[3] For a list of identified engineer social world traits see Chapter (6), Table 6.3.

recording detailed aspects of the design process. In this case, the trait is satisfied by 'layout drawings' because they formally document, for the engineers, the size and shape of the new desk and the relative positions of the dials, switches, and displays within the desk. The second influencing trait, *wasted time*, refers to the engineers' avoidance of expending energy on activities that they deem as 'not useful'. In this case, the engineers can understand the 'layout drawings' and as such avoid 'wasting time' trying to develop a transfer method that may be more useful to the operators. The third influencing trait, *people mess*, refers to the engineers' avoidance of messy issues surrounding people. In this case, the 'layout drawings' provide a transfer method that reduces the engineers' requirements for seeing the operators face to face and hence minimises their direct exposure to people mess.

The social worlds within the 5MTPA Project frequently transferred information amongst themselves as arenas repeatedly formed and dissolved. Ideas and concepts are grouped into neat, discrete packages for transfer from one social world to another. This may involve artefacts such as sketches, mock-ups, memoranda, specifications, and other forms of documentation. Through my observation of this process, I have developed a typology of 'information transfer packages' to represent the most common approaches (see Table 7.1).

| Table 7.1 Observed Information Transfer Packages | | |
|---|---|---|
| **Name** | **Description** | **Example** |
| Simplification Package | Simplified ideas, and common day analogies, may be used to assist other social worlds in their understanding of concepts. | "He's gonna have a water balance problem later," said Leo. "Its like you've got a bunch of buckets that are all full. There's nowhere left to put any more water." |
| Masking Package | Packaging ideas in such a way that the recipients are unlikely to fully understand the package's complete contents. | "None of the guys could understand the detail drawings the engineers gave us to look at," said Kevin. |
| Transparent Package | Packaging ideas in such a way that the recipients are likely to understand the package contents. | "The best way to write them is with pictures and simple text," said Ralph. "You have to avoid complex technical jargon." |

This typology of information transfer 'packages' presents a number of options from which actors within an arena may choose. In the previous vignette, the engineers chose 'layout drawings' as the discrete package for transferring information to the operators. Using the typology above, I would categorise the 'layout drawing' as a *masking package;* as the recipients of the package, the WTP operators, are unable to fully understand the content of the package when they attempt to unpack it upon delivery. In this case, the use of a masking package represents another element against which the WTP operators must fight in their ongoing struggle for greater recognition and influence. It is worth noting that the engineers may or may not have pursued this as a deliberate strategy. For example, if another engineering group were to be the receiving social world, then their use of 'layout drawings' would most likely be received as a *transparent package.*

## Skill Transfer

A second process that occurs during negotiation within arenas is *skill transfer*. This occurs in situations where certain skills required for the construction of design boundaries are absent. In such cases, the negotiation within the arena involves, amongst other things, the transfer of the missing skill from one social world to another. In the following vignette, two actors from the same social world are engaged in constructing a design boundary for which they find they do not have the requisite knowledge embodied in 'plant operating skills'.

***Vignette – Errrr, I'm not sure***

Steve DeRosa, the BOS Project engineering coordinator, and David Riley, the programmer writing the PLC code, were meeting in David's office.

"OK, what are the units for hopper weight measurement[4]," said Steve.

"Well, what's the maximum hopper load that we have to measure?" asked David.

"Errrr, I'm not sure," replied Steve.

[4] The "hopper" is a large funnel shaped reservoir, fabricated from steel plate, from which solid materials can be discharged into the BOS furnace below. The hopper is mounted on sensors that are able to measure the quantity of material in the hopper by registering variations in hopper weight.

"Well, we need to know that before we can pick our units," said David. "I'll be using binary code, so that means the maximum number I can have is 3200. So we need to know if the hopper will hold a maximum of 3200 kg or 3200 tonnes."

"Yeah, I don't know," replied Steve. "We'll have to arrange a meeting with the operators before we can decide on the units."

In this vignette, Steve and David are trying to define the 'maximum hopper load' in order to select the appropriate units of measurement. Once defined, this detail represents a design boundary that will limit the amount of material, from a system measurement perspective, that can be loaded into the hopper. In this case, however, Steve and David find they are faced with an issue for which they do not have the requisite 'plant operating skills'. In order to resolve this issue, they agree to arrange a meeting with the BOS operators so that the requisite skills can be transferred between the BOS operator social world and engineer social world for the purpose of constructing a design boundary.

In the following vignette, Leo Tims, a WTP operator, provides another perspective on the issue of skill transfer from operators to engineers during the process of design. In this case, Leo is discussing the difficulties the operators faced with screen design as a result of the lack of plant understanding of Steve Gilroy (the process control engineer responsible for designing the screens in the WTP Project).

### *Vignette - He doesn't have the skills to operate the plant*

"It's been a real pain breaking Steve in," said Leo. "His first screens were hopeless. He was new to the plant. He didn't even know what the different parts of the plant did. I mean, how can a guy design a screen if he doesn't have the skills to operate the plant? So we've been teaching him how the plant works. He's getting there now and his next set of screens will be much better."

In this vignette, Steve's initial screen designs, each of which formed part of the WTP Project design boundary, failed to satisfy the operators. As a result, arenas formed around the contentious screens. In the ensuing negotiations, plant operating skills were transferred to the engineer social world for incorporation in the revised screen designs. With the requisite skills, Steve is able to construct screens that from Leo's perspective are 'getting there now' and 'will be much better'.

The absence of plant operating skills during the construction of design boundaries is a common issue around which arenas form. In light of this recurring issue, the various social worlds have developed a routine in which an individual, with the requisite plant operating skills, is physically transferred from the operating plant to the design project. This represents not only a transfer of skills, but also a transfer of resources. The following section discusses resource transfer within an arena in further detail.

## Resource Transfer

As mentioned in Chapter (5), once a sub component enters a design space, it is provided the resources and opportunities to develop and grow within the design boundaries. The arenas that form around design boundary issues will frequently involve the transfer of resources. Three common resource types that were transferred amongst social worlds within the 5MTPA Project were *human, financial,* and *physical.* The following vignette provides an example of the transfer of a physical resource, in this case a visual display unit, between two social worlds within the WTP Project.

***Vignette – The 'four-screen' saga***

I had spent the morning at the WTP talking to the operators. Whilst there, Leo Tims (one of the operators) had told me about the fourth visual display unit. He claimed the engineers had bought it for the project but were keeping it for themselves.

Later that day, I went to see Colin More, the WTP Project manager, and asked him about Leo and this fourth screen.

Colin groaned and leaned back in his chair.

"Let me try to explain about the 'four-screen' saga," said Colin.

He sat running his fingers through his beard, as if trying to decide where to start the story.

"You see, we originally designed the control system for three screens. When it came time to buy spares, it worked out cheaper to get an entire fourth monitor, as opposed to separate spare components. So we bought a complete fourth monitor. In the event of a failure, we can just swap monitors and keep the plant running," said Colin.

He then leaned forward, put his elbows on the desk and continued.

"But now the operators know we have four screens, they want them all," said Colin. "They think we want it as our own screen, you know, set up out the back to watch the system. But it's the spare. If we install it for them, we'd need to buy a fifth screen as the spare. [Chuckling] Then they'd want five screens wouldn't they."

In this vignette, the contentious issue at the centre of the arena was the number of visual display units that the new WTP operator interface would have. The operator social world identified the issue and subsequently initiated the debate with the engineer social world. In coming together, the two social worlds have formed an arena in which, amongst other things, the physical resource of a visual display unit is being debated. Eventually the arena dissipated with the transfer of the fourth visual display unit to the WTP operators. An additional influencing factor in this vignette is that, as with the 'keyboard lock' issue raised earlier in this chapter, the 'fourth screen' represents an opportunity for the WTP operators to engage in their ongoing fight for greater recognition and influence over the plant's design and function.

In this section, I have discussed the concept of the arenas where social worlds negotiate and sometimes battle over contentious design boundary issues. During these negotiations and battles, the social worlds were observed to transfer, amongst themselves, information, skills, and resources. The processes involved in these transfers are of interest as they account for activities that influence the formation of design boundaries. The usefulness of the arena concept is that it represents a dynamic environment within which it is possible to draw actors, social worlds, and artefact trajectories together with technological, political, economic, and social circumstances.

## 7.3 Routine Action

The interplay amongst actors and social worlds over design boundaries does not proceed at random. Rather, the actors follow predetermined strategies and employ standard patterns of action. These patterns are methods or approaches that actors may use to order their exchanges amongst the relevant social worlds. In light of this observation, Strauss's (1993, pp.191-207) exploration of a theory of action, which takes into account both routine and non-routine types of interaction, seems a useful analytical framework around which to base further discussion.

Strauss defines routines as 'standardised patterns of action' and argues that without them 'nothing much could be accomplished through action carried out on a repeated basis' (1993, p.194). The basis of this argument is that goal directed action requires a patterning of activity that does not need to be invented on the spot each time that a person or collective acts. Rather, as each new situation is presented, appropriate patterns of routine action are called upon and then supplemented with subtle variations and adaptations (Strauss 1993, p.195).

It is important to note that it is impossible to draw a hard and fast line between the analytical concepts of *routine* and *non-routine* action. With many subtle changes in situations, so-called 'routine' action can never be entirely routine, and likewise, 'non-routine' action will always have some routinised aspects (Strauss 1993, p194). Thus, routine and non-routine actions represent the notional extremes on a continuum of types of action.

In the context of organisations, routines operationalise arrangements reached by virtue of explicit or tacit agreements amongst the relevant social worlds or their representatives. As mentioned previously, the way members reach agreement is varied - through negotiation, persuasion, coercion, manipulation, and so on (Strauss 1993, p195). The following vignette provides an example of routine action within a 5MTPA Project arena.

***Vignette – The way they do things is by teasing the engineers***

It was my first meeting with the WTP engineering design team. It was an opportunity for the team to meet me and discuss some general issues to do with interface design. After about an hour, Eric Haines, an electrical engineer, raised the topic of the team's experience.

"The team has a very strong steelmaking background and very strong process knowledge," said Eric. "This knowledge means we can reduce the need for operator input. I mean, we probably know what the WTP operators need better then they do."

A general murmur of agreement rippled around the table. Eric followed this by drawing some comparisons between the WTP operators and the BOS operators.

"The WTP operators don't seem to care much about the system," said Eric. "They're pretty happy with whatever we give them. It's so different to the BOS. In the BOS, the operators have a very strong political background. They argue and whinge about everything the engineers do. But really they're only razzing the engineers for the sake of it. They don't really hate engineers, but the way they get on, and the way they do things is by teasing the engineers."

In this vignette, Eric describes what appear to be two different routines or patterns of action that he and the rest of the design team recognise when interacting with the WTP operators and BOS operators. The engineers expect the WTP operators to accept their design choices with little interest or resistance[5], "they're pretty happy with whatever we give them". On the other hand, the engineers expect the BOS operators to "whinge," use "political" force, and "tease" them throughout their interactions in the process design. The common way that the engineers approach interaction with these two groups represents, from my perspective, routine action.

[5] The WTP operators, in a number of vignettes provided earlier in this chapter, have challenged this particular routine. Chapter (8) discusses changing routines in greater detail.

The following two sections identify a number of specific routines that appear to be used to order exchanges first, amongst the various social worlds and second, amongst the various individuals when they come together within an arena.

## Social World Interface Routines

Through the continued observation of social worlds in arenas it is possible to recognise certain repeated routines amongst the myriad of actions and identify social world traits that may be influencing their use. A sequence of identified routines and traits can provide an account of activities being observed.

The following two vignettes provide specific examples of interface routines and my associated analysis of the influencing social world traits.

### *Vignette – Actor exclusion*

I rang Ralph Hopkins, the BOS Project manager, to arrange a time to discuss how he felt the commissioning of the BOS Project had proceeded.

"Hi Ralph. It's Ross. I was wondering if you had some time later today for a chat about commissioning. You know, problems, successes, general issues, stuff like that."

"Not today, sorry Ross," replied Ralph. "I'm busy on other projects. Maybe next week, hmmm, say Thursday 1:00 PM in my office?"

"Yep, that will be fine. See you then Ralph, thanks, bye" I said.

I then rang Steve DeRosa, the BOS Project engineering coordinator, and asked him the same question.

"Hi Steve. It's Ross. I was wondering if you had some time later today for a chat about commissioning. You know, problems, successes, general issues, stuff like that."

"Yeah sure," replied Steve. "This is perfect timing actually. You should come along to the meeting this afternoon. Ralph is organising a meeting for all the players in the BOS Project to get together to discuss the successes and failures. [pause] I actually suggested to Ralph that he invite you, but he didn't seem real keen on it. You should ring Ralph and ask if you can go, just don't mention you heard it from me."

I thanked Steve for his advice and refrained from telling him that Ralph had conveniently avoided mentioning any such meeting in the previous phone call.

This vignette provides an example of a social world interface routine that I identified and have termed *actor exclusion*[6]. I have defined actor exclusion as the way that one social world deliberately prevents another social world from participating in certain events. In this case, Ralph excludes me, a member of the university social world, from a

[6] 'Actor exclusion' and the other routines discussed in this study have been identified through their repeated observation in my field data. This grounded theory approach systematically records both my developing theoretical analysis and my raw field data in a NUD*IST database. The 'actor exclusion' vignette presented was selected from a list of possible field incidents recorded and coded as containing the 'actor exclusion' routine.

meeting that he has arranged to discuss issues of success and failure from the BOS Project. This exclusion, presumably, gives Ralph an opportunity to filter out any information that he would prefer not to have transmitted to the university social world. The engineering trait that seems to be satisfied by this particular exclusion is that of *risk aversion,* that is, the aversion to risk that if realised could result in blame being attributed to the engineering social world. As an addendum to this vignette, Ralph did meet with me, as arranged, on the following Thursday and provided me with his filtered selection of BOS Project successes and failures[7].

The following vignette provides another example of a social world interface routine.

***Vignette – The gift***

Colin More, the WTP Project manager, and I were discussing the WTP Project.

"We ordered the desk[8] last week," said Colin. "We don't need it for months yet and there is actually no real point in ordering it. But being able to tell the operators that we placed the order has given them some confidence that the project is really moving ahead. You know, it's given us some runs on the board. So we went ahead and ordered it anyway."

[7] The attempt by Ralph to exclude me from these events is a specific example of a common fieldwork problem. That is, being given access by participants to only certain aspects of the phenomena being studied. If this is the case, the resultant account may miss many of the hidden, and sometimes most important, activities surrounding the phenomenon being studied. This problem is, to a large extent, mitigated by fieldwork carried out over longer periods of time and with a greater depth of observation. This can be demonstrated by the fact that Ralph's attempt to exclude me was foiled by several other actors providing me detailed secondary accounts of the missed meeting. Further to this, the act of exclusion subsequently provided additional detail to my account of activities.

[8] The "desk" is the primary physical object that the operators will see in the project. It houses the buttons, switches, display units, and keyboards for the new control system.

This vignette provides an example of the social world interface routine that I have termed *the gift*. I have defined the gift as the presentation of a token gesture to show good faith and placate another social world. In this case, Colin has arranged to have the new desk ordered so as to satisfy the operators that progress is being made with the project and "get some runs on the board". Colin could have chosen a number of other artefact sub components, such as software, screen design, wiring designs, that had already been produced. However, it seems Colin has specifically selected the 'desk' as *the gift* because of his knowledge of the operators' preference for physical, hard-wired artefacts over the less tangible, software and electronic artefacts. This preference of the WTP operator social world I have termed as the trait[9] of *physicality*.

These two vignettes provide examples of routines used in interface activities amongst the various social worlds within an arena. Table 7.2 provides a list, though by no means a comprehensive one, of these and other social world interface routines that I observed in the 5MTPA Project.

[9] For a list of identified WTP operator social world traits see Chapter (6), Table 6.4.

**Table 7.2 Observed Social World Interface Routines**

| Name | Description | Example |
|---|---|---|
| Actor Exclusion | Certain actors may be excluded from social world interfaces in an attempt to achieve some secondary outcome. The exclusions are made by either the actor themselves or by other actors. | "I actually suggested to Ralph that he invites you," said Steve. "But he didn't seem real keen on it. You should ring Ralph … just don't mention you heard it from me." |
| The Gift | Providing another social world a token gesture of good faith in an attempt to placate them. | "We ordered the desk last week," said Colin. "We don't need it for months yet … but … the order has given them some confidence." |
| Centrality | Nomination of specific individuals as the primary path for information transfer between one social world and another. The nominations may be made either by mutual consent or by the dominant social world. | "We nominated Kevin Robinson as the only operator that we would deal with," said Ralph. "Using a single operator allows us to control the flow of information between engineers and operators." |
| Marginalisation | Limiting the information flow to other actors and social worlds in an attempt to reduce their potential impact. | "They are scared of the BOS operators," said David. "They don't want to involve them because they are never sure of how they will react or what they will do." |
| Indirect | Attributing issues to a third party in an attempt at disassociating one's self from the issue. | "I can make the meeting but Colin's guys are strapped for time," said Ralph.<br><br>In a later response, Colin said, "No we can make it, no problems at all." |
| Eye-Balling | Using "one to one" meetings between themselves and individuals from different social worlds. This approach is a way of personalising the communication and reducing the influence of social world traits. | "I went to see each of them face to face," said Daniel. "That way you can get a personal commitment and avoid most of the issues between the different groups." |

| | | |
|---|---|---|
| Neutrality | Using "neutral ground" as a physical meeting point for social world interaction. This approach can be used to ensure that no social world has an advantage. | "Going off-site is a good idea," said Steve. "There are no distractions and it provides a neutral territory for everyone to meet." |
| Trust | Personal relationships and trust used as a tool to enable social world interfacing. | "The 'get to know you time' is a problem," said Steve. "Coz, until they trust you you can't get through all the usual barriers." |
| Observation | Observation of others in an attempt to gain greater understanding. | "One of the things you need to find out is how they think," said Steve. "To do this you really have to carefully watch what they do and say." |
| Threat | Threats and sanctions as a tool to motivate action between social worlds. | "If you don't do something during the next shutdown," said Richard. "I'm gonna start telling everyone you guys are f…ing hopeless." |
| Make-Believe | Creation of fictitious or unattainable expectations to temporarily satisfy another social world. | "The plan is ambitious to the point of foolishness," said Colin. "But so long as they don't actually try any of it no harm is done." |
| Sign-Off | Using the sign-off as a point at which responsibility is passed from one social world to another. | "Once they signed off on it," said Ralph. "It was no longer our problem." |

Entries in this table provide a basis upon which to explain repeatedly observed activities amongst the social worlds within the 5MTPA Project. Such explanations, as demonstrated through the vignettes, can be linked to the ideologies of the relevant social worlds and in some cases their secondary political agendas. The following section redirects my exploration of routines from social worlds to individuals.

## Individual Interface Routines

In the previous section, I examined the actions of individuals as representatives of social worlds. However, in a micro-organisational context, such as my research, a major problem is in determining to what extent an individual's actions are representative of his/her social world as opposed to their personal proclivities (Clarke 1991, p.132). In this section I shift my focus to individual action as a result of personal preference in order to clarify how I identified such distinctions.

As with the social worlds, when individuals enter an arena they follow certain standard patterns of action, or routines. When identifying social world interface routines, I paid attention to repetition of similar behaviours amongst members of the same social world where their identifiable actions seemed to reflect the social world traits. On the other hand, in terms of individual representation, I paid attention to the more personalised interactions where social worlds and their associated traits seemed of secondary concern. The following vignette provides an example of an individual interface routine utilised by Daniel Grace, the 5MTPA Project manager, for dealing with his subordinates[10].

[10] In this case, Daniel's subordinates are the sub project managers, engineering coordinators, engineers, etc. on the 5MTPA Project, See Chapter (6) Figure 6.4 for a comprehensive list of names and positions.

***Vignette – I don't like bad news, so nobody tells me any***

I was meeting with Daniel Grace for one of our regular update sessions. Today we were discussing, amongst other things, some of Daniel's personal approaches to interaction with his subordinates.

At one point, Daniel leaned back in his chair, looked at the ceiling, and began to laugh.

"Well my problem is I don't like bad news. So nobody tells me any," said Daniel.

Daniel leaned forward in his chair and looked a little more serious. Then he began explaining his previous statement.

"You see," said Daniel. "As the project manager, I am ultimately responsible for budgets and delivery schedules. So when one of the guys comes to me to report some slippage in one of these, I tend to beat them up."

Daniel began smiling again and continued his explanation.

"Because I beat them up when they bring me bad news, they try to avoid bringing me any. Unfortunately, that sometimes results in an 'oh shit' experience. You know, when they do finally come to see me, it's for a really major problem. I think their rationale is that they would prefer to get beaten up just the once. So they save it for the end and just get one big beat up instead of lots of little ones along the way."

In this vignette, Daniel displays an individual interface routine that I have termed *fear*. That is, he uses threats to modify the behaviour of his subordinates in certain individual interactions. Unlike the social worlds analysis, for which I have lists of identified traits, it is not possible, without further detailed observation and analysis, to postulate about which of Daniel's personal proclivities are influencing his use of the particular routine. What I can say is that Daniel's 'fear' routine does not seem characteristic of the engineering social world to which he belongs.

In another example of individual interface routines, Randall Baird and Leo Tims, both WTP operators, are discussing the issue of temperature display on the new operator interface.

***Vignette – That's a good way to do it***

First Leo, then Randall and I, stepped through the old door at the back of the brightly-lit WTP control room. Almost instantly, we were transported into a cluttered old chemical laboratory. The dirty glass cabinets lining the walls held remnants of the room's past life - beakers, pipette tubes, funnels, and perished rubber tubes. There were no chairs, no desks, and the windows were covered with yellowed newsprint. The dirt and dust seemed to be the only remaining permanent occupants of the room.

Leo explained to me that the laboratory was once part of how they controlled the water quality. It was redundant now. Automated sampling systems and monitoring probes could do the work of this laboratory without human intervention.

Leo and Randall led me to a bench on the far side of the room. Leo pulled back a grey translucent sheet of plastic revealing a new shiny visual display unit and keyboard.

"This," announced Leo, "is the development monitor! The engineers installed it as part of the project. It's hooked in to the PLC and has access to live system data. They use it to build the screens and test the software and stuff. But we have a key to the room, too. So we having been coming in and playing around looking at the new system."

Leo and Randall continued playing with the system as I watched. They were discussing the different ways certain displays should be presented.

"What about the differential pressure and flow display?" Asked Leo.

"It shouldn't be a number," replied Randall. "I reckon it should be a bar graph on the screen."

"That's OK, Randall," said Leo. "Yep, it's a good way to do it. [Pause] But be aware that if you do it that way you're gonna have other problems. Think about why we are here; think about what we both really want to use it for."

Leo proceeded to provide Randall with a list of all the probable repercussions that he could envisage occurring if Randall's proposal were accepted.

"I mean I can live with all those problems if you think it's worthwhile," said Leo.

"Nah, maybe you're right," replied Randall. "We should do it your way."

In this vignette, Leo demonstrates a number of what seem to be commonly used internal interface routines. When it becomes apparent to Leo that Randall and he have a difference of opinion, he employs the individual interface routine that I have termed *soothing*. That is, he reassures Randall that his position, with respect to the issue at the centre of the arena, is worthwhile, "That's OK Randall, yep, it's a good way to do it", before proceeding to present his counter argument, "but be aware that if you do it that way you're gonna have other problems". The second tactic that Leo seems to use is that of *common interest.* In this case, Leo draws Randall's attention back to "what we both really want to use it for" as the common ground. By the end of the vignette, the issue is resolved and the fugacious arena dissolves.

Table 7.3 provides a list, though by no means a comprehensive one, of observed individual interface tactics commonly used within arenas. These tactics may be apparent, even to a casual observer. They are, however, worth highlighting as they form part of my account of the design activities in 5MTPA Project. That is, any number of routines constitute a daily pattern of behaviour. The particular routines list seemed to have significant influence on the process of design, on establishing design boundaries, and setting the sub component trajectories.

| Table 7.3 Observed Individual Interface Routines | | |
|---|---|---|
| **Name** | **Description** | **Example** |
| Fear | Using fear as a way of influencing in individual interfaces | "Because I beat them up when they bring me bad news, they try to avoid bringing me any," said Daniel |
| Soothing | Using a variety of methods to diffuse confrontational situations within arenas. | "That's OK Randall," said Leo. "Yep, it's a good way to do it. [Pause] But..." |
| Common Interest | Common interests used as a foundation upon which to base arena discussions. | "Think about why we are here, think about what we both really want to use it for," said Leo. |
| Object Definition | Provision of definitions of new objects that others in the arena may not have previously encountered. | "Look Geoff, I have this guy in my office from the uni," said Daniel. "He is doing research on operator interfaces and is interested in the BOS and WTP Projects." |
| Official Sanction | Status used as a means of providing official sanctioning of positions on arena issues. | "He has my full support," said Daniel. "It would be great if you could assist him..." |
| Constraint Removal | Removal of previously established constraints in an attempt to facilitate the interface process. | "But if it costs you money, let me know and we will work something out to make sure you're not disadvantaged in any way," said Daniel. |
| Data Support | Quantitative data used as a support for interface activities. | "2000 US firms were surveyed," said Daniel. "And of those 2000 60% had failures because of this." |
| Avoidance | Avoidance of interface topics that have the potential to produce an arena. | "Because I beat them up when they bring me bad news they try to avoid bringing me any," said Daniel. |

| | | |
|---|---|---|
| Language | Using various styles of language based on the nature of the recipient as a method of facilitating individual interfaces. | "Ya gottada understanda why for we putta ita dare," said Kevin, imitating the uneducated way he felt operators spoke. Then looking at me and gesturing, he said clearly. "Come over Ross, I'm not busy. I'm just discussing the desk with the operators." |
| Open and Honest | Reputedly open and honest communication used as a means of facilitating individual interfaces. | "I used the open and honest approach," said Colin, "I laid all my cards on the table." |

In this section, I have introduced the notion that the activities within arenas do not proceed randomly. I observed what appeared to be variations on predetermined patterns of actions, or what I refer to as routines. In examining the patterns of action I have used the analytic concepts of social world interfaces and individual interfaces with which to tabulate the various identified routines. A combination of the social world and individual routines unfold when individuals come together within an arena. The arena provides the context within which such routines influence the process of design.

### 7.4 Summary

Arenas represent a place where we can see how forces contend and the events of design unfold. Arenas are also the microscope through which we gain a clearer view of how social worlds, and their members, influence the trajectory of a technology. Design issues such as the mass of material a hopper will hold, whether the operators will have access to a keyboard lock, and how many monitors the control desk will have each had their arenas. When the arenas that form around these specific design issues are examined in detail, the influences of particular social world traits, routines, and hidden agendas become visible. In this sense, arenas are at the heart of my account of the process of design.

Events that occur within arenas do not unfold at random. Rather, the actors involved appear to follow predetermined strategies and employ standard patterns of action. These patterns of action, here called routines, provide an analytic framework through which it is possible to dissect and explain elements of the process of design. In this chapter, I have distinguished between routines based on social world traits and those based on personal proclivities. In the next chapter, I describe a category of routines related to the negotiation of design boundaries based on social world traits, which I characterise as 'rules of engagement'.

# Chapter (8) – Rules of Engagement

## 8.1 Introduction

*Rules of engagement* characterise certain kinds of routines enacted in arenas during the process of negotiation amongst the relevant social worlds. As noted in the previous chapter, routines are standard patterns of action that allow actors to face new situations by employing variations on existing and recognised patterns of action rather than inventing new ones each time. Routines in general were observed to be employed throughout the process of design, from the mundane task of ordering lunches from the plant canteens, through to the complex interactions of industrial disputation. This Chapter focuses on a subset of routines that actors use to order exchanges over design boundary issues contested amongst relevant social worlds. These routines are of interest because of their particularly strong influence on the process of design, and hence the final form of the technology. In these cases, the routines act in a strategic sense as 'rules of engagement' among individuals and social worlds. Understanding how these rules of engagement develop, evolve, and are responded to by participants, provides a key insight into how the actors in the 5MTPA Project go about the process of design.

This chapter draws on the previously developed concepts of social worlds, social world traits, trajectories, design boundaries, and arenas to provide an empirical explanation of the origins and functions of these pivotal rules of engagement. I have identified and labelled four processes that impact on the sustainability of rules of engagement within a dynamic organisational environment – *minority challenges, majority challenges, failure* *of routines,* and *loss of relevance.* Each of these processes indirectly influences the trajectory of a technology by changing the ways in which the various social worlds engage with one another in their negotiations and battles over design boundaries.

During the process of design, individuals within relevant social worlds may react differently to the various routines encountered. Three types of responses observed were to adopt the role of *rogue, questioner,* or *believer*. This categorisation of responses represents a social ordering process that the participants themselves used, in one form or another, when selecting amongst possible courses of action in response to the behaviour of others. The categorisation also provides a basis upon which an external observer, such as myself, can attempt to distinguish between collective action and individual action.

This chapter then addresses key negotiations of design boundaries by looking at special categories of routines at two levels – collective rules of engagement and individual roles as rogue, questioner, or believer.

## 8.2 Origins and Functions of Routines

The routines discussed above do not just 'appear'; rather they evolve under the influence of the milieu of social world identities, social world traits[1], previous routines[2], and past experiences. This view is supported by Strauss's (1993, p.195) argument that

[1] A *trait* is an observable representation of the ideologies of a social world. See Chapter (6) for a more detailed discussion.

[2] Later in this chapter I explore previous routines in more detail, and examine the modifications to routines by both, minority and majority challenges.

routines are based on the 'preferences of collectives' or on their 'responses to problems'. The chief function, or consequence, of routines is their 'contribution to efficiency and/or efficacy' (Strauss 1993, p196) of certain activities from the perspective of the supporting social worlds.

Figure 8.1 diagrammatically presents my conceptual representation of routine action (shown in bold) amongst social worlds within the 5MTPA Project.

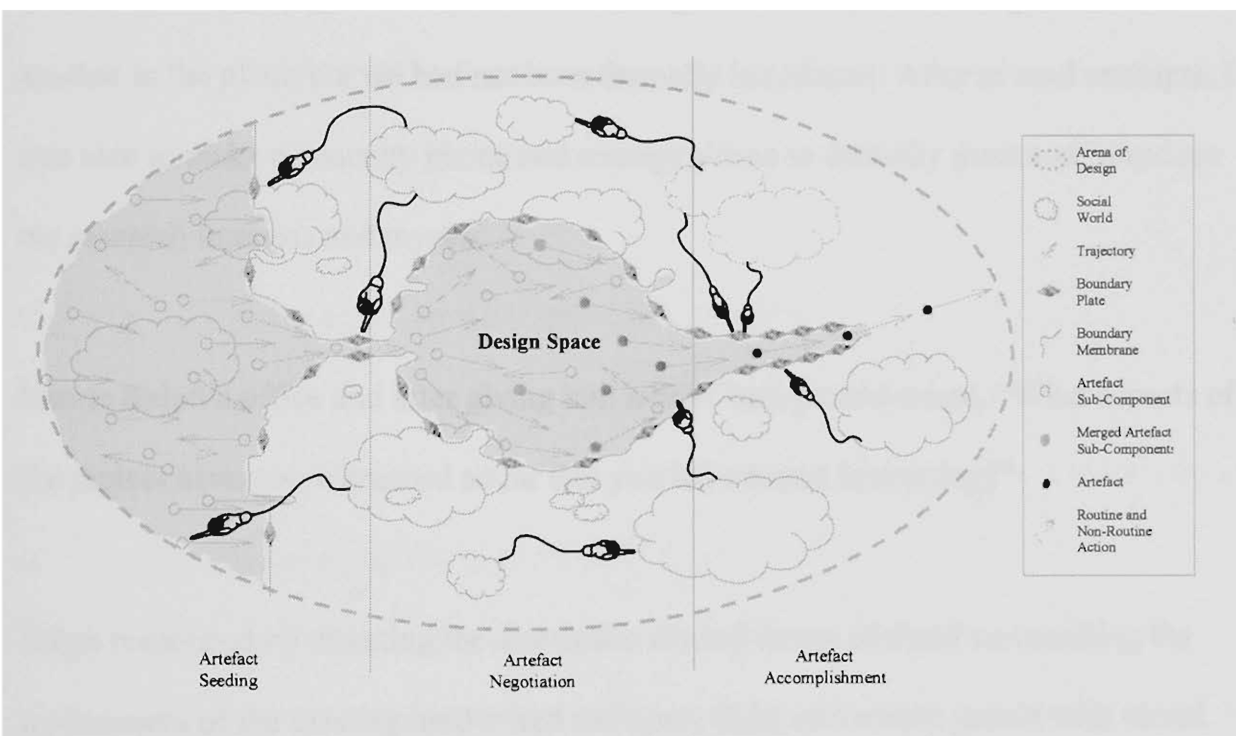


**Figure 8.1 - Routine Action in the 5MTPA Project**

The routines depicted in the diagram above represent prescribed guidelines for conduct amongst social worlds. These guidelines inform social worlds about how they should commence certain joint actions within the process of design. The following vignette demonstrates the use of a particular routine in the process of design. In this case, I have termed the routine *centrality*[3] and defined it as the nomination of an individual as the primary path for information transfer between social worlds. In the example presented, Ralph Cowie, the WTP Project operations representative, discusses his role in the application of the centrality routine to the WTP Project.

***Vignette – You see, I'm the conduit for information flow***

I had seen Ralph Cowie at a number of meetings. We smiled when we passed one another in the plant, but we had not been formally introduced. After several attempts, I was able to make contact by phone and arrange a time to formally meet and introduce my research interests and myself.

I sat in Ralph's office and after giving him a brief background asked, "What aspects of the project have you witnessed so far that you have found interesting?"

Ralph responded by directing the discussion toward issues of detail surrounding the replacement of the existing hard-wired switches, dials, and mimic panels with visual displays, dials, and new desks.

"It's difficult to satisfy all the operators," said Ralph. "I have to make sure we get feedback from the operators to the engineers. You know, I have to try to get what the operators like accommodated within the what engineers want from the new system."

[3] See Chapter (7), Table 7.2, for a more detailed definition of *centrality*.

"You see," continued Ralph. "I'm the conduit for information flow between the engineers and the operators. The engineers try to convey information from their perspective and that won't be the same as the way the operators see it. So I'm in the middle smoothing the flow between the two."

In this vignette, Ralph is discussing the practicalities of being the individual nominated as the primary path for information transfer between the engineers and the WTP operators. The centrality routine has evolved over time based on problems encountered previously and social world preferences. The following vignette further explains and highlights the multiplicity of the origins of the centrality routine.

***Vignette – It's a technique we developed over the years***

Ralph Hopkins, the BOS Project manager, was explaining to me some of the techniques he was using for managing the BOS Project.

"You see, Ross, we nominated Kevin Robinson as the only operator that we would deal with," said Ralph. "Using a single operator allows us to control the flow of information between engineers and operators. It's a technique we've developed over the years. The previous method was for engineers to converse directly with the operators. But this became unmanageable. The engineers didn't know which operator to believe. We now stipulate that operations provide one person, and only one person, to be their link. It's then that person's responsibility to make sure that their requirements are incorporated in engineering's design."

This vignette indicates that the origins of the centrality routine were based on a combination of previously encountered problems and social world traits. Ralph mentioned that in the past the engineers communicated on a broad basis with the front-line operations personnel. This resulted in, amongst other things, confusion over which specific front line personnel represented the common operational view. This confusion seems to have caused the previous technique for interacting with operators to become 'unmanageable'. In response to this problem of unmanageability, Ralph states that they developed a new technique where they requested that operations 'stipulate one person, and one person only' to be the link between the engineering and operations social worlds. In this sense, the new technique, or in my terms, routine, was developed in response to the identification of a problem.

Although the 'unmanageability' problem may have been the impetus for the new routine, the subsequent development seems to be strongly influenced by the traits of the engineers[4]. In this case, there are three specific engineer traits that seem to be influential. The first trait, *people mess,* is the apparent avoidance by engineers of messy issues to do with people. By introducing the single point of contact routine, the engineers are able to alleviate much of the people mess that was present with the previous multi-point of contact routine. The second trait, *risk aversion,* is the apparent avoidance by engineers of risk, which if realised, could result in blame being attributed to them. In the multi-point routine, the majority of the risk was being borne by the engineers. The engineers were responsible for extracting and condensing the views of multiple operations personnel into the final design. In the new routine, this responsibility is passed to the operations individual nominated as their representative.

[4] See Chapter (6), Table 6.3, for a list of identified traits for the engineer social world.

Subsequently the engineers can be understood to be reducing their exposure to risk in this area. The third trait, *wasted time*, is the apparent avoidance by engineers of expending energy on issues that they deem as 'not useful'. In this case, it seems that the usefulness of the final artefact to the operations personnel may be reduced as a result of the adoption of the new routine. They may be missing a range of insights from operators, whose input is now filtered through a single contact (this aspect will be discussed in the ensuing paragraph). However, it appears that expending effort on producing a further new routine to address this issue has apparently been deemed 'not useful' by the engineers.

One of the consequences with the previously discussed *centrality* routine has been an apparent increase in the efficiency of information transfer between the engineers and the operators. However, I would argue that there has also been an accompanying decrease in the efficacy from the perspective of the operators. In order to explain this more, I will draw on a portion of a vignette, first introduced in Chapter 4, which describes a scene from the artefact accomplishment phase of the trajectory of the BOS Project.

***Vignette – We don't intend to do anything***

I had organised through Steve DeRosa, the BOS Project coordinator, to attend some of the Flux interface training sessions. The day after my training, I bumped into Steve in the design office.

"So how did your training day go?" Steve asked.

"Oh it was great," I replied. "The prawns for lunch were a nice touch."

"Yeah, we made sure we fed the guys well to try to encourage them to go to the training," said Steve.

"Actually, one thing I wanted to ask," I said. "How are you dealing with all these last minute faults the guys are identifying during the training?"

"We don't intend to do anything," Steve replied. "They reviewed and signed off on the design as it is. Any changes they want from now on they will have to pay for themselves once we've finished."

In this vignette, the "they" that Steve refers to as "signing off" on the design is Kevin Robinson, the nominated individual through which all information was to be transferred from the engineers to the operators. The use of the centrality routine in this situation seems to have increased the efficiency of interaction, at least for the engineers. However, judging from the high levels of seemingly significant system inadequacies reported during the training sessions, the efficacy from the perspective of the operators, who are the end users, may have declined.

The routines examined above, such as the engineers process of operator consultation through centrality, represent standard patterns of action that are negotiated amongst individuals and social worlds in response to problems or repeated design tasks. The negotiations are, in turn, influenced by the relevant social world traits, as we saw, for example, people mess, risk aversion, and wasted time. Once established, these routines alleviate the need to develop totally new patterns of action for each new situation or repeated undertaking. Having said this, established routines do not persist unfettered. The following section examines some of the challenges faced by established routines in an organisational environment.

## *8.3 Disruption to Routines*

In a dynamic organisational environment, routines face many challenges to their sustainability. Four challenges that I would like to discuss in this section are - *challenges to routines by a minority, challenges to routines by a majority, failure of routines*, and *loss of relevance of routines*. This is not a comprehensive list of rules for changing routines. It contains my observations of some of the factors in the 5MTPA Project that led to changes in routines. These factors are important because they indirectly influence the final form of a technology by changing the ways in which the various social worlds engage with one another during the negotiation of design boundaries.

### Challenges to Routines by a Minority

*Challenges to routines by a minority* represent proposed modifications to routines that emanate from only a small number of the relevant actors. As mentioned in the previous section, the development of routines is strongly influenced by the relevant social worlds and their ideological perspectives. Following on from this, it should come as no surprise that challenges to established routines, inculcated with the ideology of a social world, may result in 'annoyance, anger, indignation, or other signs of passion' from members of the affected social worlds (Strauss 1993, p.197).

These minority-based challenges, and the sometimes impassioned responses they generate, are the bases for an arena to form around a routine. Further to this, it seems that when a minority challenges a routine, the resolution of the issue, and the accompanying dissolution of the arena, may only be temporary. It appears that the fragile nature of these resolutions stems from residual misalignments between the modified routine and the existing ideologies, which cause tensions to persist. The latency of these misalignments may remain until triggered by some future occurrence.

In the following vignette, Leo Tims, a WTP operator, challenges an established routine for interaction between the engineers and the WTP operators. The routine being challenged is with respect to the compliant nature of the WTP operators during interactions with engineers. According to one engineer, "they're pretty happy with whatever we give them."[5]

***Vignette – If you don't, I'll call in the unions***

Colin More, the WTP Project manager, arranged a meeting for the operators, operations management, maintenance, and himself. The meeting was held in the WTP control room and was designed to update everyone on the status of the project with respect to the up-coming plant stop.

[5] The existence of this routine was discussed previously in Chapter (7) in the vignette - '*The way they do things is by teasing the engineers*'.

Colin started the meeting and said, "We've decided not to change the desk during the next shutdown. We will be doing some hard wiring, connecting some cables, but no control changes will occur at all during the shutdown. All the wiring we install will be bridged out and left in an inoperative state."

Everyone, except Leo Tims, listened quietly and seemed satisfied with Colin's explanation.

"This just ain't good enough Colin!" exclaimed Leo. "I want to see some kind of documented implementation plan! Not this verbal update stuff!"

The group seemed uncomfortable about what to do with Leo's outburst. Ralph Cowie, the operations supervisor, stood quietly in the corner. Two operators, Randall and Brett, sat down behind the control desk. The maintenance guys, Ray and Victor, moved to the back of the room.

Colin seemed shocked. He was looking around the room and appeared unsure of what to say or do. He started shuffling side to side and said, "Ummmm, errrr, well I, errrr."

Leo seized Colin's moment of inaction and continued.

"I want a detailed written program of what you're doing and when you're doing it!" demanded Leo. "If you don't, I'll call in the unions! I'll refuse to operate the equipment! If you change something, and we don't know in advance, then I'll argue that we won't be able to safely operate the plant."

Leo's verbal attack continued and everyone remained silent and motionless. As Leo's tirade drew to a close, Colin was reluctantly nodding agreement to all of Leo's demands.

Three days after the meeting, I spoke to Colin again.

"I was totally unprepared for that meeting," said Colin. "I'm still getting over it now. I was unaware that Leo would attack me. It's not the way we do things, and on top of that, now I have a list of his demands to fulfil."

In the previous vignette, Leo aggressively challenges an established routine of *compliance*. The engineers expect the WTP operators to be happy with whatever they give them. The reactions of the other individuals present during the challenge seem to indicate that the routine was deeply ingrained and, as a result, they were unsure about how to react to such a radical challenge. More specifically, Colin was speechless, Leo's supervisor cringed in the corner, the other operators appeared to hide behind the control desk, and the maintenance guys moved to the back of the room.

Part of Leo's success in making a seemingly instant modification to the existing routine appears to be drawn from his use of other established routines. In this case, Leo invokes an industrial relations routine and threatens to "call in the unions". This routine involves union delegates and company representatives negotiating the specific contentious issues under threat of work stoppages. Colin responds to this impetus and seems to attempt to modify his pattern of action. In doing so, Colin agrees in principle to Leo's demands to provide more documented material and involve the operators in more of the decisions. In this case, it seems that Leo may have been successful, at least temporarily, in making a change to the standard pattern of action between the engineers and the WTP operators.

The following vignette comes from a meeting held two weeks after Leo's outburst and recounts Colin's subsequent introduction of one of Leo's demands to a number of other engineers involved in the WTP Project. The specific demand involves operators being given the same clearance levels for controlling the plant as that of the maintenance personnel.

***Vignette – You're kidding right?***

A group of fourteen engineers involved in the WTP Project sat around the rectangular tables in the conference room. The design review meeting had been going for almost an hour. Colin More, the meeting chairman, was methodically tabling the agenda items in sequence. Each item would draw the comments of only one or two individuals while the remaining attendees seemed to focus elsewhere. When Colin reached agenda item eighteen, this pattern changed.

"Ok, item eighteen, plant interlocks," said Colin. "The operators have requested we give them similar control access to that of maintenance mode."

The entire group's attention was now focussed on Colin and a seemingly disgruntled murmur rippled around the group.

"You're kidding right?" exclaimed Bill Woods. "No way! No way can we give operators access to maintenance mode. They'll just f...k it up."

The other engineers were nodding in agreement.

Traditionally, the engineers had designed the plant control systems with plant interlocks to stop operators creating situations that were potentially detrimental to the process or the product. However, process disturbances often occurred, and this required the plant to be operated in "maintenance mode". This was a plant mode that overrode all but the most important safety interlocks, placing the responsibility on the person at the controls to make choices that were safe.

The debate continued for fifteen minutes. Every person in the room was actively engaged in exploring the concept of placing more trust in the operator's understanding of the plant and decisions.

Finally, Colin interjected, "So we can't reach a resolution on this yet? Let's list it for further discussion next review and move on, hey."[6]

The group agreed, and as Colin introduced item nineteen, a pattern resumed where only one or two individuals seemed to pay attention to each issue.

In this vignette, Colin introduces a request from the operators (more specifically Leo Tims) that seems to challenge an established routine. In this case, the routine is with

[6] The issue was eventually resolved at the subsequent design review meeting where agreement was reached to allow the operators a limited increase in autonomy over the technical control systems.

respect to the level of control that should be available to the operators[7]. The specific problems that gave rise to this routine seem to be lost, at least to me, in the history of the organisation. However, the following quote from Leo Tims provides a possible indication of its source.

> "The supervisors used to make all the decisions, but that was back when you had dumb operators."

At some stage in the past, operators were perhaps poorly trained in the more detailed technical and operational aspects of the WTP and as such were less successful or seen as less able to make some of the more complex decisions regarding its operation. This routine appears to have been supported and developed in alignment with the engineer social world trait[8] *automation*. This trait refers to the engineer's desire to attain higher and higher levels of automation. Accompanying this desire is the expressed belief that the greater the mechanical and electrical control is over the system, the less the system will be subject to variation due to operator input.

In contrast to the previous vignette - *If you don't, I'll call in the unions,* all of the individuals present in the room for the discussion of plant interlocks actively engaged in the debate about the modification of the routine. In this case, an arena has formed around the contentious issue. One of the things that set this arena apart from the other

[7] The WTP operators have been engaged in an ongoing struggle to gain greater levels of control and responsibility. Their desire for this has been listed as a trait of WTP operator social world in Chapter (6) Table 6.3. The trait has been identified as a potential hidden agenda behind several interchanges between the WTP operators and the engineers examined in previous chapters. In this case, the WTP operators desires have been openly expressed and openly challenge the routine rather than being couched in secondary issues.

[8] See Chapter (6), Table 6.3 – Engineer Social World Traits, for more detailed explanation and a list of other identified traits.

emergent arenas within this particular meeting is the level of involvement. During the two-hour meeting, this was the only arena that had spoken contributions and seemingly attentive listening from all the attendees in the same discussion at the same time. One of the reasons for such interest seems to be that at the centre of the arena was a social world trait, not what one or another party might have seen as a banal design issue. The importance of traits, such as the engineers value for automation, are that they reflect the members' shared ideologies and commitments. A challenge to such commitment is likely to evoke impassioned responses. A second potential reason for the interest is that this particular routine empowers the engineers to define, almost without question, the situation for the operators. The WTP operators request for greater 'control access' not only gives them greater control over the plant, but also greater control over the process of design through the engineers acknowledgment of their relevance to design boundary negotiations.

Knowledge of the origins and support for the routine help to provide an account of why the engineers may have reacted as strongly as they did, using phrases like; "You're kidding right?" "No way!" and "They'll just f...k it up."

Leo's challenge to the engineer's routine represents an example of a minority challenge as it emanates from small numbers of individuals from one or more of the social worlds relevant to the routine. The responses to these challenges by the majority are often imbued with passion because the challenge not only questions the routine but also the ideologies underlying the routine. Whilst not always successful in directly changing routines, challenges by a minority may serve as the impetus for enlisting the future support of others and an eventual challenge to a routine by a majority.

## Challenges to Routines by a Majority

*Challenges to routines by a majority* represent proposed modifications to a routine that emanate from a large number of the relevant actors. The supporters of the challenge may be from within a single world or be drawn from several. The important factor is the achievement of a critical mass of support. Because of this majority support, the modifications may not result in the same level of expressed annoyance, anger, and indignation as the more openly contentious *challenges by a minority*. Nonetheless, some of the relevant actors or social worlds are likely to disagree with the proposed changes. In these cases, sometimes the contentious debates remain dormant until favourable circumstances, such as a perceived failure in the modified routine, trigger their release.

In the following vignette, Ralph Hopkins, the LK Project manager, discusses an attempt to change one of the routines for interaction and accountability between BHP and Contractors within a project.

### *Vignette – The project structure will be very different to normal*

I was sitting in Ralph Hopkins's office discussing the possibilities of researching a third 5MTPA project, the Lime Kiln. Ralph spent about forty-five minutes providing me with a technical background and content for the project.

"The new control system we are installing will result in a total replacement of the mimic panel with a panel view computer screen," said Ralph. "The hardware that sits behind the computer screen is such that if we want to in the future, we could actually get rid of the Lime Kiln operators by linking it to the BOS control room and do everything from there."

After discussing the project's technical details, Ralph moved to what he called some of the "softer issues".

"The project structure will be very different to normal engineering projects," said Ralph. "We are going to use an integrated team approach. So instead of the contractors having a hierarchical management structure for the project that is mimicked by BHP, we are going to have just one group. There will be no BHP supervisors, coordinators, or detailed contract spec's. We will operate together as one group based on trust and shared goals for the final performance of the system. And so far, so good."

Ralph's comment of "so far, so good" seemed to represent some reservations, or doubts, on his part. So I asked him, "What do you mean 'so far, so good'."

"Well I think the principle is fine," replied Ralph. "I believe in the approach. [pause] But, I have some concerns that people in BHP might harpoon the project. I mean because it's different to normal, if things go wrong in the project, there will be a witch-hunt. The reputation of the contracting firm, and the BHP engineers involved in the project, will be severely tarnished if this thing goes off the rails. There are people in BHP that would take pleasure in harpooning anyone involved."

This vignette provides an example of what I consider to be a collaborative, majority effort toward changing a routine. According to Ralph Hopkins, and my own observations, the current routine involves both the engineers and the contractors having a mirrored hierarchical management structure. This approach seems to be in response to mutual distrust, with both groups essentially carrying out the same functions whilst crosschecking on one another. For example, an engineering supervisor may stand beside a contracting supervisor to ensure a particular job starts at the designated time and with the designated number of workers.

The planned, and majority supported, challenge to this routine is for the engineers and contractors to 'operate as one group based on trust and shared goals'. They intend to form a single 'integrated team' and in doing so attempt to increase their efficiency by decreasing resources wasted in duplication of supervision and documentation. This challenge seems to reflect an apparent shift in the importance the engineer social world has placed on its trait of *risk aversion* toward those of *wasted time* and *efficiency*[9]. In previous projects, where risk aversion was the dominant trait, the engineers deemed it acceptable to duplicate management systems, such as supervision and documentation, between themselves and contractors. The added expense of such duplication was, in the eyes of the engineer, outweighed by the sense of protection afforded them by mirrored control systems that continually crosschecked one another. However, with the organisation's added importance on cost control, the engineers have shifted their focus to their traits of wasted time and efficiency, and, in doing so, developed an integrated team where contractor/engineer duplication is removed.

[9] See Chapter (6), Table 6.3 – Engineer Social World Traits, for a more detailed discussion of these traits.

Although the majority of relevant actors in the LK Project seem to support this challenge, the arena is not without controversy. It appears that there may exist a residual misalignment for certain individuals. Ralph is concerned about this misalignment and expresses the belief that should problems with the project arise, they may trigger these latent misalignments with 'some people in BHP' trying to 'harpoon the project' and start a 'witch-hunt'.

As this example illustrates, what I have labelled as majority challenges to routines emanate from large numbers of individuals from one or more social worlds relevant to the routine. In the example, both the engineers and the contractors were cooperating in their efforts to change the routine. Although these challenges are frequently successful in bringing about change to routines, in doing so participants may ostracise certain individuals who strongly support the old routine. These individuals may refrain from a *minority challenge* until favourable circumstances, such as a perceived failure of the routine, are presented.

## Failure of Routines

The chief function of routines, when viewed from the perspective of their supporters, is to contribute to the 'efficiency and/or efficacy' of certain practices or activities (Strauss 1993, p196). Having said this, routines are not likely to achieve this outcome for all relevant individuals and social worlds in all situations. The perceived failure of routines by some of the relevant actors and social worlds can motivate a significant challenge to the sustainability of the routine.

The following vignette provides an example from the BOS Project where a routine failed to achieve some of its intended outcomes (Part 1). Part 2 reveals the subsequent repercussions to the sustainability of the routine.

***Vignette – Part 1: These things are pretty hard to write***

On Wednesday the 26th of August 1998, I was sitting opposite Ralph Hopkins, the BOS Project manager, in his office. We were discussing several options regarding which projects might best fit with my research criteria.

"I reckon you should look at the BOS Flux PLC replacement," said Ralph. "It's a good project for your needs, they have a signed off CRS, and the tenders are under review. So the timing is great. Steve DeRosa is the project coordinator. I'll take you around to his office and introduce you to him. I'll also give you a list of other names that you need to negotiate access with."

I had never heard the term 'CRS' before and not wanting to sound too naive was reluctant to ask Ralph what it was. When the interview was over, I went and searched through the company Intranet for a definition. My search revealed that CRS was an acronym for "Customer Requirement Specification". Accompanying this explanation was a reference to a procedure on how to prepare and manage such a document. I printed the procedure and sat at my desk reading the detailed seven pages of explanatory text and flow diagrams. Section 1 of the CRS procedure stated,

> "A CRS is used to unambiguously define both the customer's requirements and ensure all safety, health, risk, and environment aspects are considered in the design."

A few days after reading the CRS procedure, I approached Steve DeRosa for a copy of the actual BOS Project CRS. He said he was happy to comply and proceeded to print me off a copy of the document from his computer.

While we waited, Steve said, "These things are pretty hard to write. You don't really know what you want up front and you can waste a lot of time. You know it's much easier to work out the details as you go. So we just do the CRS as best we can."

I thanked Steve and went to the central office printer to pick up the BOS Project CRS. When I arrived at the printer, page thirty-one had just been ejected and it was still churning out more. Finally, with ninety-seven pages in my hand, I returned to my desk and started to read. I found the CRS difficult reading; it was full of extremely technical jargon and acronyms. Struggling through the third page, I read,

> "The DS8 is an 8-bit Intel 8080 microprocessor and shall;
>
> - Interface to the respective control room desk via an 8 bit multiplexed bus (MB8).
> - Perform weighing calculations and flags using ASEA "ASWEP" weighing software package.

- Communicate with the BOS computer via a RS232 ADLP10 protocol link for logging of fluxes weighed out and dumped and computer setting of demanded weights in computer mode."

I was puzzled as to how such a complex document could "unambiguously define the customers requirements" especially if the customers were unable to comprehend its contents. I decided to return to Steve's office and ask him what he thought about the issue.

Steve replied, "Yeah, it is a very lengthy document. But operations signed off on it, so it has been taken as approved. [pause] This is actually a bit of a problem. It is a detailed document and in amongst that is information that the operations guys are supposed to check. [pause] The operations guys signed off on it without really understanding what they were signing, [pause] but we accepted it anyway because then the responsibility was upon operations because they had signed off on it."

***Vignette – Part 2: It's clearly an operations problem***

On the 23rd of February 1999, six months after my discussions with Steve, a near disaster occurred when the No.3 BOS vessel was blown in. The standard blow-in procedure for a relined vessel is to charge the furnace with coke (a flammable product produced by heating coal in a coke oven). Once coke is in the furnace, it is ignited and the heat generated is used to "cure" the AUD$9M of new refractory brickwork before service can begin.

This blow in was to be different. During the time that the vessel was relined with new refractory brickwork, Steve and Ralph's team had replaced the Flux PLC and control desk. The new desk had a small but significant fault. The bins containing ferro silicone and coke had been switched several years ago, and operations had not updated the documentation. As a consequence, the screen designers used the outdated documentation for the new system labelling. As a result, when the operator selected "coke" on the new computer interface screen, he was actually selecting "ferro silicone". The ferro silicone charge did not ignite, and the new refractory material was unable to cure. The only way to remove the incorrect charge was to invert the furnace and, in the process, risk dislodging and dumping AUD$9M of new refractory on the floor. A decision was made to take the risk and invert the furnace. The refractory held, and the blow-in was completed with hand written 'post-it' notes stuck on the interface screen covering the misleading electronic labels.

Several days after the labelling errors had come to light with the near disaster during blow-in, I arranged an interview with both Steve DeRosa, and his boss, Ralph Hopkins. They both expressed the opinion that it was an operator error that had absolutely nothing to do with the engineers.

> "It's clearly an operations problem," said Ralph. "Kevin [Kevin Robinson, the operations representative] gave us the documentation that we worked from. It was his documentation that was out of date. It's not our problem. It's an operations problem. We clearly identified the labelling in the CRS, and it was programmed from the CRS. Operations read the CRS and signed off on it."

> "It's not our fault," said Steve. "They should have noticed. If I were an operator, I would have noticed something so obvious! They were distracted by all the pretty colours and lights on the new system and were too busy to concentrate on the detail behind the pretty lights."

In the BOS story that I have just recounted, it appears that the complex and detailed CRS routine has failed to contribute to either the efficiency or efficacy for many of the actors involved in the BOS Project[10]. With respect to efficiency, it seems that a characteristic of the CRS - its complexity - may have created more work for those involved in the project rather than less. According to Steve, it is "pretty hard to write" a detailed CRS, which "unambiguously" defines for the customer every aspect of the project, and that it would be easier to "work out the details as you go". Further to this, it seems that the effort required for the intended recipients, the operators, to digest and comprehend the ninety-seven pages of technical jargon is correspondingly burdensome. With respect to efficacy, it seems that from the outcome of the BOS blow-in that the CRS may not provide the intended 'unambiguous' definition of the customer's requirements, or ensure 'all safety, health, risk, and environment aspects are considered in the design'.

In this specific case, the apparent failure of the CRS routine outlined above seems to have had little immediate impact in its sustainability. I would argue that this has occurred because of a hidden efficacy with respect to the engineers. In my earlier

[10] This vignette has been selected as an exemplar of a failed routine because of its suitability for illustration purposes rather than its reflection of normality. The vignette reflects how I perceive routines and their failure *may* operate in the process of design. However, it does not reflect the typical outcome of routines in the 5MTPA Project.

analysis of the ideological perspective of the engineer social world I identified a particular trait - *risk aversion*[11]. That is, the engineers display an aversion to the kind of risk that, if realised, could result in blame being attributed to them. In the BOS case, both Ralph Hopkins and Steve DeRosa are adamant that near disaster during the blow-in was entirely an operations problem. The justification for this seems to be the existence of the very detailed, yet in many ways, ineffective, ninety-seven page CRS document. Following on from this, the hidden efficacy of the routine with respect to protecting the engineers from blame can be offered as one reason the apparent failure has had no immediate impact on its sustainability.

Although the apparent failure of the CRS routine may not have had an immediate impact on its sustainability, it does seem to have triggered a process of internal reflection, for a least one of the members of the engineer social world. The following vignette recounts a conversation that I had with Ralph Hopkins six months after the BOS incident.

***Vignette – I'd like to find a way around that***

Ralph Hopkins was relaxing in his office; the pressure of commissioning the BOS Project had passed. Ralph was reflecting on the project, thinking out loud with me, the interested researcher, taking notes on his meandering thoughts.

"You know, there is a real barrier with language between us and the operators," said Ralph. "I'd like to find a way around that [pause]. Like the CRS for example [pause].

[11] See Chapter (6), Table 6.3 – Engineer Social World Traits, for a more detailed discussion of traits.

We write them in a very technical language. They'd be better written in 'operator speak'. You know, the language they use, maybe with pictures and stories so that the operators can just look at it and understand instead of this deep technical language we use."

At the start of this vignette, Ralph mentions the language differences that he perceives to exist between the engineer and operator social worlds. He then highlights a number of problems with the current CRS routine that stem from this difference. Following this he begins to explore some ways the routine could be modified to increase its efficiency and efficacy. It seems to me, although Ralph does not explicitly say so, that these reflections are a result of the near disaster with the BOS Project. At the time of the disaster, when the need to deflect blame was at its greatest, Ralph fully supported the existing routine. Now that the specific events of the BOS are fading, it seems safe for Ralph to begin to verbalise some possible modifications to the CRS routine.

The success or failure of a routine in terms of efficiency and/or efficacy is dependent on the perspective from which it is measured. Having said this, if a routine is perceived to have failed, by either a minority or majority of the relevant actors, it is likely to be challenged. These challenges may, as discussed in the previous two sections, be the impetus for changes to the routine, and hence changes to the process of design.

### Loss of Relevance of Routines

As noted earlier, routines originate with a specific problem or need and are subsequently developed under the influences of the relevant social worlds and their traits. However, as some of these routines mature, they may lose part of their relevance to the current permutations of the original problem or to the evolving social world traits. It appears that one possible response to this loss of relevance is for the majority of actors and social worlds to agree to change or modify the routine in what can be understood as an attempt to recapture its relevance for the current environment.

A further consequence of the maturing process of routines is a potential loss of the origins of the routine from the organisation's memory. Personnel leave, records are lost, interests wane, and with these changes the origins of a routine may fade. As a result, each generation inherits the sedimented routines without necessarily knowing, and sometimes not caring, about their origins (Strauss 1993, pp.199-200).

The following vignette provides an example of a selection of well-known but evidently poorly understood routines with respect to a part of the WTP. In this case, when the originator of the routines retired, his knowledge of their origins was lost.

***Vignette – It was OK when old Wally was here***

"The sludge plant is a real problem now," said Trevor. "It was OK when old Wally was here; it was his little baby. You know, he knew what to do, when to do it, and most importantly why. But when he left, the place fell apart, no one knows why he did the things he did. It's just a shambles."

Routines emerge from the milieu of social world identities, social world traits, previous routines, and past experiences. In a dynamic organisational environment, many of these influences are in a state of flux, a state that challenges the sustainability of many routines. In this section, I have explored some of the observed challenges to routines and the responses they may generate. In the ensuing section, I build on the concept of challenges to a routine by a minority and develop a typology of individual responses to routines based on personal proclivities.

## 8.4 Individual Responses to Routines

I have referred to routines as representing standard patterns of action that are negotiated amongst the social worlds. In using this analytical approach, I have been implicitly selecting the actions of some individuals as representing the social world and others as representing personal proclivities. As part of explicating this task, I have developed a typology of individual responses to routines. However, before introducing this, I would like to recount Daniel Grace's (5MTPA Project manager) description of different types of individuals in terms of their responses to rules and procedures in the process of design. The vignette demonstrates how the actors seem to use their own response typology as way of accounting for the behaviour of particular individuals.

***Vignette – We yank-em back into the box***

I always looked forward to my meetings with Daniel Grace. He was the manager of the 5MTPA Project and seemed to enjoy the time we spent reflecting on my field observations. Our meetings over the previous eight months had always been fruitful, and today was no exception.

We were discussing the theme of "us and them" or "social worlds"[12] that had been emerging from my field observations and subsequent analysis. Daniel said he was particularly interested in this theme. As a manager, he seemed interested in new ways to understand his subordinates. I postulated, from his musings, that he thought my research insights might provide him with information to better manage, or perhaps better manipulate, his subordinates.

"I am currently interested in the way the engineers and operators use the Customer Requirement Specifications," I said.

"What is it about the CRS's that has your particular interest?" asked Daniel.

"Well, I guess I'm interested in various ways individuals use it in the process of design," I replied. "I have seen them used in quite a few ways that seem to vary from the original intent."

"Some of these guys are rogues you know," said Daniel. "They don't follow the rules. We let the ones we have confidence in run wild to some extent. But the ones we don't trust we rein in."

"How do you know which ones to trust?" I asked.

"Part of the key to having our confidence, or trust, is being in the 'in-group'," replied Daniel. "They need to have a proven track record. But, even the rogues have outer

[12] The concepts that we were discussing were eventually to become the basis of Chapter (6).

limits. They may operate outside the normal boundaries of an engineer. However, they still operate within known outer limits. They can continue to operate in this zone so long as the results are good and they retain our confidence. But, the moment one of those things is gone, we yank em straight back into the box."

This vignette displays Daniel's interpretation of some of the ways in which individuals may not 'follow the rules', or in my terms, the rules of engagement. Daniel identifies three basic types of individuals in this discourse - Firstly, the individual who complies with the routines. Secondly, the individual who rebels against some of the routines but is trusted. Finally, the individual who rebels against some of the routines and is not trusted. Daniel uses his tripartite typology of individual response as a guide for selecting which 'counter-routines' he should use in response. That is, he can let them 'run wild' or 'yank em straight back into the box'.

Although Daniel's account is based on his managerial concerns with individual engineer responses to rules and procedures, it demonstrates how at least one participant in the process of design seems to have developed his own 'personal typology of responses to routines' as a way of ordering social processes and selecting amongst possible courses of action. Following on from this, based on my broader observations, I have observed three types of roles that individuals may adopt in response to routines: the *rogue*, the *questioner*, and the *believer*. As with Daniel's description, these types of individual responses form part of my account of the activities in the process of design and help explain certain courses of action and technological trajectories observed in the 5MTPA Project.

## The Rogue

*Rogues* are individuals who display behaviours that seem to differ significantly to those expected from members of their social world. Part of this difference is that they do not seem to conform, as other members do, to the established routines. That is, they do not always follow the standard patterns of action that other members have developed over time to which they consequently adhere. Another aspect of their behaviour that sets them apart is their apparent indifference, and/or opposition, to some of their social world's accepted traits. That is, they do not always seem to align their personal beliefs about what is important and worthwhile with that of their social world. Having said this, rogues are still assigned membership, by both themselves and by others, to certain social worlds. However, unlike the other members, they cut corners, ignore rules, and generally operate outside the accepted standard patterns of action.

I have bifurcated the notion of a rogue into the subcategories – *likeable rogue* and *wild rogue*. A likeable rogue is an individual who seems to operate outside some of the expected routines, whilst at the same time appearing to satisfy a number of the central social world traits. It seems that social worlds, in certain situations, may actually consider the likeable rogue as an asset. They are seen as individuals who can cut through the red tape and get the job done. However, they are also considered to be a risk as their actions and reactions are perceived to be unpredictable. As a consequence of the combination of usefulness and unpredictability, likeable rogues seem to be considered worthwhile yet irksome individuals.

The following vignette provides an example of what Steve DeRosa, the BOS Project coordinator, seems to consider a likeable rogue. In this case, Steve discusses the actions of Joel Pett, a BOS maintenance technician, in the context of expediting the BOS Project shutdown.

***Vignette – He pisses off lots of people. But the end product is really good***

Steve DeRosa and I were sitting in his office casually discussing recent changes to the timing of the BOS Project. Production concerns about excessive refractory degradation had led to the BOS vessel shutdown program being brought forward. This meant that Steve's project, which could only occur during such a shutdown, had also been brought forward.

"With the shutdown being brought forward, we are pushing things ahead much faster," said Steve.

"How is the project coping with that?" I asked.

"Things are going pretty good," said Steve. "Joel Pett is great to have on the project. He takes all sorts of short cuts. He pisses off lots of people. But the end product is really good. It's just his methods that are very unorthodox, which means I have to clean up all his loose ends once everything is up and running."

In this vignette, Steve refers to the methods used by Joel, to ensure the project is completed on time, as "pissing off lots of people" and being "very unorthodox".

However, he also comments that "the end product is really good". In this respect, it seems that Joel is operating in the BOS Project as a *likeable rogue*. That is, he is ignoring some of the expected routines in order to ensure the project is completed on time, a result valued by both the engineer and operator social worlds.

One of the routines circumvented by Joel, as alluded to by Steve, is with respect to the documentation of the project. Steve states that he will have to "clean up all [Joel's] loose ends once everything is up and running". It seems that one of the ways that Joel is able to deliver so much, in such a limited period of time, is by taking some documentation short cuts. The engineer social world has a trait that values extensive and explicit documentation[13]. This trait manifests itself in routines for project work that require documentation of all project details, from phone calls through to risk analysis. By deviating from this routine, Joel seems to stimulate impassioned responses from others, "pisses off lots of people", and creates further work for Steve. However, in spite of these failings, Steve still supports Joel. This seems to be because the end product, that is delivering the project on time, is more important to Steve than the violation of a routine. In this sense, at least from Steve's perspective, Joel is a likeable rogue.

The second of my rogue subcategories is that of the *wild rogue*. A wild rogue is an individual who openly flouts some of the established routines and a selection of social world traits. As a result, the wild rogue, unlike the likeable rogue, seems to be frequently deemed a liability by the relevant social worlds. This appears to be because neither the end products, nor the methods used to achieve them, align with what the members of the social world consider as important and worthwhile. Following on from

[13] See Chapter (6), Table 6.3 – Engineer Social World Traits, for a more detailed discussion of the documentation trait.

this, wild rogues are placed under greater pressure from those around them to conform to the expected routines and traits.

In the following vignette, Colin More, the WTP Project manager, provides an engineering perspective on an operator that he and other engineers have allocated to the category of wild rogue.

***Vignette – He's a loose cannon, no one knows how he will react***

I was sitting in Colin More's office discussing the WTP project. He was explaining an issue to do with a WTP operator, Leo Tims.

"Leo is a bit of a loose cannon, no one knows how he will react," said Colin.

From my personal observations of Leo, he seems to be a very passionate individual who often expresses his passion through his interactions with others.

"Quite a few people want me to take him on," said Colin. "You know, a major confrontation, over a major issue, and a major win. They want to see his wings clipped. They want him brought back in line with the way everyone else does it."

In this vignette, Colin refers to Leo as a "loose cannon" and states that "no one knows how he will react". This observation is similar to that made by Steve with respect to Joel in the earlier vignette - *He pisses off lots of people. But the end product is really good.* However, unlike Joel, Leo seems to have a number of more powerful detractors lobbying against him. These detractors seem to be dissatisfied with Leo's violation of accepted routines and social world traits and are actively taking steps to force him to conform.

The previous two vignettes depict incidents where individuals were observed behaving contrary to established traits and routines. However, the allocation of rogue status to an individual, by another actor, is contingent upon the actor's perspective. In the first vignette, Steve seemed to allocate Joel to the category of a "likeable rogue". On the other hand, the individuals who were "pissed off" with Joel's actions may have considered him a "wild rogue". Likewise, in the second vignette, although Colin, a member of the engineer social world, seemed to allocate Leo to the category "wild rogue", others from the operator social world may see him as a "likeable rogue". Following on from this, the classification of an individual as a rogue seems to be agreed upon by a social world, or a set of social worlds, by virtue of his or her apparent defiance of salient routines. However, the further sub classification of the rogue into "likeable" or "wild" seems to be contingent upon the alignment of the rogue's actions with the observer's social world.

*Rogues*, both *likeable* and *wild*, are individuals who typically do not follow the routines that might be expected of them by either members of their social world or other social worlds. The following section discusses individuals I refer to as *questioners* who appear to hold a similar disdain for certain routines as do rogues.

## The Questioner

*Questioners* are individuals who seem to privately express doubt about some of the routines or social world traits. However, unlike the rogue, they appear externally to conform to the expected behaviour of members of their social world. That is, questioners seemed to comply with standard patterns of action in public, while expressing opposing points of view in private. The following vignette – in two parts – provides an exemplar of what seems to be a "questioner" displaying inconsistent private and public behaviour.

***Vignette – Part 1: It's not like I'm a cave man …***

Randall Baird and I were alone in the WTP control room. I was leaning on the opposite side of the control desk from where Randall stood controlling the process, explaining to me each step as he went.

Randall leant forward and rested his finger on a red button halfway along the control desk. Then, without pressing the button, he looked at me and said, "You've always got to stop and think about what you're doing. Before I push any button, I visualise what's going to happen in the plant, what will the repercussions of this action be. Only if that all seems OK will I make the decision to push this button."

Randall pushed the button and continued explaining his tasks as an operator.

Later during my observations, Randall had a phone call from another operator in an adjoining plant. Following on from this prompt, I asked Randall who he had to normally communicate with in his job.

"Normally just the process engineers, the machine foreman, and the scarfer operator," replied Randall. "That is unless we've had a problem, then we call the supervisor or the maintenance fitters. But usually they leave us out of the problem-solving loop. It pisses me off a bit, its not like I'm a cave man! I like to fix my own problems. I can think!"

***Vignette – Part 2: I'm just an operator …***

Three months later….

Randall was attending his first WTP design review meeting. He had the official role of the representative for the WTP operators. I was sitting next to Randall; the remaining five engineers were evenly spread around the table. Colin More, the meeting chairman, started the meeting by explaining to Randall the way the meeting worked.

After thirty minutes, discussing the topics listed on the agenda, Colin turned to Randall and said, "Randall, if you get lost, just ask any questions you like."

With his head lowered and a sullen expression on his face, Randall replied, devoid of irony, "There is no real point me asking questions. I'm just an operator. I don't really know anything, and there is no point in me communicating."

In part 1 of this vignette, Randall expresses, in private, his ability to think and his desire to be taken more seriously. This seems to be in conflict with one of the routines depicted in a vignette presented in Chapter (7) – *The way they do things is by teasing the engineers*. In this case, when the engineer social world interacts with the WTP operator social world, they seem to expect the operators to have little or no power to influence the process of design. Further to this, engineers seem to expect a relatively subservient set of individuals who accept what they are given. What makes Randall a questioner in this situation and not a rogue is that at the end of this vignette, he displays in public the behaviour that the engineers attending the meeting might expect from a WTP operator, "I'm just an operator. I don't really know anything…." It seems that although Randall may question this routine in private, in public he is seen to conform.

Having said this, questioners may, under limited circumstances, extend their doubts or dissension into public forums without being labelled as rogues. In the following vignette, Bill Woods, the WTP Project coordinator, and Eric Haines, a WTP Project electrical engineer, both publicly question the 'change control' routine. In this case, Bill uses a formal but indirect approach, while Eric uses humour as a guard for his more direct questions.

***Vignette – What does Dean's signature add?***

Colin More, the WTP project manager, looked up from his notes and glanced around the room. The ten participants were all members of the WTP project team and were gathered together for the fortnightly project update meeting. He seemed to be checking if everyone was there before commencing the meeting. After the room scan, Colin commenced the meeting.

"Ok, lets get started," said Colin. "The first item of business that I would like to discuss is that of 'change controls'."

'Change control' is the term used to refer to a routine designed to ensure that continually evolving plants remain within business objectives and safety margins. The change control routine relies on applicants completing approval forms, having checks carried out, and attaining relevant levels of authorisation before, for example, changing between types of valves, altering control logic, or installing additional equipment.

"Everyone is getting sloppy with their change controls," said Colin. "We have to tighten this up and make sure our documentation is up to scratch. We have to make sure the plant modification forms are signed before we proceed on site with any changes."

The group then discussed the long list of superintendents and senior engineers who had to be chased for signatures on change documentation. The final signature required was that of the senior quality officer, Dean Best.

"What value does Dean Best's signature add?" asked Bill Woods.

Eric Haines quickly replied, "At least three days to the process."

Everyone in the room, including Colin, laughed. Then, as the seriousness returned, Colin moved on to the next item, Bill's question not having been answered.

In this vignette, Bill raises a serious question regarding the usefulness of some of the levels of authorisation required prior to modifying any plant and equipment. Although the question seems to be specifically aimed at the value of the routine, it is couched in a more legitimate debate about the value of Dean Best's signature. When Bill questions the established plant modification routine, which seems to have its basis in the engineer's *aversion to risk*, he does so by drawing on another of the engineer's traits, *efficiency*. In doing so, Bill is able to question a routine whilst still firmly aligning himself with the social world from which it emanates.

Counter to this, Eric quickly cuts to the core of the debate with humour. When Bill poses the question, Eric quickly interjects that the only value added by Dean's signature is "... three days to the process". By this, Eric means the change control form normally sits in Dean's in-tray for three days before he finally signs and returns an authorisation for a detailed plant modification for which he may very well have no knowledge or interest. Eric can be understood to be able to question the validity of the routine without risking the wrath of fellow social world members because he does so within the protective environs of humour. Rebuttal is prevented by laughter, an indicator of derision in this case, that might only be countered by a strong case in Dean's favour, one that is not forthcoming.

The following vignette provides another example of humour being used by a questioner to query the efficiency and efficacy of an established routine. In this case, Bill Woods seems to use humour as a means of expressing his doubts with respect to the routine of the rigorous 'design review process'.

***Vignette – I volunteer not to come***

I was attending another of the WTP 'design review' meetings. The importance placed on the meeting was well known, and the fourteen engineers invited were present in body, if not mind. Every four weeks, they were required to meet and systematically review all the items active within the WTP Project. The meeting seemed to be acknowledged as a common low point for the attendees. It was characterised by them as a boring procedure-driven activity with limited value.

Today's meeting had been moved from the usual venue of Conference Room 1 with a seating capacity of twenty, to Conference Room 3 with a seating capacity of only ten. The fourteen individuals attending were busy cramming seats together around the table.

Eric Haines said, "Come on Colin. This room is a joke. There's not enough room for all of us in here."

Without hesitation, Bill Woods raised his hand and said, "Hey Colin, I volunteer not to come in future. That'll reduce numbers and make this room more comfortable."

Colin More chose to ignore Bill's comments, but the rest of the room did not and laughed as they continued to shuffle about in preparation for the meeting.

In this vignette, Eric raises a simple question regarding the seating capacity of the venue for the design review meeting. However, Bill uses this question as an opportunity to dispute the usefulness of the established routine. Part of the intent of the design review routine appears to be to provide a formal review and document trail for all items being designed. It seems that the design review routine has as its basis the engineer social world traits of *documentation* and *risk aversion*. By using humour, Bill appears able to question the routine without directly attacking its foundations in the social world. In doing so, Bill is permitted to publicly express a position in opposition to the social world values without fear of sanction.

Questioners, then, are individuals who appear to follow the expected routines, whilst at the same time expressing in private, and under limited circumstances in public, doubts about the efficiency and/or efficacy of certain of those routines. The limited public circumstances under which they express their doubts are couched in diffusing mechanisms, such as humour. By doing this, questioners are able to express dissension without incurring the impassioned responses commonly attributed to the actions of rogues.

## The Believer

*Believers* are individuals who seem to express agreement, both in public and in private, with established routines. This expression of agreement seems to run very deep, as they appear to align their personal position very closely with that of their social world. In the following vignette, Steve Bull, the 5MTPA Project engineering technical manager, appears to express, and display through action, his belief in the documentation control routines established for engineering projects.

***Vignette – I spend most of my time developing systems to control the design process***

Steve Bull seemed like a very serious guy with a very serious approach to his job. His desk was uncluttered. A new looking laptop computer sat in the centre of the desk with a thick red folder carefully open beside it. His office was neat and tidy, seemingly exuding an air of control and purpose.

I commenced the discussion by asking Steve a question about his role in the 5MTPA Project.

"What do you see as your role in the process of design?" I asked.

"Well, I spend most of my time developing systems to control the design process," replied Steve.

Steve turned to his laptop and the open red folder, gesturing for me to pull my chair closer.

As I moved over, I looked at the neat shelves around his office. They were filled with rows of thick red folders similar to the open one on his desk. The folders were like those that I had seen in the offices of other engineers. My understanding, gained from these previous experiences, was that these folders were an integral part of engineering's standard procedure for managing projects.

I pulled up my chair beside Steve. He began to flick through the red folder, explaining the system to me as he went.

"The idea is to make sure there is a fully auditable document trail," said Steve. "I make sure that everyone uses the system. It's a structured methodology for controlling the design process for the engineering components. It also provides mechanisms for cross referencing between the engineering disciplines."

For the next thirty minutes, Steve continued to proudly show me his project documentation and systems for control.

In this vignette, Steve displays the behaviour of a *believer*. He expresses, and demonstrates through action, his apparent belief in the documentation control routine. This routine seems to be based on the engineering social world traits of *documentation, control*, *rules*, and *detail*.

Not all *believers* are able to match Steve's ability to align their rhetoric so rigorously with their actions. I observed some *believers* using the rhetoric and, on the surface, displaying the actions. However, when their actions are more carefully examined areas of misalignment became apparent. In the following vignette, Colin More, the WTP Project manager, displays rhetoric and actions that on the surface seem similar to Steve's. However, when more deeply examined, misalignments appear.

***Vignette – Well err the problem is...***

I was sitting in Colin More's office chatting with him about general issues regarding the WTP project. Colin was explaining to me his role as the project manager and engineering coordinator.

Colin said, "One of the important tasks I have to do is to keep track of what all the various disciplines are doing within the project."

Colin spun his chair to the left and waved his hand toward a row of shelves behind his desk and said, "You see, Ross, I have everything fully documented."

Colin reached up and selected a folder from the shelf and laid it on the desk. "I have documentation on all the various aspects of the project, things like design plans, customer requirement specs, orders, and meeting minutes," said Colin.

I replied, "Oh great, could I borrow one of the engineering job files at some stage in the future to review some of the documentation?"

Colin shifted in his seat, and seemed a little uncomfortable, then paused for some time, before replying.

"Well err the problem is the file can tend to get a little untidy at times. It may not have all the stuff attached and may not be completely up to date," said Colin.

In this vignette, Colin expounds the value of the documentation control routine. However, he is reluctant to allow me access to it because it is "a little untidy at times". Colin seems to support the engineer group traits of *documentation, control, rules,* and *detail* with rhetoric, but he is not able to follow though as rigorously with his with actions as Steve was in the previous vignette.

Believers are individuals who openly express support; both in public and in private, for the routines that they might be expected to follow. Having said this, not all believers are able to fully incorporate all aspects of these routines into their activities within the process of design. In these cases, it seems that certain personal proclivities override the desire to conform to the expected and espoused routines.

This section as a whole shows how individuals can be recognised in terms of their responses to routines. My observation of these responses has led to a classification of types, from the *wild rogue*, who totally rejects a specific routine, through to the complete *believer*, who incorporates the routine in its entirety into his or her daily work activities. This typology is an important component in my account of activities in the 5MTPA Project. It reflects a social ordering process that the participants themselves seem to employ when selecting amongst possible courses of action in response to the individualistic behaviour of other actors. It also provides a basis upon which an external observer, such as myself, can attempt to distinguish between collective and individual action, and the various shades of grey that exist between them.

### 8.5 Summary

The process of design does not follow a natural linear path from inception to completion, nor however, are its participants thrust into complete anarchy. Rather, the relevant social worlds, imbued with member beliefs, provide both purpose and order to the process of design. A salient embodiment of the order imposed by social worlds can be characterised by the concept of rules of engagement, the type of routines discussed in this chapter.

Rules of engagement describe routines that are enacted during negotiations amongst social worlds involved in the process of design. These specific routines are more or less sedimented patterns of actions that provide information for actors about what others might expect of them and in turn what they might expect of others. The rules of engagement developed for negotiation amongst social worlds over design boundary issues are particularly influential in the process of design because they contain information about who has power, what is valued, and how disputes are settled.

Rules of engagement are developed in response to recurring problems or repeated action by various actors and social worlds and are imbued with the traits of the social worlds that develop them, though they also reflect previous routines and experiences. The chief function, or consequence, of a routine, at least from the perspective of the dominant supporting social world, is an increase in the efficiency and/or efficacy of a designated process. If routines either fail to deliver the desired output, or if they begin to lose relevance, from the perspective of one or more of the participating social worlds, they can be placed under pressure to change and evolve. Although routines are developed to aid collective action, some individuals may deem them to be undesirable influences in such action due to their personal preferences or a sense that social world values conflict. The variation of individual response to routines - rogue, questioner, and believer - yield a further patterning of action that knowledgeable participants may employ to influence the process of design.

The following chapter concludes this thesis by drawing together the themes of this and the previous chapters into a condensed account of the process of design. This condensed account uses the concepts of design boundaries and routines to demonstrate the ways in which individuals and social worlds were able to influence the final shape of the technologies whose development was observed in the case studies.

# Chapter (9) – Conclusion

## 9.1 Introduction

This study's sociological account of the activities undertaken in a process of engineering design is meant to provide hitherto unavailable detail on, and case specific explanation of, how individuals and groups go about creating new artefacts within an engineering design context. My two-year ethnographic study addressed three, linked, design projects involving the modernisation of existing, push button and dial control panels with computerised control systems at BHP Pty Ltd, an Australian iron and steel producing company.

The findings of this study have been synthesised in this chapter into a condensed account of the process of design as characterised by the three case studies. This account is then reflected in a description of the salient social processes observed in the first case study, the BOS Project.

Although the analysis provided in this study has been drawn from a unique setting, it nonetheless encompasses a set of concepts that have a broader application in providing a sociological explanation of the process of engineering design. This broader application provides a potentially fruitful area of future study for researchers with an interest in modifying the process of design through the introduction of prescriptive design methodologies.

## 9.2 A Condensed Account of a Process of Design

Authors from economic and engineering fields have traditionally characterised the process of design as following a natural path. This path or trajectory is seen as a sequence of linear stages in which each stage feeds into the next. The process of design is considered to commence with the recognition of a need, and it is deemed complete when a final solution is implemented. This model of design may be useful for managerial representations of how the process might best be coordinated. However, shortcomings become apparent when the model is used as an expositor for how existing technologies have developed (see Bijker 1995b). From a sociological perspective, one of the shortcomings of this model is that it does not provide an explanation of the interactions that occur amongst individuals, social collectives, and the technology being created.

In addressing this deficit, the social collectives in this study have been examined under the auspices of the symbolic interactionist concept of a 'social world'. A social world can be defined as a group of individuals with shared commitments and beliefs about what is and is not important. The social worlds delineated in this study were identified by the action and discourse of both members and non members alike. In this sense, my use of social worlds differs from those typical in interactionist literature in that I consider both voluntary and involuntary allocation of social world ideology and membership.

As in fractal geometry (in diagrams such as the Mandelbrot set[1]), when a technology is examined in detail, numerous sub components become visible. In turn, examining these sub components reveals further sub sub components, and so the process could go on. For example, a bicycle can be considered to be a composite artefact, the components of which are - frame, wheels, seat, chain, pedals, etc. These sub components are in turn made up of their own sets of sub sub components - a wheel is composed of a rim, spokes, nipples, hub, bearings, etc. Each of these sub components can be seen to develop via its own unique trajectory. These trajectories are shaped by interactions amongst actors and social worlds within the broader constraints of external technological, political, cultural, economic, and social circumstances. Sub component trajectories, though, are interlinked so that the trajectory of a technology can be seen to be an amalgam of its sub component trajectories. That is, a bicycle's frame geometry reflects the size of its wheels, which is a response to constraints on gearing, human size, and road roughness.

Sub component trajectories have been analysed in this study by a characterisation of phases of development. These phases, though, do not represent chronological stages through which all sub components must pass in unison. Rather, they are sociological constructs that represent changes observed over time in the interaction between actors and social worlds with sub components. Three phases – seeding, negotiation, and accomplishment were evident in the sub component trajectories in this study. The *seeding phase* can be characterised by an eclectic mix of sub components that exist without specifically established bonds or relationships with one another. Certain of

[1] The Mandelbrot fractal set is one of the most widely recognised groups of fractal diagrams. It is defined by iteration on complex numbers, $Z := Z * Z + C$. The iterations are so numerous that when the results are graphed that every shape is composed of an infinite number of smaller shapes (Lanius 2001).

these sub components are provided admission to design projects through their compliance, at least in appearance, with the conditions of the obligatory passage point that marks the juncture between seeding and negotiation phases. The sub components that fail to meet these conditions may be resubmitted on later projects. Once inside the *negotiation phase,* the now loosely related sub components begin to develop more individual detail and stronger inter relationships with one another. This process continues within the limits of the design boundaries until linkages align the sub component trajectories, and a synthesised technology enters the accomplishment phase. The *accomplishment phase* represents the last stage in the design process. In this phase, the various actors and social worlds negotiate amongst themselves the final form of the technology. The resulting technology that emerges is stable only with respect to completion of the design project. The technology itself is likely to continue to change and evolve under the influence of similar sources of pressure to those by which it was created.

This conception of trajectories does not provide a description of the actual linking mechanisms through which an individual or social world is able to influence the development of a technology. For example, a potter working with clay is able to influence the shape a pot through subtle hand or finger movements. Without this unrestricted physical contact, a bicycle designer must use other mechanisms, such as drawings and specifications to influence the shape of the bicycle. To explore the mechanisms used by individuals and social worlds to influence the shape of a technology that they can not physically touch, I have developed the notion of a design boundary.

Design boundaries are specifications that constrain and enable sub component trajectories by representing specific variations or options that may or may not be pursued. They are mechanisms, such as drawings and detailed component descriptions, through which individuals and social worlds are able to stipulate specific design details that they wish to see reflected in the final physical form of a technology. Design boundaries can be seen to have two overlapping elements. One element, a *boundary plate*, is a relatively rigid boundary that is recognised and generally understood by the various actors and social worlds. A second element, a *boundary membrane*, is a more flexible boundary that is negotiated on a local level and may not be recognised by other relevant actors or social worlds. Membranes and plates join together to form a continuous boundary of explicit and public, and implicit or private, constraints that encompass the design space of a technology and dictate its final shape.

Design boundaries are produced through negotiations amongst actors and social worlds. These negotiations are often battles, with winners, losers, and only sometimes agreeable truces. At the heart of these battles are conflicts over the shapes that will ultimately be taken by the various technology sub components. The shapes being pursued are influenced by the ideologies and traits of the participating social worlds. Differences in ideologies and traits amongst the social worlds may manifest themselves in surrogate battles over design issues. In these cases, the resultant design boundaries reflect the hidden agendas and power struggles that often occur within the design process.

Negotiations over design boundaries do not proceed at random. Rather, the combatants engage in standard patterns of action. These standard patterns of action or routines evolve over time usually in response to previously encountered problems. During this evolutionary process, routines are inculcated with the ideologies and traits of the participating social worlds. Rules of engagement are a type of routine that provides individuals and social worlds with information on how they might be expected to act and in turn how they might expect others to react when they meet in an arena. These recognised patterns of action alleviate the need for individuals and social worlds to invent new approaches every time they negotiate about design boundaries.

Thus one sees that the ways in which individuals and social worlds construct design boundaries are influenced by the routines through which collective action is made possible. The activities undertaken by individuals and social worlds during the process of design can be characterised as being primarily concerned with the negotiation of design boundaries. These design boundaries represent the mechanisms through which individuals and social worlds are able to influence the trajectory by which a technology develops. The following section relates this description of the design process to one of my case studies – the BOS Project.

### 9.3 An Account of the BOS Project

Although the BOS Project[2] was conducted under the auspices of the 5MTPA Project, the trajectory by which the BOS Project developed can be considered to have commenced some twenty-years prior to the inception of the 5MTPA Project. In 1975, a fire completely destroyed the BOS control rooms and control systems. Because of the

[2] Three case studies were undertaken – BOS, WTP, and LK. However, in order to avoid repetition, a condensed account of only one of the cases, the BOS Project, is presented in this final chapter. The BOS Project was selected over the others because it contained the most concise, easily explained illustrations of the emergent themes of this study.

high costs of having such an important part of an integrated iron and steel making plant inoperable, the ensuing reparations were based on a combination of expediency, equipment availability, and functionality.

Several years after these hasty reconstructions were completed, the machinations for newer, improved control rooms seemed to have commenced. The engineers visited a highly automated BOS plant in Japan – a plant where operators pushed a 'start' button and an autonomous control system took charge, monitoring and guiding the steelmaking process unaided. The maintenance personnel began to covet the newer and more reliable software and PLC (Programmable Logic Controller) based control systems over the already aging, hard-wired, relay-based control systems. The operations personnel were under pressure to produce steel within tighter and tighter tolerances and, as such, desired a control system that permitted closer regulation of the process.

In the mid 1980's, these three social worlds – engineers, BOS operators, and BOS maintenance – appear to have formed a loose consortium to promote a perception that the BOS control rooms were in need of upgrading. During this 'artefact seeding phase' of the BOS Project, the consortium actively sought opportunities to progress their desired developments for the control rooms. The opportunities they sought were typically embodied in formal organisational projects empowered with the financial resources to bring about significant technological changes.

Numerous unsuccessful attempts over a ten-year period were finally rewarded in the form of the 5MTPA Project. The 5MTPA Project was a large multi-million-dollar, BHP-wide initiative to increase the steel making capacity of the plant from 4.6 to 5.0

million tonnes per annum. Access to the resources of 5MTPA Project was made possible by the consortium's creation of the perception that the BOS Project satisfied the terms and conditions of the obligatory passage point represented by the '5MTPA official scope of work'.

The availability of resources from the 5MTPA Project signified the commencement of the 'artefact negotiation phase' of the BOS Project. This phase was characterised by negotiations amongst the relevant social worlds with respect to specific details of the many loosely related sub components that made up the BOS Project. During this phase, it became apparent that some of the goals of the members in the consortium were divergent. The engineers expressed a preference for the latest, most highly automated, flexible system. The operators made known their penchant for functionality, simplicity, and reliability. Maintenance conveyed what appeared to be a desire for reliability and compatibility with nearby systems.

The variation of goals amongst the engineers, BOS operators, and BOS maintenance can be traced back to what each of these social worlds believe is important and worthwhile, described here as *traits*. These traits influence how the participants in the BOS Project acted toward, and perceived, one another. For example, there was a constant tension during the BOS Project's artefact negotiation phase between the operators and the engineers over how critical BOS equipment would be activated from the control room. That is, how a pump would be switched on and off, or how a hopper gate would be opened or closed. The engineers seemed to have a preference for the flexibility and 'high tech' nature of software buttons displayed as icons on computer screens. Counter to this, the operators appeared to value more highly the perceived reliability of a physical button mounted in a physical desk.

This contentious 'button' issue, characterised in this dissertation as an *arena*, persisted unresolved as the two social worlds presented to one another arguments and counter arguments. This process of negotiation did not proceed at random. Rather, both social worlds followed mutually understood patterns of action or *routines*. The first action taken by the engineers was to produce an 'engineering layout drawing'[3] depicting four visual display units embedded in a control desk devoid of physical buttons. This drawing was transferred via a nominated operator spokesperson for review by the operators as a collective. The operator spokesperson translated the drawing for the operators, collected their responses, and then transferred a condensed version of the operators comments back to the engineers. The engineers amended portions of the drawings of the desk and returned them to the operator spokesperson for further review. This process continued back and forth until finally 'seven critical buttons' were selected for physical inclusion on the desk. The remaining buttons were designated as icons on the computer screens.

The routines observed within this 'button' arena, such as the nomination of an operator as a single point of contact and the use of drawings to transfer information, were not invented specifically for the BOS Project. Rather, they seem to have evolved under the influence of social world traits, previous routines, and past experiences.

[3] An 'engineering layout drawing' is an overarching graphical representation of an artefact. These drawings are produced primarily for discussion purposes. As such, they contain very little detailed information, eg, hole diameters, bolt sizes, dimension tolerances. This information is presented later in the design process in the 'detailed engineering drawings'.

With the assistance of these routines, a truce over the contentious 'button' issue was eventually negotiated. Once this occurred, the arena dissolved and the resolutions were recorded as design specifications or what I have termed *design boundaries*. In the case of the buttons, the design boundary stipulated the size, location, type, and number of physical buttons that would appear on the final desk. Once established, this design boundary influenced future negotiations concerning the control desk. For example, the materials used to construct the control desk could not be altered from six millimetre stainless steel to four millimetre stainless steel without first considering what implications the alterations may have on the buttons. As the BOS Project continued through the artefact negotiation phase, more and more design boundaries were constructed, and in turn more and more interdependencies were defined.

The 'artefact accomplishment phase' of the BOS Project was characterised by a preponderance of design boundaries that effectively defined the final physical form of the equipment being designed. To complete the project, the design boundaries, as represented by drawings and specifications, were transferred to individuals within organisations with the physical skills and resources to construct the final artefacts. For example, the drawings of the control desk were presented to an organisation specialising in the fabrication of stainless steel. The workers in this organisation transferred the positions of the 'seven critical buttons' negotiated by the engineers and the BOS operators from the detailed engineering drawings to the sheets of stainless steel from which the control desk was to be constructed. In this sense, the design boundaries provided a mechanism through which the engineers and the BOS operators were able to render the outcomes of their negotiations over 'buttons' in the final physical form of the stainless steel control desk.

## 9.4 Generalisable Implications of this Account

This study has presented an account of the activities observed in the 5MTPA Project design process. The unique details, such as the specific conflict between the BOS operators and the engineers over buttons, may bear little or no significance for interpreting other cases of design. However, the notions of social worlds, trajectories, design boundaries, arenas, routines, and the relationships that exist between these concepts (see Fig 9.1) can be taken as a hypothetical explanation of the general process of engineering design within an industrial setting.

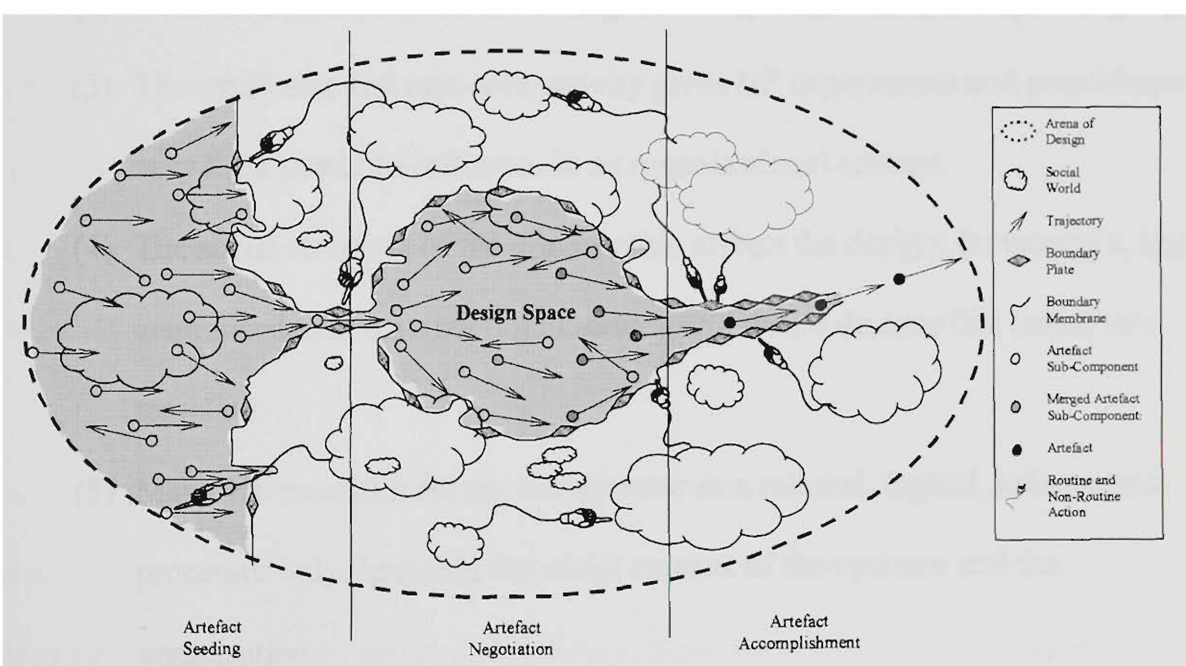


**Figure 9.1 An Account of the Process of Engineering Design**

The broader application of the notions presented in this study can be demonstrated by returning to the prescriptive literature on design methodology reviewed in Chapter (3).

This literature encompasses approaches to the design of technology that specify sets of design rules or heuristics. Practitioners within this field often provide descriptive commentaries on the difficulties that they experienced in the application of their particular design method. The notions developed in this study can provide analytical insights into these difficulties.

For example, Perrow (1983) lists five points describing factors that he sees as limiting the application of Human Factors[4] (HF) knowledge to the process of design.

(1) There is a lack of organisational commitment to HF, in terms of rewards, sanctions, and management beliefs.
(2) There is a contradiction between good design logic and good operating logic.
(3) The small size and non-core activity gives HF departments and practitioners very little power or influence in an organisational context.
(4) The social structure of the organisation affects the design; for example, highly centralised authoritarian organisations will desire designs that match this template.
(5) Many HF practitioners see the operator as a rational, logical, information processor only, ignoring the social context of the operator and the organisation.

These five points can be explored using concepts and relationships that were developed earlier in this study. In point (1), the 'organisation' referred to by Perrow may be seen as

[4] Human Factors or ergonomics is a field that uses knowledge of human abilities and limitations to design systems, organisations, machines, and products for safe, efficient, and comfortable human use (Helander 1997, p.4). See Chapter (3) for a more detailed discussion.

number of interlinked and overlapping social worlds, one of which is the HF social world. Each of these social worlds has a set of traits that represent what they believe is and is not important. These traits are imbued in the routines that guide collective action within the organisation. Thus, Perrow's observation of a 'lack of organisational commitment' might be better described as a set of negotiated design routines in which the contributions of HF knowledge have been perceived as less important than other factors more highly valued by the participating social worlds.

Similarly, the influence that a social world has over the process of design is not necessarily, as Perrow suggests in point (3), a function of the 'size' of the social world. Rather, I see it as a function of how well the social world has been represented previously in negotiations over the development of design routines. The rules of engagement set down in these routines specify who has power, and over what details it may be exercised. In these terms, the lack of HF 'power or influence', cited by Perrow, is not a result of its small size. Rather, it is a result of existing design routines favouring the other social worlds, large or small.

In point (2), Perrow's notion of 'good design logic' and 'good operating logic' may be seen as two sets of design routines, one from a designer's social world and the other from an operator's social world. In this sense, there is not an unresolvable contradiction between two 'universally recognised' methods for 'good design' and 'good operation'. Rather, there are two social worlds with differing perspectives on what is and is not important in the design of technology. These differing perspectives may still be unresolvable. However, they are based on localised differences and not a *fait accompli* for all engineering design projects.

The trajectory by which a technology develops is linked to the social structure of the organisation within which it develops. Having said this, Perrow's statement in point (4) of a causal relationship between the two is not reflected in my interpretation of the process of design. Instead, the ideologies and traits of the relevant social worlds can be seen as the independent variables, with organisational structure and technological trajectories considered the dependent variables. This means that modifying an organisational structure will not necessarily affect the trajectory of a technology, that is, unless there is an accompanying change in the ideologies and traits of the relevant social worlds.

According to Perrow in point (5), many HF practitioners see the operator as a rational, logical, information processor. This is an example of what I refer to as externally assigned social world traits. These traits influence the way non-members interact with members regardless of whether the traits reflect the behaviour of those within the social world. In this case, the HF social world has conceived of an operator social world where the members are rational information processors. These externally assigned traits subsequently influence the routines developed by the HF social world for interaction with members of the operator social world.

The concepts and relationships applied to the systematic examination of Perrow's observations can be similarly useful for formulating potential strategies to redress the limitations encountered in the application of design rules and heuristics. These strategies must start with the recognition that design is first and foremost a social process. This social process involves battles and negotiations conducted under the influence of social world traits and routines. In applying prescriptive design methods, proponents are entering this fray and attempting to change routines imbued with the traits of the supporting social worlds. Such changes are likely to result in impassioned responses of resistance if they are interpreted as challenges to the things that the social worlds feels most strongly about. To avoid this resistance, the proponents of the prescriptive design methods need to be aware of the relevant social worlds and ensure that a perception of alignment exists between the proposed changes to the design routine and important traits from each of the social worlds.

For example, in the 5MTPA Project, the predominant social worlds were the engineers, the WTP operators, and the BOS operators. In applying the KOMPASS design heuristic to the WTP Project, I aligned the method for the engineer social world with their traits[5] of *documentation, efficiency, risk aversion,* and *people mess.* On the other hand, with the WTP operator social world, I aligned the method with their traits[6] of *reliability, deskilling,* and *low power*. By doing this, I was able to implement a modification to an existing design routine with the support of the two predominant social worlds. Such support would have been unlikely had I introduced the method based on its proponents' accolades that it was an approach 'for the complementary analysis and design of production tasks for optimal design of human computer interfaces' (Grote 1996).

The concepts and relationships developed in my account of the 5MTPA Project thus provide a useful explanatory framework through which the social processes of general

[5] For detailed discussions of engineer social world traits see Chapter (6), Table 6.2.

[6] For detailed discussions of WTP operator social world traits see Chapter (6), Table 6.3.

engineering design can be better understood and worked with. This understanding provides a theoretical component to accompany the descriptive observations of practitioners of prescriptive design methods. Combining theoretical and descriptive accounts serves to illuminate potential strategies available for overcoming common hindrances experienced in the application of external design rules and heuristics.

### 9.5 Recommendations for Future Research

This study has involved detailed participant observation over an extended period of time. In spite of this, I have not been privy to all of the activities that can occur during a process of design. For example, the majority of the activities in the artefact seeding phase of the design process occur prior to formal recognition of the design project. The three case studies that I examined were selected from a list of approved, but at the time not started, BHP design projects. This meant that my observations commenced after many of the artefact seeding phase activities were complete. However, examination of discourse, documentation, and questioning of participants provided sufficient secondary data upon which I was able to develop an account of the largely unseen activities of the artefact seeding phase. Likewise, the activities that occur during the construction of the diaphanous boundary membranes remained largely beyond the observations of this study. Further research specifically aimed at revealing characteristics of these two phenomena may help to construct a more complete picture of the process of design.

The generalisable aspects of the sociological account of the process of design contained in this study represent a fecund set of concepts for proponents of prescriptive design methodologies. Further research is required into developing prescriptive design methods that address the social nature of design, in the way the methods are both constructed and implemented. Such research may provide part of the solution to the continuing proliferation of inadequate human computer interfaces that was noted as one of the justifications for this research in Chapter (1).

## 9.6 Summary

At the start of this thesis, I introduced the notion that there were multiple technological and social faces to the process of engineering design. These faces have been watched, pondered over, and even touched during the course of this study. The description here of what I discovered reveals individuals and social worlds engaged in battles where contentious design issues and social world ideologies merge. These battles are frequently conducted according to predetermined rules of engagement that define who has power, and over what elements of the battle that power can exercised. The outcomes of these battles are the design boundaries that dictate the final shape of a technology.

One might conclude that understanding the process of design is akin to watching the toss of a Janus-faced coin. It spins through space, momentarily revealing changing facets of its many faces. As the coin tumbles though its arc these glimpses form an almost three-dimensional image of the inseparable technological and social aspects of the process of design.

## Bibliography


Agar, M. H. (1996). *The Professional Stranger: An Informal Introduction to Ethnography*. San Diego, Academic Press Inc.

Anderson, R. J. (1997). "Work, Ethnography and Design". In *The Encyclopedia of Microcomputers*, Kent, A., and Williams, J.G. (Eds.). New York, Marcel Dekker. 20: 159 - 183.

Anderson, R. J., Button, G., and Sharrock, W.W. (1993). "Getting the Design Job Done: Notes on the Social Organisation of Technical Work." *Journal of Intelligent Systems* Vol 3: 319-344.

Atkinson, P., and Hammersley, M. (1994). "Ethnography and Participant Observation". In *Handbook of Qualitative Research*. N. K. Denzin, and Y.S. Lincoln (Eds.), London, Sage: 248 -261.

Australian Stock Exchange, (2001). "Top 150 Companies". *The Sydney Morning Herald.* Sydney, April 23: 39.

Badke-Schaub, P., and Frankenberger, E. (1999). "Analysis of Design Projects." *Design Studies,* 20: 465 - 480.

Baird, F., Moore, C.J., and Jagodzinski, A.P. (2000). "An Ethnographic Study of Engineering Design Teams at Roll-Royce Aerospace." *Design Studies,* 21(4): 333 - 355.

Ball, L. J., and Ormerod, T.C. (2000). "Applying Ethnography in the Analysis and Support of Expertise in Engineering Design." *Design Studies*, 21(4): 403 - 421.

Becker, H. S. (1998). *Tricks of the Trade - How to Think About Your Research While You're Doing It.* Chicago, University of Chicago Press.

Bennatan, E. M. (1995). *On Time, Within Budget - Software Project Management Practices and Techniques*. New York, John Wiley and Sons.

BHP (1992). *Where You Work.* Wollongong, BHP.

BHP (1996). *The 1996 BHP Pocketbook.* Melbourne, BHP.

BHP (1997). *Design Control Procedure*. Wollongong, BHP.

BHP (1998). "Integrated Team Workshop", *BHP - SCS/WEE, 5MTPA Project - BOS Lime Kiln Upgrade,* BHP Steel Port Kembla: 1-20.

BHP (1999). *BHP Steel*, BHP.

BHP Engineering. (1998a). *BOS Flux PLC Upgrade - Scope of Work and Estimate*, BHP Steel Works, Port Kembla.

BHP Engineering. (1998b). *Caster Water Treatment Plant PLC Upgrade - Scope of Work and Estimate*, BHP Steel Works, Port Kembla.

BHP Engineering. (1998c). *Lime Kiln PLC Upgrade - Scope of Work and Estimate*, BHP Steel Works, Port Kembla.

Bijker, E. B., Hughes, T.P., and Pinch, T.J. (1987). *The Social Construction of Technological Systems - New Directions in the Sociology and History of Technology*. Cambridge, The MIT Press.

Bijker, W. B. (1995a). "Sociohistorical Technology Studies". In *Handbook of Science and Technology Studies*. Jasanoff, S., Markle, G.E., Petersen, J.C., and Pinch, T. (Eds.), London, Sage.

Bijker, W. B. (1995b). *Of Bicycles. Bakelites, and Bulbs - Toward a Theory of Sociotechnical Change*. Cambridge, Mass., The MIT Press.

Bijker, W. E., and Law, J. (Eds.). (1992). *Shaping Technology/Building History - Studies in Sociotechnical Change*. Massachusetts, MIT Press.

Blackburn, P., Coombs, R., and Green, K. (1985). *Technology, Economic Growth, and Labour Process*. New York, St. Martin's Press.

Blauner, R. (1964). *Alienation and Freedom*. Chicago, Chicago University Press.

Blomberg, J., Suchman, L., and Trigg, R.H. (1997). "Reflections on a Work-Oriented Design Project. Social Science", In *Technical Systems, and Cooperative Work - Beyond the Great Divide*. G. Bowker, Leigh Star, S., Turner, W., and Gasser, L. (Eds.). New Jersey, Lawrence Erlbaum Associates: 189-215.

Blumer, H. (1969). *Symbolic Interaction - Perspective and Method*. Los Angeles, University of California Press.

Braverman, H. (1974). *Labor and Monopoly Capital: Degradation of Work in the Twentieth Century*. New York, Monthly Review Press.

Bucciarelli, L. L. (1988). "An Ethnographic Perspective on Engineering Design." *Design Studies*, 9(3): 159-168.

Bucciarelli, L. L. (1994). *Designing Engineers*. Cambridge, The MIT Press.

Buchanan, D., and Badham, R. (1999). *Power, Politics, and Organisational Change - Winning the Turf Game*. London, Sage.

Buchanan, D., Boddy, D., and McCalman, J. (1988). "Getting In, Getting On, Getting Out, and Getting Back - The Art of the Possible". In *Doing Research in Organisations*. A. Bryman. London, Routledge: 53 - 67.

Buckley, W. (1967). *Sociology and Modern Systems Theory*. New Jersey, Prentice Hall.

Burawoy, M. (1979). *Manufacturing Consent: Changes in Labor Process Under Monopoly Capitalism*. Chicago, University of Chicago Press.

Burgess, R. G. (Ed.). (1982). *Field Research: A Sourcebook and Field Manual. Contemporary Social Research Series*. London, G. Allen and Unwin.

Button, G. (2000). "The Ethnographic Tradition and Design." *Design Studies*, 21(4): 319-332.

Button, G., and Sharrock, W. (1998). "The Organisational Accountability of Technological Work." *Social Studies of Science*, 28(1): 73-102.

Button, G., and Sharrock, W. (1996). "Project Work: The Organisation of Collaborative Design and Development in Software Engineering." *Computer Supported Cooperative Work*, 5: 369 - 385.

Callon, M. (1980). "The State of Technical Innovation - A Case Study of the Electrical Vehicle in France." *Research Policy*, 9: 358-376.

Carroll, J. M. (1997). "Scenario-Based Design". In *Handbook of Human Computer Interaction*. M. Helander, Landauer, P., and Prabhu, P. Amsterdam, Elsevier Science B.V. (Eds.): 383-404.

Cassell, C., and Symon, G. (1994). *Qualitative Methods in Organisation Research: A Practical Guide*. London, Sage Publications.

Castlerock Entertainment. (1991). *City Slickers*. Los Angeles, MGM Home Entertainment.

Clark, J., McLoughlin, I., Rose, H., and King, R. (1988). *The Process of Technological Change: New Technology and Social Choice in the Workplace*. Cambridge, Cambridge University Press.

Clarke, A. E. (1991). "Social Worlds/Arenas Theory as Organisational Theory". In *Social Organisation and Social Process - Essays in Honour of Anselm Strauss*. D. R. Maines (Ed.). New York, Aldine De Gruyter: 119 - 158.

Clarke, A. E. (1997). "A Social worlds Research Adventure - The Case of Reproductive Science". In *Grounded Theory in Practice*. A. Strauss, and Corbin, J. (Eds.). California, Sage: 63-94.

Clegg, C. (1993). *Social Systems that Marginalise the Organisational Aspects of Information Technology*, Applied Psychology Unit, Sheffield University, memo.1395.

Clegg, G. (1972). *The Selection of Design*. London, Cambridge University Press.

Collins, H. M. (Ed.). (1982). *Sociology of Scientific Knowledge - A Source Book*. Bath, Bath University Press.

Constant, E. (1980). *The Origins of the Turbojet Revolution*. Baltimore, Johns Hopkins University Press.

Cross, N., and Clayburn Cross, A. (1995). "Observations of Teamwork and Social Process in Design." *Design Studies*, 16(2): 143 - 170.

Czaja, S. (1997). "Systems Design and Evaluation". *Handbook of Human Factors and Ergonomics* 2nd edition. G. Salvendy. (Ed). New York, John Wiley and Sons. 1: 17-40.

Dieter, G. E. (1983). *Engineering Design*. New York, John Wiley and Sons.

Dosi, G. (1984). *Technical Change and Industrial Transformation*. London, Macmillan.

Dougherty, E. M., and Fragola, J. R. (1988). *Human Reliability Analysis*. New York, John Wiley and Sons.

Downey, G. L., and Lucena, J.C. (1995). "Engineering Studies". *Handbook of Science and Technology Studies*. Jasanoff, S., Markle, G.E., Petersen, J.C., and Pinch, T. (Eds.). London, Sage.

DRS (2001). *Design Research Society - What We Are*. May 12, http://www.drs.org.uk/WhatMenu.html2001.

Ehn, P. (1989). *Work Oriented Design of Computer Artefacts*. Stockholm, Arbetslivscentrum.

Ehn, P. (1998). Personal Communication.

Emery, F. E., and Trist, E.L. (1978). "Analytical Model for Sociotechnical Systems". In *Sociotechnical Systems: A Sourcebook*. Passmore, W. A., and Sherwood, J.J. (Eds.). La Jolla, California, University Associates Inc.: 120-131.

Friedman, A. L. (1977). *Industry and Labour: Class Struggle at Work and Monopoly Capitalism*. London, Macmillan.

Fujimura, J. H. (1992). Crafting Science: Standardised Packages, Boundary Objects, and 'Translation". In *Science as Practice and Culture*. A. Pickering (Ed.). Chicago, The University of Chicago Press.

Garrety, K. (1997). *Negotiating Dietary Knowledge Inside and Outside Laboratories: The Cholesterol Controversy*. School of Science and Technology Studies. Sydney, The University of New South Wales: 285.

Garrety, K., and Badham, R. (2000). "The Politics of Socio-technical Intervention: An Interactionist View." *Technology Analysis and Strategic Management*, 12(1): 103-118.

Gasser, L., and Majchrzark, A. (1998). *TOP Modeler*. Los Angeles, topintegration.

Geertz, C. (1973). *The Interpretation of Cultures: Selected Essays*. New York, Basic Books.

Gibson, R. (1992). *Managing Computer Projects - Avoiding the Pitfalls*. London, Prentice Hall International.

Glaser, B., and Strauss, A. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*. New York, Aldine.

Goel, V., and Pirolli, P. (1992). "The Structure of Design Problem Spaces." *Cognitive Science*, 16: 395 - 429.

Goodall, Jr., H.L. (1994). *Casing a Promised Land - The Autobiography of an Organisational Detective as Cultural Ethnographer*. Carbondale and Edwardsville, Southern Illinios University Press.

Gould, J. D., Boies, S.J., and Ukelson, J. (1997). "How to Design Useable Systems". *Handbook of Human Computer Interaction*. M. Helander, Landauer, P., and Prabhu, P (Eds.). Amsterdam, Elsevier Science B.V.: 231-254.

Greif, I. (Ed.). (1988). *Computer Supported Cooperative Work: A Book of Readings*. San Mateo, Morgan Kaufmann Publishers.

Grint, K., and Woolgar, S. (1997). *The Machine at Work - Technology, Work and Organisation*. Cambridge, Polity Press.

Grote, G., (Ed.). (1994). "A Participatory Approach to the Complimentary Design of Highly Automated Work Systems". *Human Factors in Organisational and Design Management*, Elsevier.

Grote, G., Weick, S., and Wafler, T. (1996). "KOMPASS: Complimentary Allocation of Production Tasks in Sociotechnical Systems." *Contemporary Ergonomics*: 306-311.

Grote, G., Weik, S., Wafler, T., and Zolch, M. (1995). "Criteria for the Complementary Allocation of Functions in Automated Work Systems and their use in Simultaneous Engineering Projects." *International Journal of Industrial Ergonomics* 16: 367-382.

Guindon, R. (1990). "Knowledge Exploited by Experts during Software System Design." *International Journal of Man Machine Studies*, 33: 279 - 304.

Hall, P. M. (1997). "Meta-Power, Social Organisation, and the Shaping of Social Action." *Symbolic Interaction*, 20(4): 397-418.

Haralambos, M., Holborn, M., and Heald, R. (1990). *Sociology - Themes and Perspectives*. London, HarperCollins.

Helander, M. G. (1997). "The Human Factors Profession". In *Handbook of Human Factors and Ergonomics* 2nd edition. G. Salvendy (Ed.). New York, John Wiley and Sons. 1: 4-15.

Helander, M., Landauer, P., and Prabhu, P. (Eds.). (1997). *Handbook of Human Computer Interaction*. Amsterdam, Elsevier Science B.V.

Hill, P. H. (1970). *The Science of Engineering Design*. New York, Holt, Rhinehart and Winston.

Hopkins, A. (2000). *Lessons From Longford - The Esso Gas Plant Explosion*. Sydney, CCH Australia.

Houde, S. a. H., C. (1997). "What do Prototypes Prototype". In *Handbook of Human Computer Interaction*. M. Helander, Landauer, P., and Prabhu, P. (Eds.). Amsterdam, Elsevier Science B.V.: 367-380.

Ireson, W. G., Coombs, Jr. C.F., and Moss, R.Y. (Eds.). (1998). *Handbook of Reliability Engineering and Management*. New York, McGaw Hill.

Jagodzinski, P., Reid, F.J.M., Culverhouse, P., Parsons, R., and Phillips, P. (2000). "A Study of Electronics Engineering Design Teams." *Design Studies*, 21(4): 375 - 402.

Jensen, R. S. (1992). "Pilot Judgement: Training and Evaluation." *Human Factors*, 34: 61-73.

Kline, S. J. (1985). "Innovation is Not a Linear Process." *Research Management*, 28(4): 36-45.

Knights, D., and Willmott, H. (1988). *New Technology and the Labour Process*. London, Macmillan.

Landauer, T. K. (1995). *The Trouble with Computers: Usefulness, Useability, and Productivity*. Cambridge MA, MIT Press.

Lanius, C. (2001). *Fractals*. July 12, http://math.rice.edu/~lanius/frac/

Latour, B. (1987). *Science in Action - How to Follow Scientists and Engineers Through Society*. Milton Keynes, Open University Press.

Latour, B. (1996). *Aramis, or the Love of Technology*. Cambridge, Harvard University Press.

Latour, B., and Woolgar, S. (1979). *Laboratory Life: The Social Construction of Scientific Facts*. Beverly Hills, Sage Publications.

Law, J. (1987). "Technology and Heterogenous Engineering - The Case of Portuguese Expansion". In *The Social Construction of Technological Systems - New Directions in the Sociology and History of Technology*. W. Bijker, Hughes, T., and Pinch, T. (Eds.). Cambridge, MIT Press: 111-134.

Lee, T. Y., and Radcliffe, D.F. (1990). "Innate Design Abilities of First Year engineering and industrial design students." *Design Studies*, 11: 96 - 106.

Lewis, W. P., and Samuel, A.E. (1989). *Fundamentals of Engineering Design*. Sydney, Prentice Hall.

Lim, K. Y., Long, J.B., and Silock, N. (1992). "Integrating Human Factors with the Jackson Development Method - An Illustrative Overview." *Ergonomics*, 35(10): 1135-1161.

Lloyd, P. (2000). "Storytelling and the Development of Discourse in the Engineering Design Process." *Design Studies*, 21(4): 357 - 373.

Long, J. (1997). "Twenty-five Years of HCI: Growth without Progress". *HCI 97*, San Francisco, Elsevier.

MacKenzie, D., and Wajcman, J. (Eds.). (1985). *The Social Shaping of Technology - How the Refrigerator got its Hum.* Milton Keynes, Open University Press.

Majchrzak, A., and Finley, L. (1995). "A Practical Theory and Tool for Specifying Sociotechnical Requirements to Achieve Organisational Effectiveness". In *The Symbiosis of Work and Technology*. J. Benders, de Haan, J., and Bennett, D. (Eds.). London, Taylor and Francis.

Majchrzak, A. (1997). "What To Do When You Can't Have It All: Toward a Theory of Sociotechnical Dependencies." *Human Relations*, 50(5): 535-565.

Majchrzak, A., Findley, L., and Fredrick, K. (1997). *Innovative Expert Systems for Integrating Technology, People and Organisational Issues with Business Strategies and Performance Goals*, University of Southern California.

Malinowski, B. (1922). *Argonauts of the Wester Pacific: An Account of Native Enterprise and Adventure in the Archipelagoes of Melanesian New Guinea.* London, Routledge and Kegan.

March, J. G., and Olson, J.P. (1983). "Organising Political Life: What Administrative Reorganisation tells us about Government." *American Political Science Review*, 77(2): 281-296.

McLoughlin, I., and Clark, J. (1992). *Technological Change at Work.* Buckingham, Open University Press.

Meltzer, B. N., Petras, J.W., and Reynolds, L.T. (1975). *Symbolic Interactionism - Genesis, Varieties and Criticism.* London, Routledge and Kegan Paul.

Moray, N. (1997). "Human Factors in Process Control". *Handbook of Human Factors and Ergonomics* 2nd edition. G. Salvendy (Ed.). New York, John Wiley and Sons. 1: 1944-1971.

Mumford, E. (1980). "Participative Design of Clerical Information Systems: Two Case Studies". In *The Human Side of Information Processing: Proceedings of the Copenhagen Conference on Computer Impact-78*. N. Bjorn-Andersen. Amsterdam, North-Holland Publishing Co.

Nardi, B. A. (1997). "The Use of Ethnographic Methods in Design and Evaluation". In *Handbook of Human Computer Interaction*. M. Helander, Landauer, P., and Prabhu, P. Amsterdam (Eds.). Amsterdam, Elsevier Science B.V.: 361-366.

Nelson, R. R., and Winter, S.G. (1982). *An evolutionary Theory of Economic Change. Cambridge,* Mass., Bleknap Press.

Newman, W. (1994). "A Preliminary Analysis of the Products of HCI Research Using Pro-forma Abstracts". In *CHI 94' Human Factors in Computing Systems : "Celebrating Interdependence",* Boston Massachusetts USA, ACM Press.

Nickerson, R. S., and Landauer (1997). "Human-Computer Interaction: Background and Issues". In *Handbook of Human Computer Interaction*. M. Helander, Landauer, P., and Prabhu, P. (Eds.). Amsterdam, Elsevier Science B.V.: 3-33.

Noble, D. F. (1984). *Forces of Production: A Social History of Industrial Automation*. New York, Knopf.

Norman, D. A. (1988). *The Psychology of Everyday Things*. New York, Basic Books.

Norman, D. A. (1998). *The Design of Everyday Things*. London, MIT Press.

Olson, G. M., and Olson, J.S. (1997). "Research on Computer Supported Cooperative Work". In *Handbook of Human Computer Interaction*. M. Helander, Landauer, P., and Prabhu, P. (Eds.). Amsterdam, Elsevier Science B.V.: 1433 - 1450.

Passmore, W. A., and Sherwood, J.J., (Eds.). (1978). *Sociotechnical Systems: A Sourcebook*. La Jolla, California, University Associates, Inc.

Perrow, C. (1983). "The Organisational Context of Human Factors Engineering." *Administrative Science Quarterly,* December: 521-541.

Petroski, H. (1996). *Invention by Design - How Engineers get from Thought to Thing*. Cambridge, Harvard University Press.

Phillips, D. (1998). *The Software Project Managers Handbook - Principles that Work at Work*. Los Alamitos, IEEE Computer Society.

Purba, S., Sawh, D., and Shah, B. (1995). *How to Manage a Successful Software Project - Methodologies, Techniques, Tools*. New York, John Wiley and Sons.

Rasmussen, J., Pejtersen, A. M., and Goodstein, L. P. (1994). *Cognitive Systems Engineering*. New York, John Wiley and Sons.

Reason, J. (1990). *Human Error*. New York, Cambridge University Press.

Reason, P. (1994). "Three Approaches to Participatory Inquiry". *Handbook of Qualitative Research*. N. K. Denzin, and Lincoln, Y.S. (Eds.). London, Sage: 324-339.

Rice, A. K. (1958). *Productivity and Social Organisation, the Ahmedabad Experiment: Technical Innovation, Work, and Organisational Management*. London, Tavistock Pub.

Robertson, I. (1987). *Sociology*. New York, Worth Publishers, Inc.

Roy, R., and Cross, N. (1976). *Technology and Society*, The Open University Press.

Russell, M. (1998). *BHP Integrated Steel Division, 5MTPA Project, Scope of Work and Estimate*, MP.05. Wollongong, BHP.

Samson, D. (1997). *Management for Engineers*. Melbourne, Addison Wesley Longman Australia Pty Ltd.

Schuler, D., and Namioka, A., (Eds.). (1993). *Participatory Design: Principles and Practices*. Hillsdale, N.J., Erlbaum Associates.

Sharrock, W., and Button, G. (1997). "Engineering Investigations: Practical Sociological Reasoning in the Work of Engineers". In *Social Science, Technical Systems, and Cooperative Work - Beyond the Great Divide*. G. Bowker, Leigh Star, S., Turner, W., and Gasser, L. (Eds.). New Jersey, Lawrence Erlbaum Associates: 70-104.

Silverman, D. (1978). *The Theory of Organisations*. London, Heinemann.

Smith, J. S. (1998). "Physics of Failure". In *Handbook of Reliability Engineering and Management*. W. G. Ireson, Coombs, C.F.Jr., Moss, R.Y. (Eds.). New York, McGaw Hill.

Star, S. L., and Griesemer, J. R., (1989). "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkley's Museum of Vertebrate Zoology, 1907-39." *Social Studies of Science*, 19(3): 387-420.

Strauss, A. (1978). "A Social World Perspective." *Studies in Symbolic Interaction*. 1: 110-128.

Strauss, A. (1987). *Qualitative Analysis for Social Scientists*, Cambridge University Press.

Strauss, A. (1993). *Continual Permutations of Action.* New York, Aldine de Gruyter.

Strauss, A., and Corbin, J. (1990). *Basics of Qualitative Research, Grounded Theory Procedures and Techniques.* New York, Sage Publications.

Strauss, A., and Corbin, J. (1994). "Grounded Theory Methodology - An Overview". In *Handbook of Qualitative Research.* N. K. Denzin, and Lincoln, Y.S. (Eds.). London, Sage: 273 - 283.

Strauss, A., and Corbin, J. (Eds.). (1997). *Grounded Theory in Practice.* California, Sage.

Strauss, A., Fagerhaugh, S., Suczek, B., and Wiener, C. (1985). *Social Organisation of Medical Work.* Chicago, The University of Chicago Press.

Suchman, L. A. (1987). *Plans and Situated Actions.* Cambridge, Cambridge University Press.

Taylor, J. C., and Felten, D.F. (1988). *Performance by Design: Sociotechnical Systems in North America.* New Jersey, Prentice Hall Inc.

Thimbleby, T. (1990). *User Interface Design.* New York, ACM Press.

Thomas, R. J. (1994). *What Machines Can't Do : Politics and Technology in the Industrial Enterprise.* Los Angeles, University of California Press.

Thompson, P. (1989). *The Nature of Work: An Introduction to Debates on the Labour Process,* Macmillan.

Trist, E. L., and Bamforth, K.W. (1951). "Some Social and Psychological Consequences of the Long Wall Method of Coal Cutting." *Human Relations*, 4(1): 3-38.

van der Belt, H., and Rip, A. (1987). "The Nelson-Winter-Dosi Model and Synthetic Dye Chemistry". In *The Social Construction of Technological Systems - New Directions in the Sociology and History of Technology.* E. B. Bijker, Hughes, T.P., and Pinch, T.J. (Eds.). Cambridge, The MIT Press.

Van Maanen, J. (1988). *Tales of the Field - On Writing Ethnography.* Chicago, University of Chicago Press.

Vidosic, J. P. (1969). *Elements of Design Engineering.* New York, The Roland Press Company.

Wafler, T., and Older, M.T. (1997). "Comparison of Two Approaches Supporting Decisions on Function Allocation". In *Feelings Work in Europe.* F. Avallone, Arnold, J., and Witte, K.D. (Eds.). : 234-242.

Wallace, K. M., and Hales, C. (1987). "Detailed Analysis of an Engineering Design Project". *International Conference on Engineering Design*, ASME.

Wood, S. (1982). *The Degradation of Work: Skill, Deskilling and the Labour Process.* London, Hutchinson.

Woodward, J. (1958). *Management and Technology*. London, HMSO.

## Appendix (1) - Sample Report on Sub Nodes

Q.S.R. NUD.IST Power version, revision 4.0.

PROJECT - 5MTPA Project, User Ross Wotherspoon, 10:00 am, Jul 6, 2001.

**Table A1 – Sample Report on Sub Nodes**

| Node Title | Node Description |
|---|---|
| THE GROUPS | the SI concept of social worlds |
| THE GROUPS/social world internal | things occurring within social worlds |
| THE GROUPS/social world internal/norm conflict | some social worlds have norms that conflict and create tension |
| THE GROUPS/social world internal/full engagement | some ideas or activities capture all observers some don't |
| THE GROUPS/social world internal/bias | social worlds have views on what is important, this bias influences the way things are treated explicitly and implicitly |
| THE GROUPS/social world internal/dissent | the ways disagreement and dissent within the social world are handled |
| THE GROUPS/social world internal/dissent/humour | the use of humour as a method of voicing dissent without actually risking social world rule breaking |
| THE GROUPS/social world internal/Norm review | reviewing group norms |
| THE GROUPS/social world internal/group pressure | the attitudes and norms of group members influencing individuals actions |
| THE GROUPS/SOCIAL WORLD distinction | the acknowledgment of differences between various social world by their constituents and/or similarities with other social world |
| THE GROUPS/SOCIAL WORLD distinction/understanding | a demonstrated lack of understanding of the other world eg use of black art as a means of justification of lack of understanding |
| THE GROUPS/SOCIAL WORLD distinction/association | the association of respondent of themselves with a social world |
| THE GROUPS/SOCIAL WORLD distinction/manifestation | the manifestation of a distinction between social worlds in a physical object |
| THE GROUPS/SOCIAL WORLD distinction/acceptance | the point at which a member of another social world becomes an individual with individual characteristics for interaction instead of stereotypical characteristics |
| THE GROUPS/SOCIAL WORLD distinction/social world pigeon holing | placing individuals within social worlds that they may not associate themselves with |

| | |
|---|---|
| THE GROUPS/SOCIAL WORLD distinction/power | some social worlds have greater power then other social worlds , eg eng vs ops |
| THE GROUPS/SOCIAL WORLD id's | various social worlds that have been identified by respondents during the observation process |
| THE GROUPS/SOCIAL WORLD id's/political social world | the social world of active players in the realm of viewing actors, linkages and projecting strategies amongst them. |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD | the social world of the engineer |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD/eng disciplines social world | the social world of the various engineering disciplines, eg, electrical, mechanical, process, including BHPE |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD/eng disciplines social world/eec proc cntrl | electrical process control group |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD/eng disciplines social world/elec eng | the electrical eng group |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD/eng disciplines social world/engineers | this is a non specific grouping of individual engineers |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD/eng disciplines social world/process eng | process engineers |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD/values | values that are either espoused or in use within the social world of the eng |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD/values/documentation | the engineering value providing documentation on projects |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD/values/esp vs in use | espoused values versus values in use |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD/values/esp vs in use/non-espoused in use | values that are not espoused but seem to be in use |
| THE GROUPS/SOCIAL WORLD id's/ENG SOCIAL WORLD/values/efficiency | efficiency is an important value to eng, bottom line measurable contributions ..cost red, time red, etc |

## Appendix (2) – BOS Project Technical Details

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**Figure A1 BOS Project Plant Schematic**

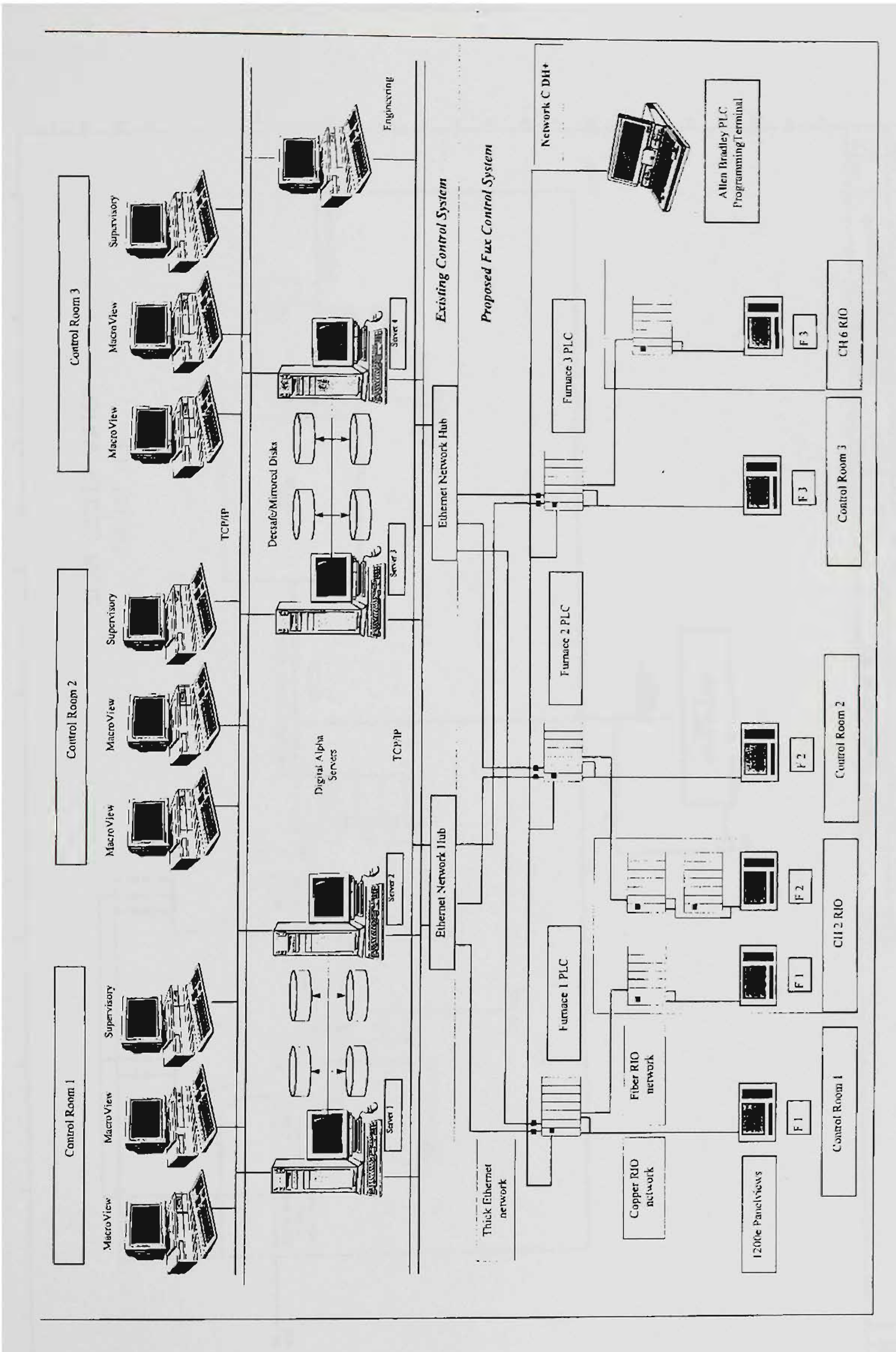


**Figure A2 BOS Project Hardware Configuration**

## Appendix (3) – WTP Project Technical Details

Please see print copy for image

**Figure A3 WTP Project Plant Schematic**

Please see print copy for image

**Figure A4 WTP Project Desk Layout**

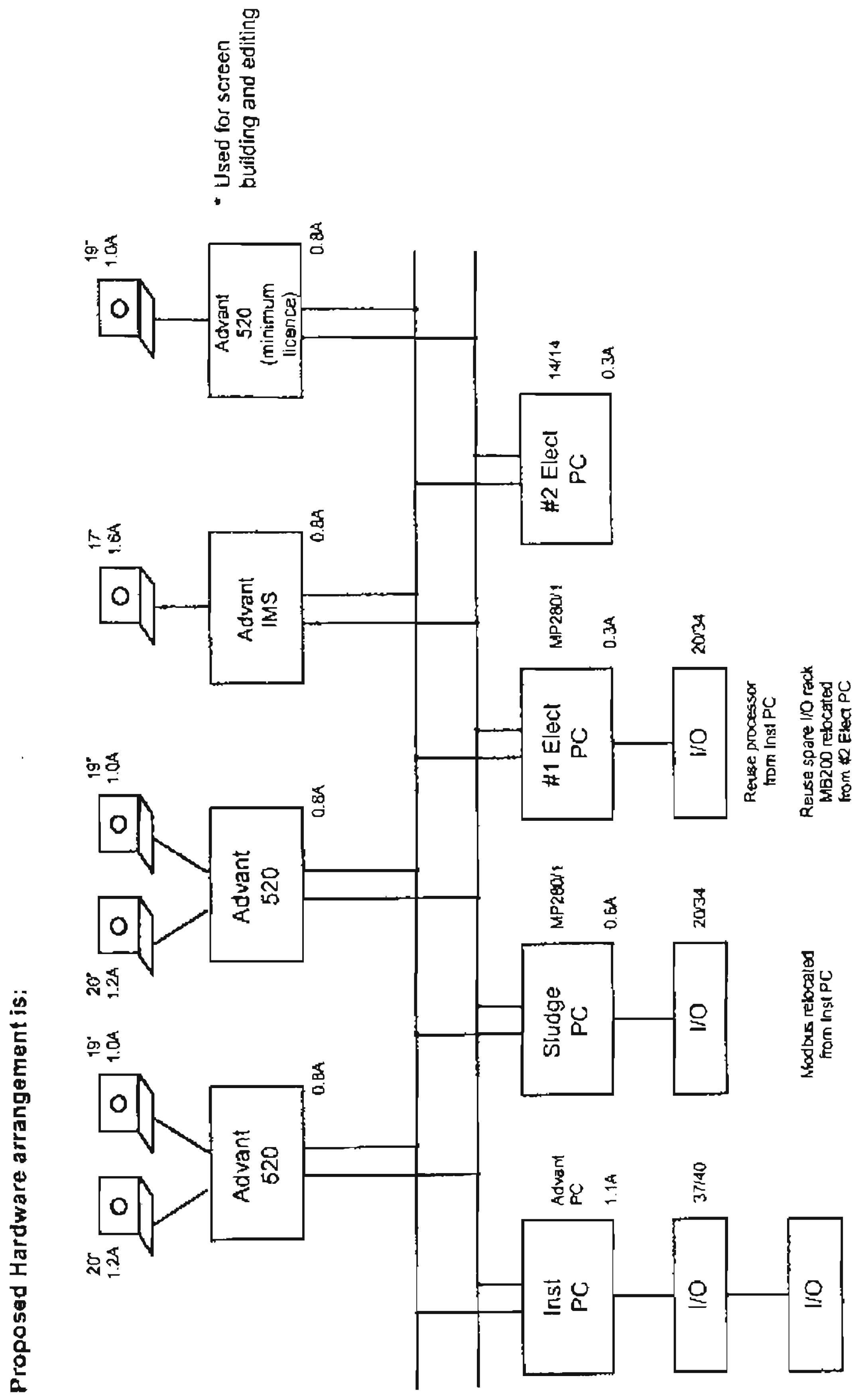


**Figure A5 WTP Project Hardware Configuration**

## Appendix (4) – LK Project Technical Details

Please see print copy for image

Figure A6 LK Project Plant Schematic

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**Figure A7 LK Project Desk Layout**

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**Figure A8 LK Project Hardware Configuration**

**Appendix (5) - KOMPASS**

KOMPASS was developed by the Swiss Federal Institute of Technology, (ETH), Work and Organisational Psychology Unit, Zurich, Switzerland (for more details see Grote 1994; Grote 1995; Grote 1996; Wafler 1997). KOMPASS is an abbreviation of the German version of 'Complementary Analysis and Design of Production Tasks in Sociotechnical. The method is applied by a trained 'expert' and sets out a list of things to be considered and a series of steps to be followed that should, its proponents claim, lead to the optimal design of a human computer interface (Garrety 2000, p.113). To develop my competence and 'expert' status, I visited Zurich to observe the approach in use and receive first hand tuition.

The KOMPASS method is comprised of three modules, two geared toward system design supporting explicit definition of a design philosophy and the development and evaluation of design options. The third module contains guidelines for the analysis of existing systems on three levels of analysis: work system, individual job, and human machine system. The KOMPASS method has a set of four operationalised criteria, derived from work psychology, that are used for guidance and assessment in the design process (Grote 1995):

1. Dynamic coupling – This criterion describes the degree of control the human operator has with respect to the coupling between him or her and the technical system. Tight coupling as well as decoupling are to be avoided.

2. Process transparency – A crucial prerequisite for fulfilling supervisory control tasks is the transparency of the process for the human operator, which permits that mental models adequate to the task to be performed can be formed.
3. Decision authority – The distribution of decision authority in human machine systems determines to what extent the human operator and the technical systems can control the actual processes.
4. Flexibility – Human machine systems fulfil the criterion of flexibility if they permit different levels of decision authority for a given function.

In applying the KOMPASS method I conducted a series of workshops that guided the design sub-team through the three modules. During this process the design sub-team used the criterion as an aide to detailed design analysis and decision making. The following section contains the results of two KOMPASS workshops conducted for the WTP Project.

# BHP Port Kembla
# BHP Institute for Steel Processing and Products
# Caster Water Treatment Plant
# KOMPASS Workshop I
# May 1999

*Facilitators:*

| | |
|---|---|
| Ross Wotherspoon | BHP Steel Institute, University of Wollongong |
| Christina Kirsch | BHP Steel Institute, University of Wollongong |

*Participants:*

| | |
|---|---|
| ***Leo Tims*** | ***BHP PK, WTP Operations*** |
| ***Frank Stanic*** | ***BHP PK, WTP Operations*** |
| ***Ralph Cowie*** | ***BHP PK, WTP Operations*** |
| ***Trevor Lord*** | ***BHP PK, Process Engineering*** |
| ***Steve Gilroy*** | ***BHP PK, WTP Operations*** |
| ***Colin More*** | ***BHP PK, Process Control*** |
| ***Bill Woods*** | ***BHP PK, Process Control*** |
| ***Eric Haines*** | ***BHP PK, Plant Engineering*** |
| ***Victor Dunn*** | ***BHP PK, WTP Maintenance*** |
| ***Ray Denley*** | ***BHP PK, WTP Maintenance*** |

*Objectives:*

- Create a shared and mutually agreed upon understanding of the work system, its purpose and objectives, the tasks performed within the system and problems and variances that occur.
- Open the technology focus and make the participants think in systems.
- Create a shared understanding of the scope of the project.
- Make people consider the qualitative difference between man and machine, to make them think in working conditions, not in either technology or people.

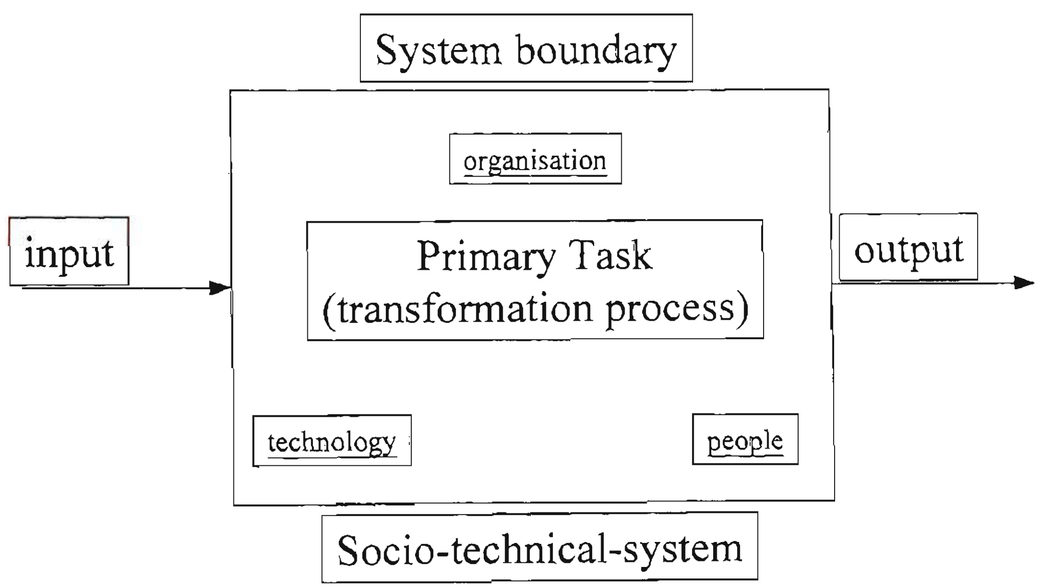
**Results:**

## 1. PURPOSE AND MAIN TASK OF THE WATER TREATMENT PLANT

The primary task of the WTP is to:

| |
|---|
| Safely treat and supply water to the right conditions and customer requirements. |

### 1.1 Socio-technical-system




### 1.2 Input

- used water (used, dirty, hot, acidic)
- lots of chemicals
- electricity and other services
- clean water
- information from other sources
- maintenance spares
- supply of chemicals
- information on plant demands (planning)
- management directions on plant operation
- Variation in operation techniques
- improvements

### 1.3 Input from ...

- slab making / casting
- Sydney water
- energy services
- transport services
- chemical companies

- maintenance department
- engineering/ technology services
- external environment (temperature, humidity etc.)

### 1.4 Transformation

- water is treated (cleaned, cooled)
- chemically balanced
- pumped to other places
- monitor and test
- remove waste products (slabs)
- use/ consume the services
- installation of new components/ spares

### 1.5 Output

- treated water (cooler, cleaner, chemically balanced)
- supplied under the right pressure
- some by-products
- noise
- ("happy customer")

### 1.6 Output to ...

- customers

*2. MAIN SUB-FUNCTIONS PERFORMED IN THE WATER TREATMENT PLANT*

The main sub-functions that must be performed in the WTP in order to achieve the primary task are:

5. Communication
6. Administration
7. Safety management
8. Routine Operations - Process
9. Waste Handling
10. Data Collection & Feedback
11. Planning
12. Technical Support
13. Routine Operation - Non-Process
14. Quality Control

### 2.1. Communication

- diplomatising
- management of personnel
- interpret directives
- interacting with others
- interaction with other people, outside sources
- inform maintenance
- communication security / store
- get info/ updates on changes anything that affects the WTP

### 2.2 Administration

- train (operators in procedures, safety etc.)
- organising rosters
- auditing vs., procedures
- training of personnel

### 2.3 Safety Management

- safety of people on plant
- maintain safe working environment
- testing emergency systems
- isolating equipment
- emergency chlorine test
- emergency head tank test
- emergency diesel test (power, tank )
- chemical handling safety
- chlorine detection test
- ensuring alarm, SVS function
- backup system availability

- emergency fire alarm
- inspect breathing gear
- access control
- safety orders
- review SOPs

**2.4 Routine Operations - Process**

- add sodium bicarb
- connect chlorine tank
- make-up water
- ordering chemicals
- plan/ schedule chlorine adjustment
- monitor chlorine consumption
- evaluate condition of machinery etc.
- receiving chemicals
- start/ stop pumps
- isolating equipment
- fault finding
- drive crane
- hourly records

**2.5 Waste Handling**

- back washing
- removing waste
- filter
- sludging

**2.6 Data Collection & Feedback**

- monitoring
- accepting alarms and understanding
- inspections general
- trouble shooting
- processing info
- daily reports
- acting on plant variation
- monitor fans, pumps etc.
  plant set up
- cooling
- optimising operation
- fault finding

**2.7 Planning**

- coordination and prioritisation of sub-tasks
- prioritise sub-tasks

- coordinate maintenance activities
- coordinate people/ labor/ services

**2.8 Technical Support**

- major plant change projects
- plant modification
- fault finding
- problem feedback, reporting
- routine maintenance
- modification control system
- performance tests
- ensure plant availability
- documentation maintenance
- ensure redundancy
- design/ installation improvements

**2.9 Routine Operation - Non-Process**

- house keeping
- polish floors
- ordering tools etc.
- coordinate supply of materials
- signing ATWs
- Gate access control
- recording the files

**2.10 Quality Testing ./Control**

- water quality testing
- testing of chlorine
- grease and oil sampling
- test alkalinity
- testing metal
- microbiological test
- biocide testing

## <u>3. VARIANCES AND DISTURBANCES</u>

The main variances and disturbances that that impact on the WTP achieving its primary task are:

1. Interpersonal communication Difficulties
2. External Influences (beyond control)
3. Supply (goods and services)
4. Management Policy Changes
5. Equipment Availability
6. Non-standard Operation

7. Planned non-standard Operation
8. Influences on individuals (individual work design)
9. Influences on Personnel (human relations)
10. Routine Distractions
11. Data Quality

**3.1 Interpersonal communication Difficulties**

- reaction to customer
- personal clashes
- major televised sporting events
- communication
- interpretation, variation in work execution
- priority conflicts

**3.2 External Influences (beyond control)**

- power loss
- equipment failure
- lightning
- quality of the tools and equipment (variations) / cost cutting and cheaper equipment
- weather
- temperature
- poor quality materials
- external inputs to water
- complex interactions
- resources (electricity, gas etc.)
- fires
- chlorine leak
- work place accidents
- asbestos discovery
- legionella/ bacteria growth

**3.3 Supply (goods and services)**

- supply quality (chemicals, maintenance, services)
- supply delays
- chemical consistency
- chemical content of water (input water quality)
- external supply redundancy
- change contractors
- availability of breakdown maintenance
- expert availability

**3.4 Management Policy Changes**

- management changes policy
- changing customer specs

- changes in OHS requirements
- customer requirements, demands
- management policy

**3.5 Equipment Availability**

- poorly maintained equipment
- equipment performance
- faulty spares
- machine breakdown
- new equipment

**3.6 Non-standard Operation**

- tolerance levels
- change in work practices
- operational demands (water supply)
- modified plant updates
- change of parameters
- change in process
- plant loading

**3.7 Planned non-standard Operation**

- d/days
- op. interface changes
- trials and testing
- extended shutdowns
- shift changes
- receiving dangerous goods
- maintenance planning

**3.8 Influences on individuals (individual work design)**

- increased workload
- fatigue (manning level, overtime)
- pressure - responsibility but no control
- motivation of operators
- expertise, multi-skilling, job rotation
- lack of training
- responsibility allocation
- workload increases
- work load
- poor planning
- procedural conflict - plant access

**3.9 Influences on Personnel (human relations)**

- strikes
- absenteeism
- people
- public holidays
- people resources
- operators (are people)
- job rotation
- personnel rationalisation
- cost cutting
- cost cutting
- number of people inputting

**3.10 Routine Distractions**

- telephone communication
- ATW signing
- doing hourly readings
- gate control
- backwashing

**3.11 Data Quality**

- incorrect data
- incorrect documentation
- corrupted data

## 4. GOALS FOR SUCCESS

The main goals or criterion for a successful WTP as defined by the workshop are:

| | |
|---|---|
| 1. | Safety / Environment |
| 2. | Support Efficiency |
| 3. | Personal Fulfilment |
| 4. | Plant Reliability |
| 5. | Customer Satisfaction |
| 6. | Plant Efficiency |
| 7. | Plant Robustness |

**4.1 Safety / Environment**

- OHS compliance
- no bacteria growth
- EPA satisfaction
- minimise unusable waste
- no emission into Adam's creek
- no injuries
- keep safety equipment in good order

- safe operation
- zero chlorine leaks

**4.2 Support Efficiency**

- effective maintenance plans
- dedicated maintenance team
- detailed knowledge base (Permanent)
- open communication between op/ maint/ eng
- people having understanding of the system
- efficient plant d/time system
- efficient monitoring
- long term contractors

**4.3 Personal Fulfilment**

- ownership
- personal satisfaction
- nice plant looking
- people satisfied with work/ work environment
- employee satisfaction
- able to take holidays
- alert/ interested operators
- sufficient resources to operate

**4.4 Plant Reliability**

- breakdowns low
- zero breakdowns
- 100% availability
- long period between downdays
- achieving equipment life-span
- Y2K compliant

**4.5 Customer Satisfaction**

- customer satisfaction
- zero disruptions to caster
- no wood to caster
- meet water KPIs
- happy managers

**4.6 Plant Efficiency**

- cost effective
- no industrial disputes
- efficient use of chemicals
- low costs to run the place

- electrically efficient
- reduce personnel on site
- supply material on time
- SOPs for normal/ abnormal conditions
- efficient monitoring

**4.7 Plant Robustness**

- minimal impact of disturbances (fast set-up)
- minimum Op. intervention

## 5. IMPROVEMENT POTENTIALS

In light of the primary task and the identified goals for success the following improvement potentials were identified:

### 5.1 Communication

- streamline communication channels (, so that all info is coming down one path so that people don't miss out on info)
- re-educate difficult personnel, (if someone is going completely against group - re-educate)

5.2 Environment

- design to minimise effects of external influences (you can't do much, but design equipment so that environmental forces and impacts don't have harmful effects)
- design equipment (lightning rods, redundancy eg. have redundant PLCs in case of loss of a PLC)
- condition monitoring, so that you can better foretell

5.3 Supply

- conduct trials prior to establishing contracts
- supply services - improved procedures

5.4 Equipment Reliability

- it will always break down, people that are responsible for repair should be trained and skilled enough to repair it quicker

5.5 Management Policy

- consultative process for management policy changes
- we have no control, but if they change, we should have a consultative process where the manager comes to the plant and spends time on the shopfloor, talks to people, discuss, learn how they operate before he changes anything

5.6 Planned Non-Standard Operation

- minimise downdays
- communicate changes (the Plan)
- make sure that trails and test are monitored correctly
- use extra resources if required (its a non-standard operation)
- less shift changes, smoother transfer of information across shifts

5.7 Individual work design/ Influences on Individual

- clear job responsibilities (not a fussy line)

- overall authority to allocate and manage fixes, implement improvements
- ensure the operators have enough training, targeted training
- screen for operators, accreditation scheme for operators

5.8 Influence on personnel

- ban strikes
- personnel morale (number of people, conditions, future security)
- call out system (to fix problems )
- keeping knowledge in house (succession plans; engineers tend to get moved around and we lose knowledge)
- more people if needed

5.9 Routine Distractions

- limit phone calls or improve individual access to communication
- get a person to be  a dayshift supervisor
- people inducted to have a card
- review hourly readings (may be print a sheet) - we might still need something to keep us awake, but there might be other options
- automate sludge plant

5.10 Data Quality

- correct documentation
- knowledge of process
- instrumentation maintenance and reliability ( so they know that what they see on the screen is the correct data)

## 6. *CONTRIBUTIONS AND HINDRANCES AT WATER TREATMENT PLANT*

In light of the primary task and the identified goals for success the potential contributions and hindrances of technology, organisation and people have been evaluated.

### 6.1 CONTRIBUTIONS

| Goal | People | Technology | Organisation |
|---|---|---|---|
| 1. Plant Reliability. | Knowledge of process inspections | - condition monitoring | - audits<br>- standard procedures. |
| 2. Plant Efficiency | training | reporting<br>monitoring | audits<br>SOPs |
| 3. Support Efficiency | training to maintenance people, knowledge of the process at the WTP | condition monitoring to allow maintenance | SOP, so that maintenance people know what to do; planning, so that it has minimal impact |
| 4. Personal Fulfilment | responsibility and authority to make decisions, so that operators actually can make decisions | appropriate tools to perform those tasks | positive reinforcement, pat on the back, monetary reinforcement for having made the right decisions |
| 5. Safety / Environment | diligence,<br>duty of care,<br>training | correct information monitoring & reporting | training,<br>SOPs |
| 6. Customer Satisfaction | improved communication skills and teamwork workshops so that WTP people feel as part of caster team | efficient reporting | feedback and framework, so that there is a way of reporting non-standard things to the caster |
| 7. Plant Robustness | communication skills, they report what has to be fixed; problem solving skills (so WTP people solved the problem and engineers just do the fixing),training. | monitoring<br>reporting,<br>automation | resources<br>authority |

### 6.2 HINDRANCES

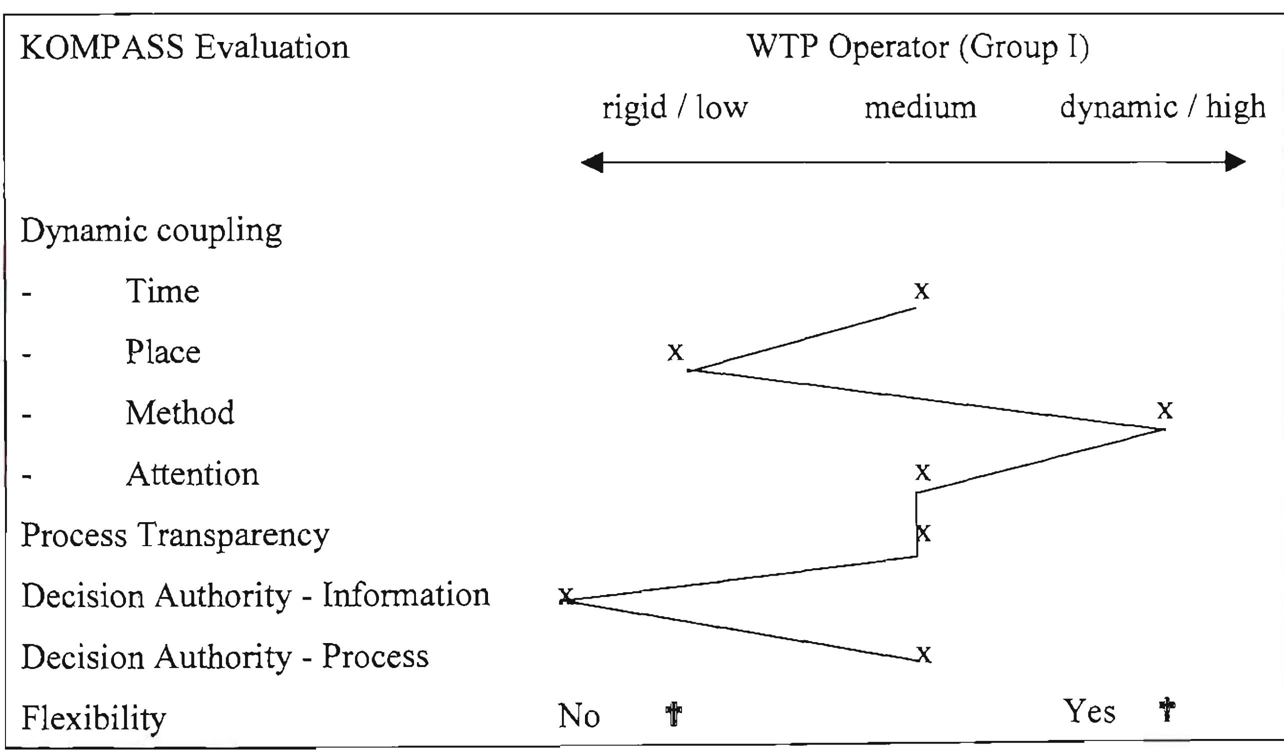
| Goal | People | Technology | Organisation |
|---|---|---|---|
| 1. Plant Reliability | not doing regular | unsupported equip, | complicated |

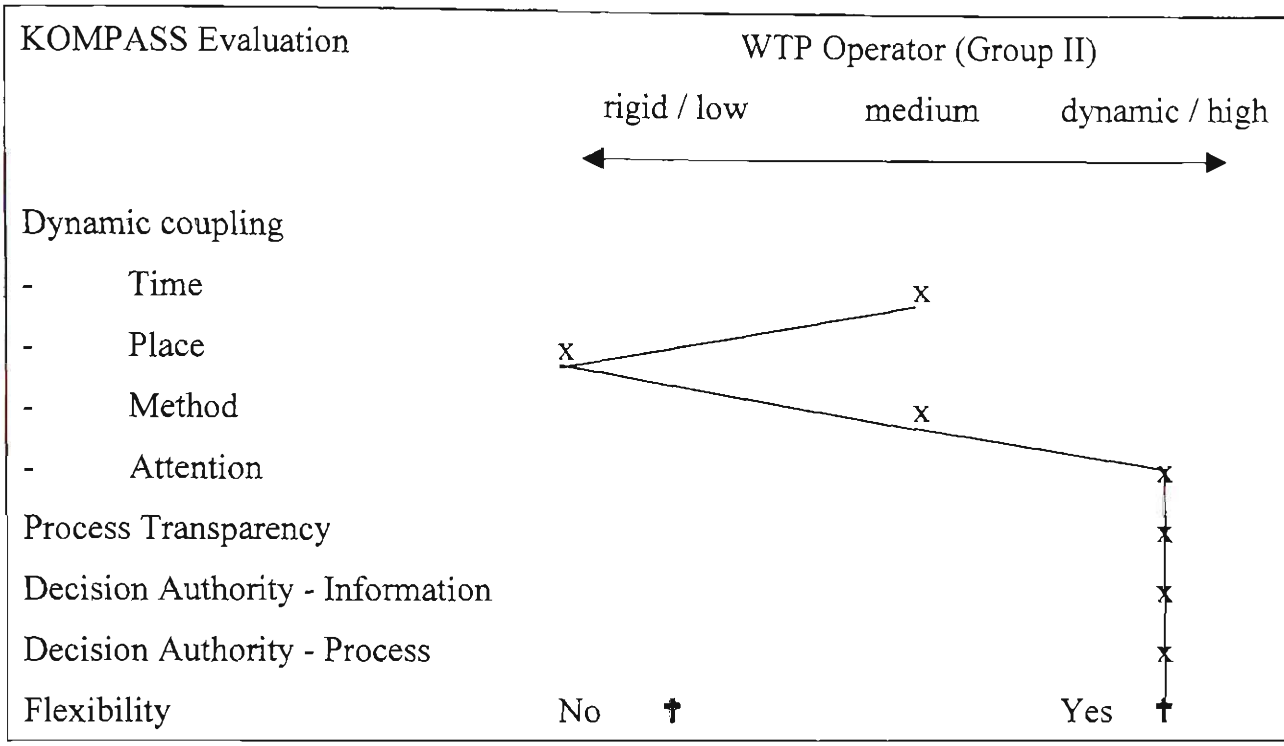
| | | | |
|---|---|---|---|
| | inspections and checks, not following up on maintenance reports | non-integrated design eg. pump set not matching | reporting system which makes it difficult to get feedback |
| 2. Plant Efficiency | inconsistent operation | difficult interaction with technology | single authority (not having), unclear authority, responsibility |
| 3. Support Efficiency | inconsistent maintenance<br>plant knowledge insufficient | SAP cumbersome | succession plus |
| 4. Personal Fulfilment | frustration at repetition (tasks and trying to get things done)<br>- no commitment | understanding | no structure to give plant ownership |
| 5 Safety / Environment | people not taking personal responsibility. | not designed with safety and environment in mind, old stuff | cumbersome reporting system, |
| 6. Customer Satisfaction | no customer focus<br>no plant ownership | can't meet future changes in customer requirements | poor communication<br>lack of funds |
| 7. Plant Robustness | training | restrictive (under certain conditions)<br>- semi-automatic operation (projects not completed) | manpower level for improvement projects<br>abnormal conditions |

## 7. KOMPASS EVALUATION OF THE CURRENT WTP OPERATOR JOB

Evaluation of the current WTP operator role using the 4 KOMPASS criteria.

- **Dynamic coupling**
  Availability and use of technically provided options regarding time, place, work procedures, and required cognitive effort.
- **Process transparency**
  Opportunities for forming and maintaining mental models of the general nature and temporal structure of production processes and of required interventions, process feedback modalities.
- **Decision authority**
  Distribution of decision authority regarding information access and process control between human operator and technical system.
- **Flexibility**
  Variability of function allocation between human operator and technical system and distribution of the respective decision authority.






| | |
|---|---|
| Time | sludge plant operation / backwashing |
| place | need to control via control room |
| method | some functions via operator station/ panel and desk |
| attention | has some peripheral view via panel; high low priority alarm systems |
| transparency | visual display via panel/ screen; audible high priority alarm when out of operating room |
| Authority (info.) | information freely available to operators |
| Authority (process) | auto/ man functions |

## 8. FUNCTION ALLOCATION

The main sub-functions required to perform the primary task have been allocated to either technology, operator or both based upon the KOMPASS criteria

Group I

| Functions | Technology | Flexible | Operator |
|---|---|---|---|
| communication | provides plant ownership | - | - |
| waste handling | | should be flexible -normal -auto but can be manual | (need to be automated at sludge plant) |
| take hourly readings | | | use technology to record + trend + alarm |
| quality testing & control | people to evaluate | needs to be flexible | technology to collect data water quality variables to be collected automatically |
| make up H2 O add | | needs to be flexible | try an automated system |
| water balance | | needs to be flexible | try an automated system |
| trouble shooting | person needs to evaluate | | monitoring, reporting faults |
| monitoring chlorine gas leak | | | install equip to read Cl-gas level remotely |

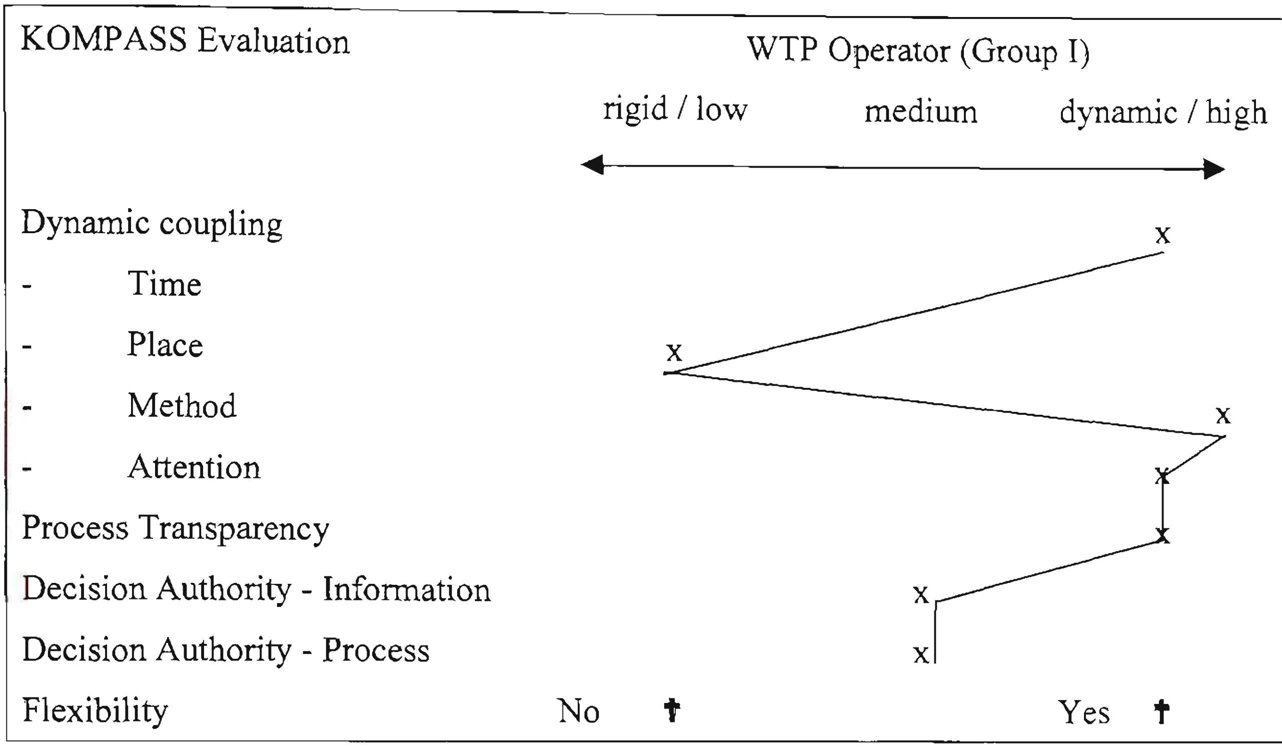
Group II

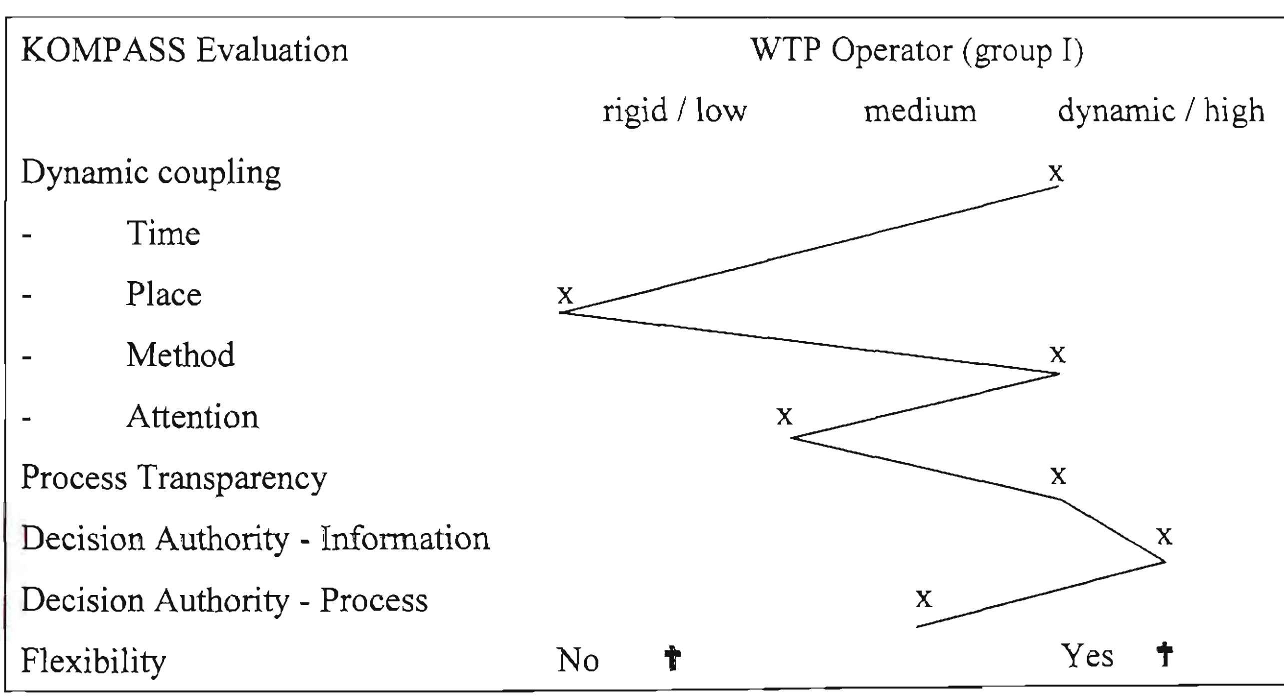
| **Functions** | **Technology** | **Flexible** | **Operator** |
|---|---|---|---|
| communication<br>- inform<br>maintenance | creates involvement<br>=> learn process<br>- allows operator to fitter | | |
| administration - rosters | allows flexibility | | |
| safety management<br>- testing emergency systems | | started by people but a standard technical test | |
| - alarm test | by people to keep understanding of system and control | | |
| Testing<br>- water quality | | standard routine tests but people able to do extras | |
| Data collection<br>- daily reports | analysed | | collected |
| data variation all | all | all | all |
| monitoring fans & pumps | | technology to do, people to be able to check | |
| routine ops - non process<br>gate access | | technical for regular people, non standard access for gate | |
| Planning:<br>- priorities | people | | |
| - coordinating maintenance - labour | | standard work generated by technology, other by people | |
| Tech. support | people or engineers and maintenance have no job | | to collect data |
| Routine Ops - Process:<br>-bicarb | | routine ops by technology, people to check | |
| - connect chlorine | people so that system is understood | | |
| - M/C water | | logic to control in normal ops.<br>Operator to add when filling up | |
| - ordering chemicals. | | technology lets operator know when to order -> people | |

| | | | |
|---|---|---|---|
| | | need to check it | |
| chlorine resident | technology isn't reliable yet | | |
| monitor chlorine consumption | | | routine job need a cable run |
| evaluate condition of machinery | | used for continual maintenance and fault finding | |
| receiving chemicals | people to ensure actual delivery | | |
| start/stop purpose | | some non-standard ops | |
| drive crane | | | automated to de-couple |
| hourly records | | some auto, but have to go to look for it to couple the operator, Not time driven | |
| waste handling:<br>- back washing | | driven by dp, time etc. also able to be initiated manually | |
| - removing waste | keep operator in touch with plant | | automated |
| - filtering<br>- sludging | | need operator to initiate | should have the technology to de-couple |

## 9. *KOMPASS EVALUATION OF THE FUTURE WTP OPERATORS JOB.*

Based upon the modified function allocation the WTP operator job is re-evaluated using the KOMPASS criteria.



# BHP Port Kembla
# BHP Institute for Steel Processing and Products
# Caster Water Treatment Plant
# KOMPASS Workshop II
# July 1999

*Facilitator:*

| | |
|---|---|
| Ross Wotherspoon | BHP Steel Institute, University of Wollongong |

*Participants:*

| | |
|---|---|
| ***Leo Tims*** | ***BHP PK, WTP Operations*** |
| ***Frank Stanic*** | ***BHP PK, WTP Operations*** |
| ***Ralph Cowie*** | ***BHP PK, WTP Operations*** |
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| ***Bill Woods*** | ***BHP PK, Process Control*** |
| ***Eric Haines*** | ***BHP PK, Plant Engineering*** |
| ***Victor Dunn*** | ***BHP PK, WTP Maintenance*** |
| ***Ray Denley*** | ***BHP PK, WTP Maintenance*** |

*Objectives:*

- Create a shared and mutually agreed upon understanding of the Scarfer water system, its purpose and objectives, the tasks performed within the system and problems and variances that occur.
- Open the technology focus and make the participants think in systems.
- Create a shared understanding of the scope of the project.
- Consider the qualitative difference between man and machine, thinking in working conditions, not in either technology or people.

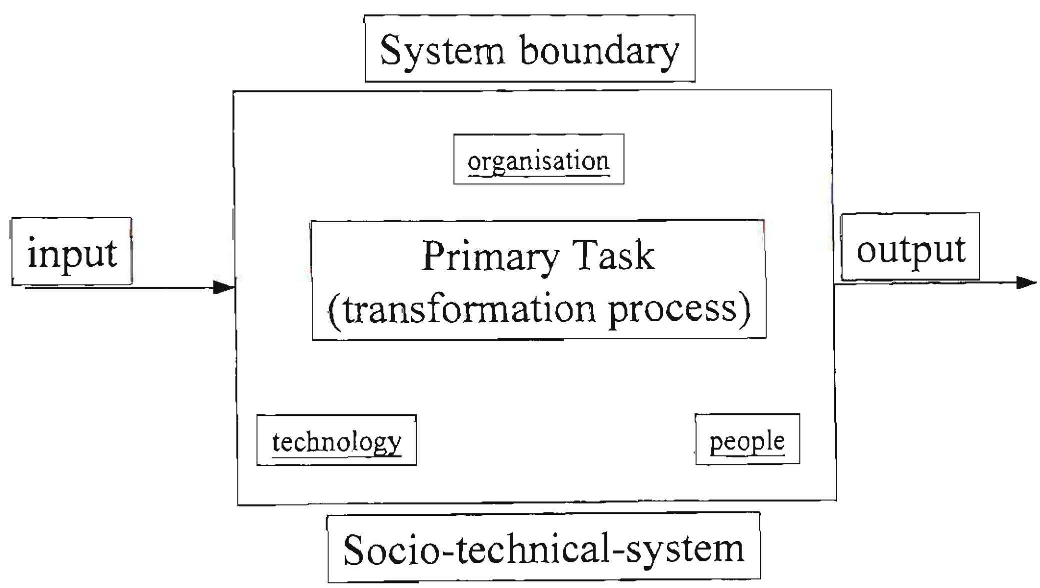
**Results:**

## 1. PURPOSE AND MAIN TASK OF THE WATER TREATMENT PLANT SCARFER CIRCUIT

The primary task of the WTP Scarfer circuit is to:

| |
|---|
| Safely treat and supply water to the right conditions and requirements for the Slab Handling Scarfer. |

### 1.2 Socio-technical-system




### 1.2 Input

- Cascade water
- Scarfer dirty return water
- Gland water
- Scale
- Oil/grease run offs
- Chemicals
- Overflow from other systems
- Heat
- Electrical power
- Communications verbal
- Maintenance

### 1.4 Transformation

- water is treated (cleaned, cooled)
- chemically balanced
- pumped to other places
- monitor and test
- remove waste products
- use/ consume the services
- installation of new components/ spares

### 1.5 Output

- treated water (cooler, cleaner, chemically balanced)
- supplied under the right pressure
- some by-products
- noise

## *2. MAIN SUB-FUNCTIONS PERFORMED IN THE WATER TREATMENT PLANT SCARFER CIRCUIT.*

The main sub-functions that must be performed in the WTP scarfer circuit in order to achieve the primary task are:

15. Process monitoring and feed back
16. Process doing
17. Repairs and maintenance
18. Planned disturbances
19. Unplanned disturbances
20. Communication
21. Water quality management
22. Training
23. Safety

### 2.1. Process monitoring and feedback

- Monitor flows
- Monitor temps
- Monitor supply pressure
- Check cooling tower levels
- Check pump pit levels
- Monitor fan
- Fan vibration
- Monitor filter
- Monitor alarms
- Report problems
- Monitor what you do is actually working

### 2.2 Process doing

- Interact with control system
- Start stop fan
- Ensure wetting pump starts
- Start stop pumps
- Change duty pump
- Record temp levels
- Back wash
- Add make up water

### 2.3 Repairs and maintenance

- Routine scheduled maintenance
- Spares availability
- Modification control
- Equipment maintenance
- Gravel filter inspection
- Equipment status and availability
- Report problems

### 2.4 Planned disturbances

- Coordinate with isolation
- Empty W24 inner and outer well
- Down day preparation
- Empty cooling tower
- Recommission plant

### 2.5 Unplanned disturbances

- Recovery management
- Power failure at scarfer

### 2.6 Communication

- With Nalco
- With Maintenance
- With scarfer operator
- With engineering
- With supervision
- Problem reporting

### 2.7 Water quality management

- Water quality control
- Water quality measurement
- Chemical balance
- Order receive chemicals

### 2.8 Safety

- Ensure plant in safe condition
- Access control
- Authority to work permits

### 2.9 Training

- Understanding standard operating procedures

## 3. VARIANCES AND DISTURBANCES

The main variances and disturbances that that impact on the WTP scarfer circuit in achieving its primary task are:

12. Equipment failure at WTP
13. Process disturbances
14. Planned disturbances
15. Operator variances
16. Management disturbances
17. External bodies
18. Emergencies
19. Training
20. Water quality
21. Maintenance issues

### 3.1 Equipment failure at WTP

- Sensor failure
- PLC failure
- General equipment failure
- Pipe leak rupture
- Communication failure
- Breakdowns
- Screen failure
- Power failure

### 3.2 Process disturbances

- Filter performance
- Weather conditions
- Not enough water
- Too much water
- Excessive temperatures
- Nuisance alarms
- Communication failure

**3.3 Planned disturbances**

- Down days
- Stop start scarfing
- Projects occuring

**3.4 Operator variances**

- Different operators
- Shift changes
- Operator attention
- Operator overload
- Operator busy onsite
- Alarm priority

**3.5 Management disturbances**

- Budget
- Management decisions
- Customer requirements
- Cost cutting
- Communication failure

**3.6 External bodies**

- Regulatory authorities – EPA, NSW Health
- Strikes

**3.7 Emergencies**

- Plant emergency
- Operator failure

**3.8 Water quality**

- Chemical imbalance
- Scarfer polymer
- Hydraulic leaks at scarfer
- Chemical supply failure

**3.9 Maintenance issues**

- Labour requirements
- Lack of spares
- Communication failure

## 4. GOALS FOR SUCCESS

The main goals or criterion for a successful WTP as defined by the workshop are:

| |
|---|
| 1. Safety / Environment |
| 2. Plant Robustness |
| 3. Plant Reliability |
| 4. Customer Satisfaction |
| 5. Personal Fulfilment |
| 6. Support Efficiency |
| 7. Plant Efficiency |

### 4.1 Safety / Environment

- OHS compliance
- no bacteria growth
- EPA satisfaction
- minimise unusable waste
- no emission into Adam's creek
- no injuries
- keep safety equipment in good order
- safe operation
- zero chlorine leaks

### 4.2 Plant Robustness

- minimal impact of disturbances (fast set-up)
- minimum Op. intervention

### 4.3 Plant Reliability

- breakdowns low
- zero breakdowns
- 100% availability
- long period between downdays
- achieving equipment life-span
- Y2K compliant

### 4.4 Customer Satisfaction

- customer satisfaction
- zero disruptions to caster
- no wood to caster
- meet water KPIs
- happy managers

### 4.5 Personal Fulfilment

- ownership
- personal satisfaction
- nice plant looking
- people satisfied with work/ work environment
- employee satisfaction
- able to take holidays
- alert/ interested operators
- sufficient resources to operate

**4.6 Support Efficiency**

- effective maintenance plans
- dedicated maintenance team
- detailed knowledge base (Permanent)
- open communication between op/ maint/ eng
- people having understanding of the system
- efficient plant d/time system
- efficient monitoring
- long term contractors

**4.7 Plant Efficiency**

- cost effective
- no industrial disputes
- efficient use of chemicals
- low costs to run the place
- electrically efficient
- reduce personnel on site
- supply material on time
- SOPs for normal/ abnormal conditions
- efficient monitoring

## 5. DETAILED SUB TASK ANALYSIS

### 5.1 Backwashing

Purpose:

- To clean filters (W26A/W26B)

Improvement potential:

- Process transparency through clear filter process diagrams (ie, process screen, filter overview screen, filter detail screen, WTP overview screen).
- Eventing of backwash on screen (ability to filter list, ie, just W26A).
- Trend backwash flows.
- Backwash blower screen

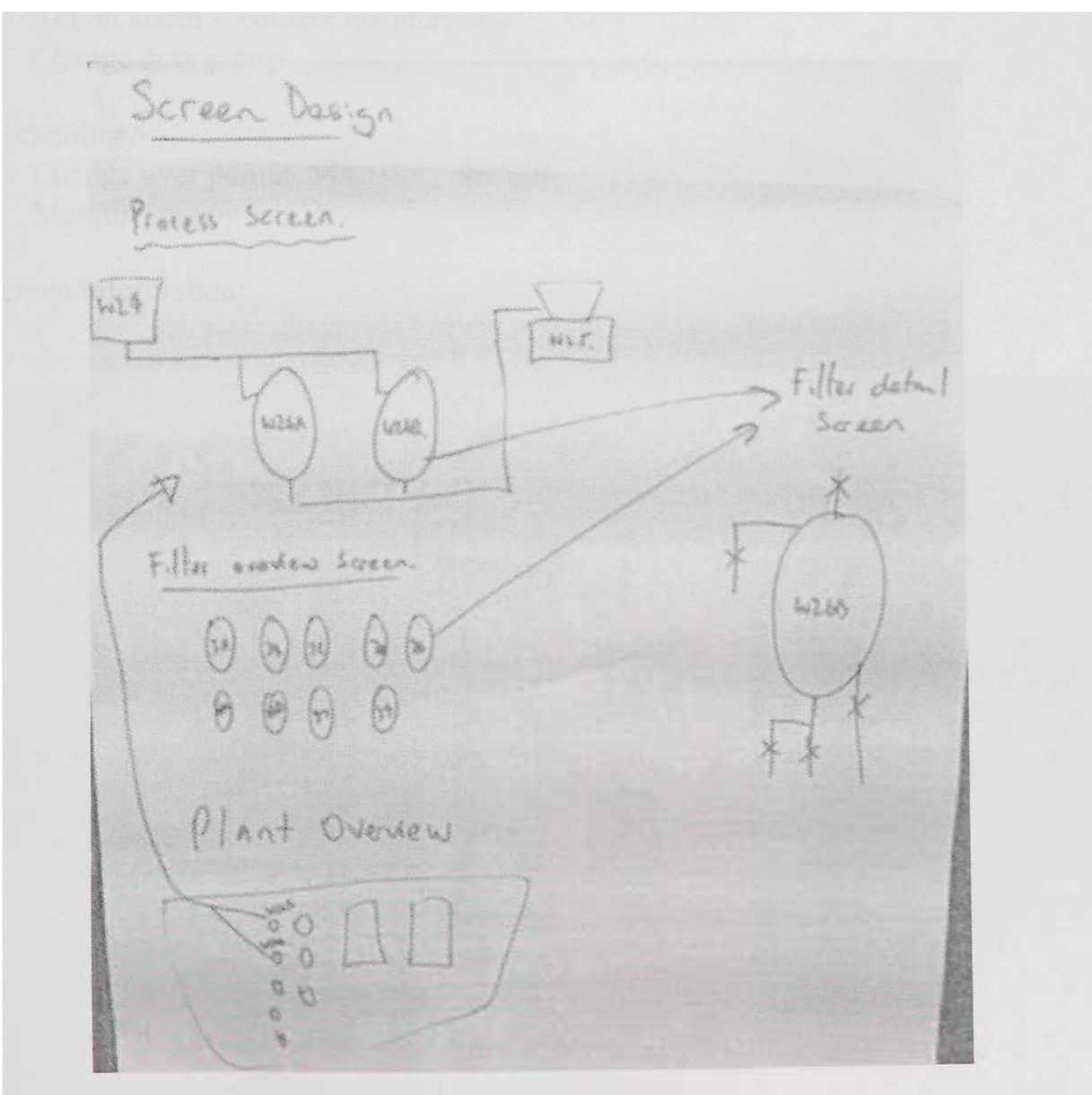
- Process screen to have link from air line to blower screen.

Function allocation:

People-
- Manual start/stop of backwash
- Full manual control
- Act on alarms
- Check backwash events screen

Technology-
- Auto sequence of backwash
- Detailed event list
- Time/dp driven backwash

Screen information:




### 5.2 Start/stop pumps and change duty pump

Purpose:

- To start/stop pumps as required, including wetting pumps.

Improvement potential:

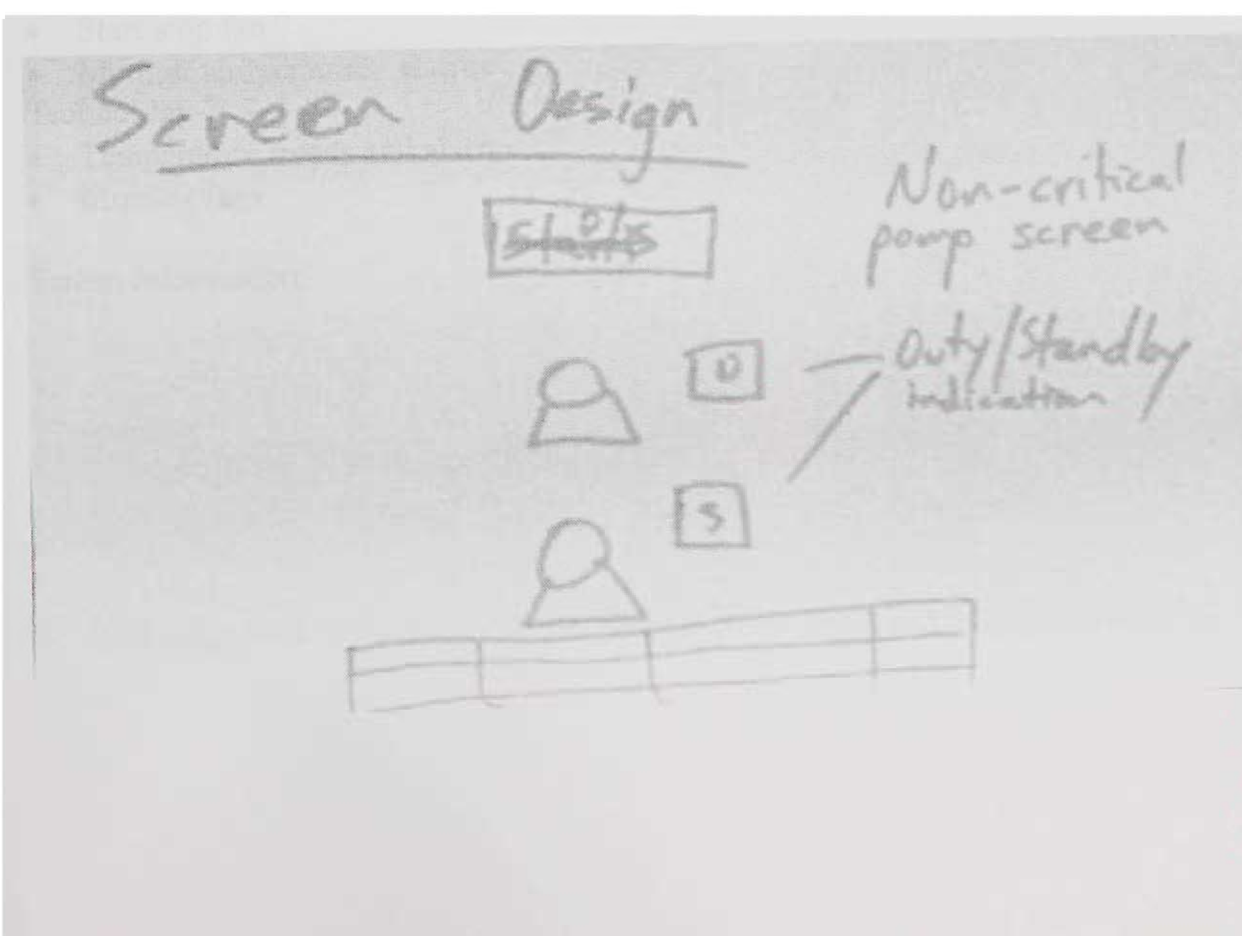
- Put on non critical pump screen.
- Start pump from process screen
- Group start, duty pump will start for T and X pumps
- Alarm FTS&S, event start stop

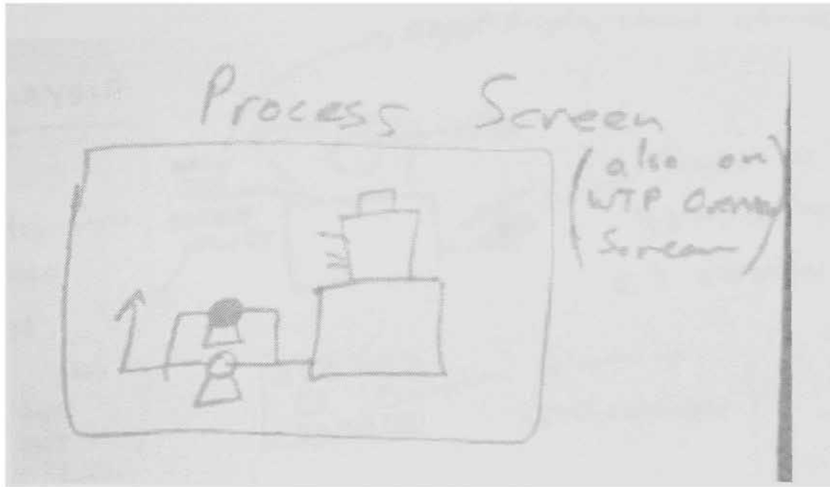
Function allocation:

People-
- Start stop pump or pump group
- Act on alarm - contact maintenance
- Change duty pump

Technology-
- Change over pumps when duty changes
- Monitor pumps

Screen information:






### 5.3 Start/stop fan

Purpose:

- To start and stop fan for cooling of water

Improvement potential:

- Which fans running on plant overview
- Temperature shown where fan controlled
- Temperature trends
- Temperature alarm / FTS/S alarm
- Vibration system into PLC

Function allocation:

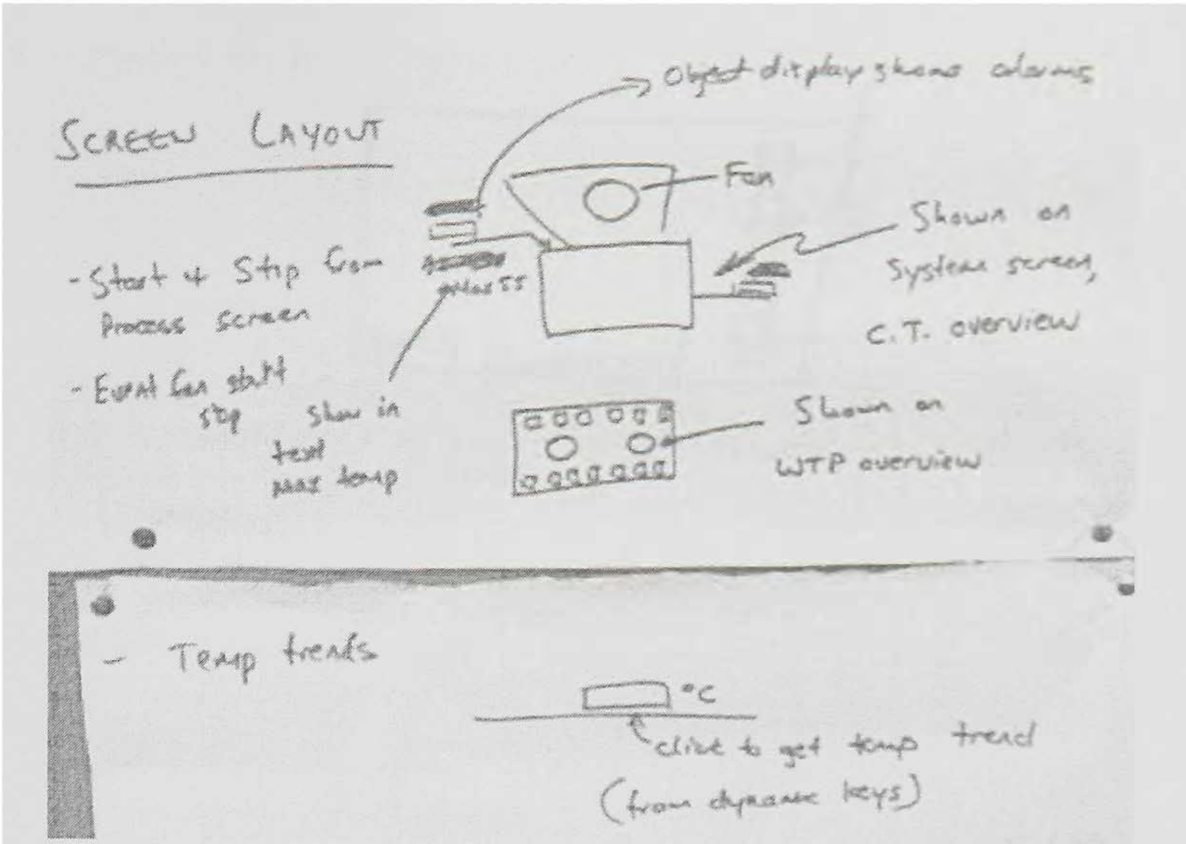
People-

- Start/stop fan
- Monitor temperature / alarms

Technology-

- Temperature trends and alarms
- Monitor fans

Screen information:




### 5.4 Monitor pump pit levels

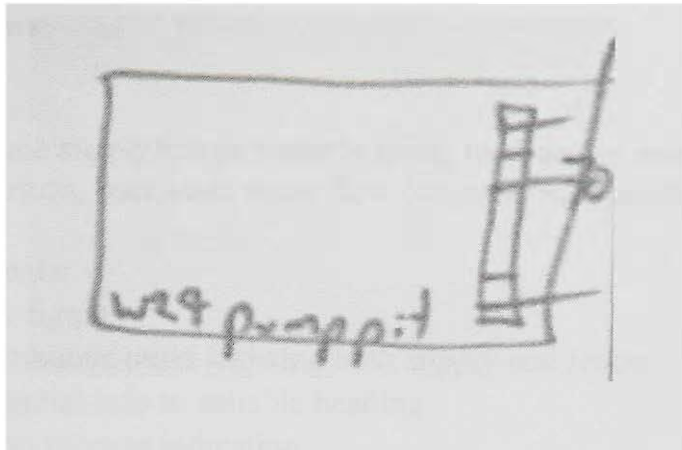
Purpose:
- Ensure safe operating range of levels in W25 and W24, not overflowing and pump protection.

Improvement potentials:
- Levels to be on scarfer overview screen
- W25 level to be on cascade screen
- W24 set points to be entered by keyboard
- Alarms coupled to process indication

Function allocation:
People-
- Operator to adjust level set points – down days
- Acknowledge and respond to alarms

Technology-
- Measure, display, alarm levels
- W25 level to be trended

Screen information:
- W24 set point entered as per W13 make up water ( including auto/manual)



### 5.5 Monitor flows

Purpose:

- To ensure adequate supply/return water is going to allocated areas, ie, scarfer supply, scarfer return, backwash water flow (on backwash handling system display)

Potential Improvements:

- Total return flow figure
- Overlapping continuous trend showing both supply and return
- Remove non essential info to suitable heading
- Alarms coupled to process indication.

Function allocation:

People-

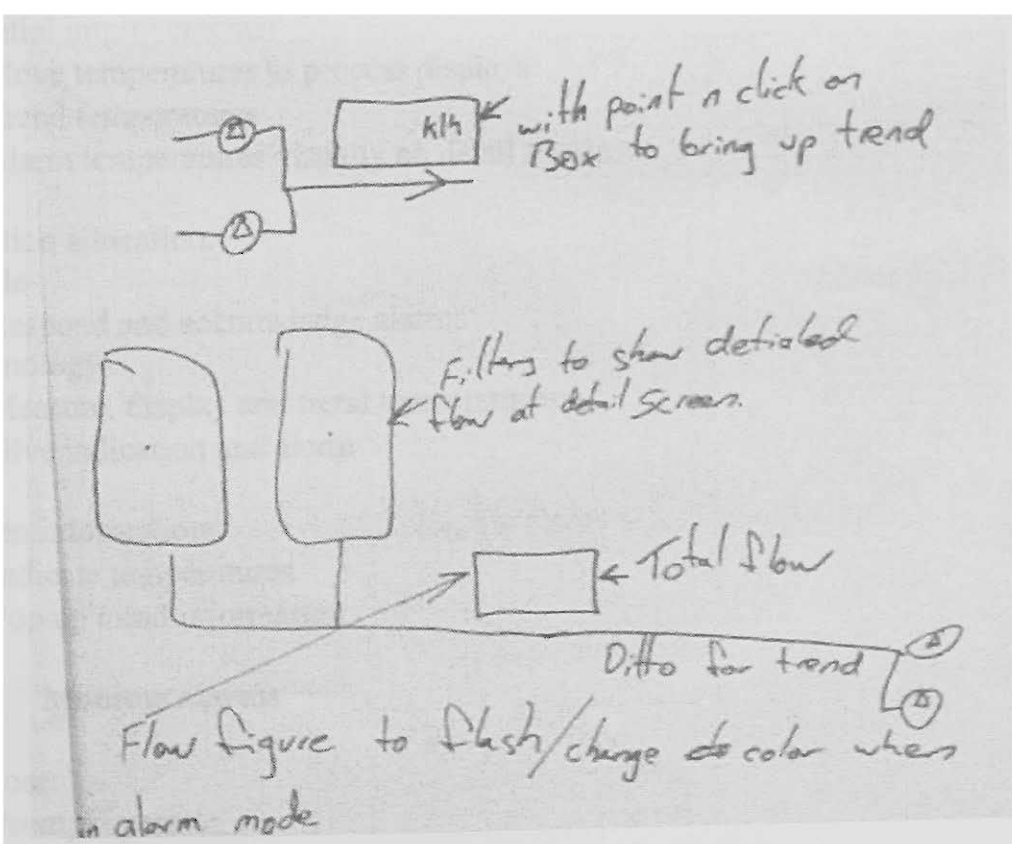
- Start flow by turning pumps on
- Acknowledge and respond to alarms

Technology-

- Measure and display flows
- Give indication and alarm low flows
- Monitor pump well levels

Screen information:

- Diagram and relevant information on scarfer circuit screen
- Trends to pop up when required




### 5.6 Monitor system pressure

Purpose:

- To display gravel filters DP and trend.

- Scarfer supply pressure has no use for operator

Potential Improvements:
- Move gravel filter DP and flow to detail screen
- Delete pressure reading
- Couple alarm to process indication

Function allocation:
People-
- High DP to initiate investigation

Technology-
- Measure and display all DP and alarm at high DP

Screen Information:
- Move filter DP to detail screen
- Obtainable by clicking on appropriate filter in process display or from general filter overview screen.

### 5.7 Monitor temperatures

Purpose:
- Ensure safe operating range of temperatures
- Supply/return lines but not in basin.

Potential improvements:
- Move temperatures to process displays
- Trend temperatures
- Alarm temperatures visually on detail screen

Function allocation:
People-
- Respond and acknowledge alarms

Technology-
- Measure, display and trend temperatures
- Give indication and alarm

Screen information:
- Indicate temperatures
- Pop up trend information

### 5.8 Monitor alarms

Purpose:
- Prompt operator
- Alarm for abnormal conditions

Potential improvement:
- Maintain high level alarms on panel

- Alarm filtering
- Colour coding of alarms on priority
- Alarms coupled to process indication
- Integrated system – single accept
- Eliminate nuisance alarms by necessity and smarts in design

Function allocation:
People-
- Acknowledge and respond to alarms
- Investigate and rectify

Technology-
- Display alarms

Screen information:
- Coupled to the process
- Filtering and colour coding
- Common alarm page
- Alarms to be logged

## Appendix (6) – TOP Modeler

TOP Modeler was developed by the University of Southern California in collaboration with a five-year, US$10M, investment by the U.S. Air Force ManTech program, the National Centre for Manufacturing Sciences, Digital Equipment Corporation, Texas Instruments, Hewlett Packard, Hughes, and General Motors (for more details see Majchrzak 1995; Majchrzak 1997a; Majchrzak 1997b; Gasser 1998). TOP Modeler is a software package that contains a knowledge base to help designers, managers, engineers, or shop-floor workers make design choices about integrating technology, organisation, and people. As with KOMPASS, to help develop my competence with the TOP Modeler software I visited its developers at the University of Southern California to receive first hand tuition.

The knowledge base embedded in the software is reported by its developers to assist designers in three central areas. Firstly, it provides comprehensive list of operational features describing a sociotechnical work system. Secondly, the knowledge base contains a large number of the ideal relationships among the operational features. Finally, the knowledge base provides a sensitivity analysis function. Real life poses many constraints on design efforts, many ideal relationships may not be feasible. As a result, design teams make trade-offs about which ideal relationships will take precedence over others. The sensitivity feature allows design teams to the predicted organisational effectiveness of their chosen trade-offs (Majchrzak 1995).

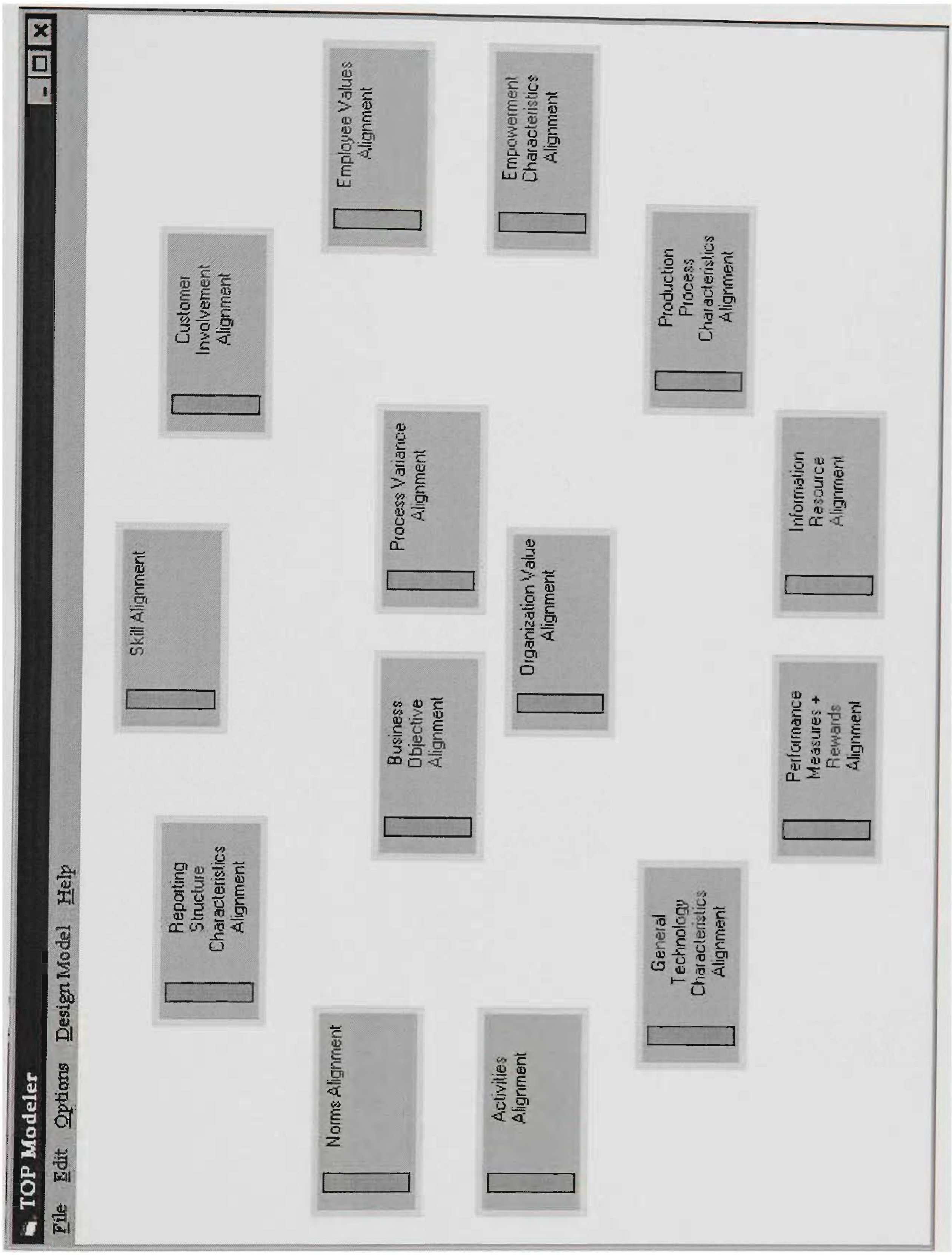



**Figure A9 TOP Modeler Control Screen**