Modelling The World : The Social Constructions Of Systems Analysts

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MODELLING THE WORLD

The Social Constructions of Systems Analysts

VOLUME ONE

By

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ABSTRACT

This dissertation is concerned with a case study of system dynamics, a well-known simulation modelling methodology, and its implicit theory of social system behaviour. System dynamics is policy oriented and is directed towards the control and management of social systems. It originally evolved in the context of military systems and then the application of systems engineering to the problems of corporate management, but was later expanded to tackle the problems of urban decay, population growth, and environmental collapse. It is therefore now aimed at large scale social engineering.

The aim of the dissertation is to take tools drawn largely from the sociology of knowledge in order to provide a perspective on the development of this particular strand of the systems movement. We investigate the status of system dynamics as a cultural artefact which is both a product of social structures and a resource for mediating and reinforcing such structures. The dissertation is addressed to the systems community, but must also meet the academic standards of the sociology of knowledge.

There are seven chapters. The first two deal with the background to system dynamics and with methodological aspects of the perspective adopted in our approach. The following two chapters examine system dynamics as a social construction: firstly, with special emphasis on the social development of the cultural context in which it evolved; and secondly, on the social experience and cosmology of the System Dynamics Group at MIT. The next two chapters deal with the social effects of system dynamics, particularly its role as a 'binding agent' in negotiating social consensus. The seventh and final chapter discusses our conclusions.
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Figures (1) & (2) are taken from:

J.W. Forrester, 'World Dynamics' (Wright-Allen Press Inc. 1971)

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Anthropologists tell us that reality is always a social construction, that our conceptions of the social and natural worlds are mediated by social relations. In contrast to the position adopted by those scholars who argue that the intrusion of social factors into the production of knowledge leads to error or falsity, the notion that reality is socially constructed does not imply judgements about the validity of our socially produced knowledge. Rather, it aims to make explicit the existential conditions which underpin the ways in which we think about the world, and indeed, which make knowledge possible.

In this dissertation we will employ this idea to examine a controversial theory about the nature of man's place in the world and the problems which confront him. This theory - known as system dynamics - suggests that man lives in a network of social systems (incorporating economic, political, and ecological subsystems) and that the properties of these systems determine many of the problems - from famine to overcrowding, and from unemployment to ecological collapse - which have caused much public concern over the past ten years or so. System dynamics purports to explain the causes of these problems and to provide a resource for devising policies to remedy them.

We are not primarily interested in the truth or falsity of the propositions of system dynamics but rather in its status as a socially constructed body of knowledge. We aim to unravel the interconnections of this construction in order to seek some insights into how this systems view of the world has been generated.

System dynamics was originally developed within the Sloan School of Management at the Massachusetts Institute of Technology in the United States. Its intellectual roots stem from systems engineering and the design of technological systems. Having achieved considerable success with such applications, systems engineering was later generalised to become a tool for the design and control of social systems, i.e. social engineering. It was thought that it could bring a more rigorous and objective approach to policy formation.

System dynamics is thus policy oriented, and is concerned with the management and control of social systems. Further, it belongs to the class of theories known as general systems theories which aim to explain the properties of all systems, whether physical, social or other types.
Basically, the approach involves the building of a computer simulation model to describe the behaviour of the system under study, followed by experimentation with the model in order to derive suitable policy options for modifying the behaviour of the 'real' system. To date it has been used to investigate a wide range of problems, including urban stagnation, pollution, population growth, inflation and unemployment.

The justification for analysing system dynamics lies not only in its alleged efficacy in understanding social problems which are of considerable importance in themselves, but also in the fact that its proponents claim that it offers a new and better approach to studying such problems. The system dynamicists actually envisage a reorientation of the social sciences - towards a concentration on the feedback structures of social systems which are argued to be the bases for comprehending the behaviour modes of such systems. Further, they suggest that the human brain is not adapted to understanding the properties of complex systems - where many variables interact through time - and they argue that computers should be employed to aid this task. Though the human brain may correctly perceive the structure of a complex system, they contend that it cannot predict how that structure will behave dynamically.

The system dynamicists envisage the spread of system dynamics into all levels of education, and advocate the education of the voting population in order that people might appreciate the properties of social systems and thereby make more 'informed' choices in voting for policies.

We should also mention the well-known system dynamics world models which were built in the early 1970s, and which looked at the world as a closed global ecosystem. From their behaviour patterns it was concluded that the world was facing a catastrophic collapse in its life-support systems. This message captured much attention within Western societies and the debate which it stimulated still continues in many circles.

This background underscores the desirability of developing a comprehensive understanding of system dynamics - both as a social construction or artefact, and as a resource for formulating social policies.

Previous studies have often been technical ones, in the sense that they have tended to address the mathematical aspects of system dynamics models or the problems associated with the empirical data bases which are used in their construction\(^1\). In contrast, it is our contention that system dynamics is not merely a modelling tool or technique, but is - as
the system dynamicists themselves claim - a theory of the behaviour of social systems. It is, in other words, a type of social theory.

Other critics have concentrated on the ideological content of specific models which some have seen as a reflection of the interests of multinational corporations or of the bourgeois social class. To a number of writers, systems analysis appears as a symbol of the technocratic consciousness which they identify with modern bureaucratic capitalism. Technocratic rationality reduces social and political problems to technical and administrative ones. With system dynamics we shall see that whilst it also tends towards the apolitical or suprapolitical conception of social problems, it sometimes perceives them as moral ones and does not narrow seek recourse to technical or administrative solutions. Quite the contrary, in fact, for we can discern an emphasis upon individual morality and the necessity for preserving long-term value structures. These elements can neither be explained in relation to the engineering origins of system dynamics nor solely in terms of technocratic rationality, and indicate the need for more comprehensive tools for understanding its relationship to the prevailing cultural context in which it evolved.

Our intention, therefore, is not to repeat previous lines of criticism but to adopt a framework derived from sociology and modern anthropology and seek to throw some new light on the subject. The thrust of the argument is related to recent work in the sociology of science and specifically employs the insights of social anthropology about the relationship between conceptions of social and natural order - i.e., social reality and physical reality. Some of this work has investigated the ways in which the knowledge of the natural sciences is a product of social relations (i.e. the social order is in Mackenzie's terms, "read onto" nature) and how this knowledge may then be used to legitimate the social order through the medium of appeals concerning the 'natural order of things'.

These ideas underpin our own efforts here. Our focus - the general systems-theoretic perspective of system dynamics - provides a particularly interesting subject because it is explicitly oriented towards social policy, and addresses the laws and principles which are alleged to underlie the behaviour of physical and social systems.

We do not propose, therefore, to examine specific models in isolation but instead try to view system dynamics in much broader terms, to understand its social origins and the social influences which have shaped it. In addition to this line of enquiry, we also wish to investigate the social
role of system dynamics as a resource for formulating social policies. More specifically, we will consider the consequences that system dynamics has for social structures.

Our objectives are as follows. Firstly, to elucidate the cultural tradition from which system dynamics emerged and the social contexts which shaped its extension to different domains. Secondly, to uncover the relationship between the micro-social environment which unites the system dynamicists as a social group, and the intellectual style and content of system dynamics as a theory. Thirdly, we want to understand the role of system dynamics in mediating and reinforcing specific patterns of social relations - ranging from the legitimation of social policies in urban systems to the assimilation of certain elements of system dynamics within a plethora of alternative visions of future society - from technocratic ideas of world government to utopian ideas of small-scale alternative communities.

This dissertation actually falls between two intellectual camps or communities. On the one hand there is the sociology of knowledge and on the other systems theory; it draws upon the former in order to provide an interpretation of the specific development and social role of one strand of the latter. This means that the pursuit of our three goals must conform to the academic standards of two communities; more specifically, the sociological and anthropological tools which we employ must be used in accordance with the standards of the sociology of knowledge whilst we must also seek to meet the expectations of systems thinking. As regards the latter, we must conduct our investigation with a broad vision - broader than the confines suggested by any single approach or discipline; we must also bear in mind the notion of holism and seek to offer multiple perspectives on our subject matter. Although we will not adopt any formal systems methodology we will endeavour to meet these expectations; indeed, they are taken as part of the background knowledge which informs the spirit of our work.

The body of this dissertation consists of seven chapters. Chapter One discusses the historical background to system dynamics, including the career of its inventor - J.W.Forrester. We will refer to the intellectual and practical foundations from which it developed as well as the main features of the expansion of its domain of applications and theoretical core. In Chapter Two we will provide the theoretical groundwork for the approach adopted in this dissertation, and more specifically, for the structure of the argument which is pursued in the later chapters.
Chapters Three and Four will be concerned with the social construction of knowledge, with the social and cultural factors which have shaped the development of system dynamics within the System Dynamics Laboratory. Conversely, Chapters Five and Six will focus on the extra-laboratory role of system dynamics.

In Chapter Three we will continue our investigation by looking at a dynamic general model of the relationship between worldviews and social structures. The aim will be to locate system dynamics within a cultural tradition; more specifically, we will concentrate upon Forrester in order to understand the relationship between his outlook, values and theoretical beliefs on the one hand, and his social background on the other. As part of this task we will draw an analogy between system dynamics and the social theory of Parsons. This will establish that - as with Parsons - Forrester's worldview is oriented towards the traditional middle-class concern (social interest) with the preservation of social order, and is similarly committed to society's dominant institutions and values. The analysis will be conducted in dynamic rather than in static terms, leading us to consider the evolution of system dynamics in respect of developments - particularly social crises - within United States society. We will argue that it was originally devised in the spirit of furthering U.S. dominance in the international system, but was later expanded to address the crises of urban decline and environmental degradation. We will see that - in the face of such crises - the aim was primarily to maintain social order, and to do so without challenging society's dominant institutions such as capitalism and wealth. The expansion to each new domain entailed various theoretical shifts and extensions of its theoretical content, and we will examine these in relation to the specific social crises to which they were a response.

Although we will trace the relationship between the development of system dynamics and Forrester's social interests, our dynamic orientation will also allow consideration of changes in interpretation of his interests. This is particularly important in view of Forrester's shifting perspective on capitalism - wherein he came to expound the thesis that industrial growth must be halted.

Having looked at the broader cultural tradition from which system dynamics has emerged and developed we will turn our attention - in Chapter Four - to the pattern of social relations which unite the system dynamicists - i.e. the System Dynamics Group. This chapter will form the most detailed and exhaustive part of the dissertation: it forms the centrepiece of the investigation, constituting its most significant contribution in terms of original research. We will employ the
anthropological concept of cosmology in order to obtain a more specific picture of the system dynamicists' view of the world and style of thought. To illustrate these we will undertake a comparative analysis in relation to a selected control group. We will compare and contrast the two groups on three different levels. To begin with we will endeavour to describe the respective social structures, the institutional settings, within which each group resides. Secondly, we will consider their methodological orientation - including their approaches to modelling and response to theoretical anomalies - which constitutes their style of thought. Thirdly, we will turn our attention to the content of their knowledge; this will include reference to their beliefs about knowledge, nature, man and society, and time. Each of these levels will be independently interpreted in terms of Douglas' grid-group theory of cosmologies.

In Chapter Five our task will be to examine the social role of system dynamics and of its exponents. For they not only put forward policies for the control and management of social systems, but also seek to carve out a special niche for the experts needed to build and interpret the requisite computer models. We will investigate the ways in which system dynamics aims to re-structure social relations within the particular systems to which it has been applied, and the means by which it claims legitimacy in its proposed task. This discussion will centre mainly upon the urban modelling work but its implications are pertinent to system dynamics as a whole, and perhaps even to other uses of expertise in policymaking. The main questions we focus on concern the type of urban structure which is advocated in Forrester's urban policies; the role of system dynamicists in relation to politicians and the electorate; and the way in which system dynamics provides an explanatory resource for structuring the problems of urban decline.

The use of system dynamics for the design of social policy raises the question of the negotiation of social consensus and the reasons why it may be seen as legitimate - both to the electorate and to the politicians and administrators who would be responsible for implementing the policies. Given the predominantly technological orientation of its cultural setting - the U.S. - its legitimacy would seem unproblematical. For example, Williams has described American society as a "culture centering its interests upon purposive technical mastery of its physical environment (and to some degree, of its social problems also)..." in which, "emphasis upon efficiency is obviously related to the high place accorded science (especially as translated into technology) and to the overwhelming importance attributed to practicality." Whilst this has certainly been one dimension of the
appeal of system dynamics, we must also note that when the system
dynamicists addressed the problems of potential environmental collapse
they eschewed technological fixes and talked of harmony with nature.
This indicates that its sources of legitimacy are not solely rooted in
images of technical rationality. We therefore need to discuss the
cosmological elements - the symbols and metaphors pertaining to the
ultimate nature of the world or cosmos - which permeate system dynamics' policy recommendations and give them their moral import.

In Chapter Six our attention will turn to the message of the world
models and to its social effects. We will focus on the role of the models
in explaining the world and endowing it with meaning and coherence. This
will include the way in which they symbolised the social context of the
time - a period which included the blossoming of the environmental
movement. Dominant themes during this period centred upon the
relationship of man to the natural environment, and projections of
alternative futures in which different groups sought respite from the
material, social, and spiritual decay that they saw as pervading Western
society. The policy recommendations to emerge from the world models
included an image of a global equilibrium society - a stable state which
would last indefinitely and where man would live in harmony with nature.
Here, religious and ethical concerns would supposedly help to
reorientate people away from material desires and values towards long-
term values centred on the stability of the global ecosystem and the
perpetuation of the human species.

The world models emerged onto a social landscape where many people were
looking for an alternative belief system and we will argue that - like a
computerised form of astrology - system dynamics offered to bring
structure and certainty into a world that appeared to be rent by
contrarities and mounting global problems. In this sense it held out an
ideology which could enable people to adjust and accept the conditions
on 'Spaceship Earth'; pitched in curiously suprapolitical terms the
message of the world models demanded individual moral restraint and
self-discipline. But, the message was also incorporated into more
radical visions of future society and to understand these responses we
will consider the millenarian aspects of the period.

The final chapter - Chapter Seven - summarizes the main conclusions of
this investigation, discusses the rationale for the approach adopted and
considers the extent to which it has shed light on the nature of system
dynamics and opened up new lines of enquiry.
CHAPTER ONE

THE BACKGROUND TO SYSTEM DYNAMICS
In this chapter we wish to provide an introduction to system dynamics and to its inventor and chief exponent J.W. Forrester - the figure who is the centre of attention in Chapter Three. We will briefly sketch Forrester's career and then go on to chart the history of system dynamics as seen in relation to his application of the theory to different domains.

FORRESTER'S CAREER

Forrester was born in 1918 in Nebraska where his family owned a cattle ranch. He studied electrical engineering at the University of Nebraska from where he graduated in 1939. From 1940 to 1946 he worked at the MIT Servomechanisms Laboratory - where feedback control theory was being used in the design of military equipment - before going on to become director of the MIT Digital Computer Laboratory. There he was responsible for the construction of "Whirlwind I" which was one of the world's first high-speed digital computers. In fact, whilst engaged upon this work Forrester invented (and indeed, holds the basic patents on) random-access magnetic core storage memory devices - for many years the standard memory units in digital computers.

The next stage in Forrester's career took him to MIT's Lincoln Laboratory where between 1952 and 1956 he was head of the Digital Computers Division. During this period he directed the military and operational planning and technical design of the Air Force SAGE system for continental air defense - this was one of the first applications for the Whirlwind computer.

In 1956 Forrester's career took a distinctive turn when he decided to move into the field of management science and became Professor of Management at MIT's Alfred P. Sloan School of Management. He sought to bring his experience and knowledge of engineering systems, military decision-making structures and computers into the domain of corporate management. The Sloan School was established in 1952 at the bequest of Alfred P. Sloan who had been head of General Motors for many years. Management training at the school has a long engineering orientation, and in fact its origins actually stem from the School of Engineering at MIT. Whilst at the Sloan School Forrester devised the forerunner of system dynamics - industrial dynamics - which is a theory of the behaviour of industrial systems. Later, he extended industrial dynamics to urban systems, the world system, and finally, the national economy of the United States.
Since 1972 he has been Germeshausen Professor of Management at the Sloan School; this post was established in 1968 by Mr. K. Germeshausen with the aim of supporting continued research into the "humanitarian use of technology".

During his distinguished career Forrester has received many honorary degrees and awards and has published numerous books and articles. In Chapter Four we will argue that Forrester's early background in military systems was an important element in the subsequent evolution of system dynamics: not just in an intellectual sense, which is something we shall refer to next, but in a cultural sense in that it stands as a social referent, a marker of the cultural tradition in which his work is located.

1.2 HISTORY OF SYSTEM DYNAMICS

System dynamics is a more general name for industrial dynamics which was devised by Forrester between 1956 and 1961 at the Sloan School.

"Industrial dynamics is a way of studying the behavior of industrial systems to show how policies, decisions, structure and delays are interrelated to influence growth and stability. It integrates the separate functional areas of management - marketing, investment, research, personnel, production, and accounting. Each of these functions is reduced to a common basis by recognizing that any economic or corporate activity consists of flows of money, orders, materials, personnel, and capital equipment. These five flows are integrated by an information network. Industrial dynamics recognizes the critical importance of this information network in giving the systems its own dynamic characteristics." (4)

Industrial dynamics grew out of an interest in finding and developing connections between engineering and management, and was based upon four foundations: information-feedback control theory, knowledge of decision-making processes, the experimental approach to systems analysis, and the digital computer.

For some time prior to Forrester's initial interest in these matters, operations research - incorporating mathematics and scientific method - had been used to tackle various industrial problems. However, Forrester saw these efforts as being restricted to individual low-level problems and decisions, characterised as 'open-loop' processes where the policy output was seen as unconnected to the information input used in deciding upon the policy.

```
INFORMATION INPUT ---→ DECISION ---→ POLICY OUTPUT
```
In contrast, Forrester advocated a 'closed-loop' approach in which a feedback loop is established between the policy output and the information input.

This approach grew out of his experience at the Servomechanisms Laboratory and the use of information-feedback control theory. Forrester's work in this field was connected with military projects, but a more simple example of a closed loop system is that of a heating system and thermostat. The thermostat receives information about the temperature in a given room and 'decides' whether or not to start up the boiler; if it does so, it monitors the increasing temperature of the room before eventually shutting off the boiler at some pre-selected temperature. Forrester contended that the feedback approach was more representative of real-world situations and was therefore more suitable for the complex problems of corporate management.

The second foundation was knowledge about decision-making processes in which Forrester had gained much experience at the Lincoln Laboratory when - as part of his work - he had developed systems for automating military tactical operations.

"As in military decisions, we shall see that there is an orderly basis that prescribes much of our present managerial decision making. Decisions are not entirely 'free will' but are strongly conditioned by the environment. This being true, we can set down the policies governing such decisions and determine how the policies are affecting industrial and economic behavior." (5)

Forrester perceived that the mathematical approach of operations research had a second limitation - namely, that it could not deal with non-linear relationships (which he deemed to be important in complex systems) because they defy analytical treatment. This leads to the third foundation - i.e. Forrester's belief that the experimental approach to systems analysis offered the technique of simulating a system using a mathematical model and did not require analytical solutions for the equations involved in describing the system.

*Control theory is a branch of mathematics which is applied to the engineering problems involved in the design of feedback control devices.
The fourth foundation - the **digital computer** - provided the means whereby large simulation models could be programmed and run relatively cheaply at a high speed. These four elements - which had all largely been spurred by military and commercial interests - fused into the development of industrial dynamics.

"Aided by a grant from the Ford Foundation, a research program began to relate the elementary concepts of feedback systems, previously developed in the engineering fields, to the processes in social systems. Compatible with the overriding determination to avoid restriction to simple linear systems, analytical treatment was subordinated. One could for the first time turn away from mathematical solutions as the principle means of analysis because computers had reached the point where convenient low-cost system simulation was possible. With simulation available as a procedure for determining the behavior of a model system, it became fruitful to concentrate not on mathematical methods but on the fundamental nature of structure in systems." (6)

The conceptual development of industrial dynamics was complemented by the formulation of a specialised computer language - called **DYNAMO** - to handle the model simulations. This caused some people to view industrial dynamics merely as a technique; however, Forrester saw it in much broader terms.

"Although still very incomplete, industrial dynamics is a body of theory dealing with feedback dynamics. It is a view of the nature of structure in purposeful systems." (7)

In formulating the concepts of industrial dynamics Forrester drew upon the state variable approach of engineering. He saw this as a distinct part of many fields, including economics and psychology from which he has referred to the work of Lewin and the idea of a 'psychological field". It is worth explaining this approach in some detail because it underpins the basis of all system dynamics models.

At any given moment in time, the state of a system can be described by the values of its variables - the state variables (which in system dynamics terminology are called **levels**). Given knowledge of the present state of the system, together with information about its present and future inputs, the future states and future outputs can be calculated. Thus, the state of the system at the time \( (t+1) \) is only dependent upon the state of the system at time \( (t) \) and the inputs between \( (t) \) and \( (t+1) \). Let us illustrate this with the example of a water cistern. Using system dynamics notation we have
The height of the water in the cistern is represented by \( L \) the state or level variable; \( R \) represents the rate of inflow of water, which of course is related to \( L \) by a feedback loop which is effected mechanically by a ballcock. Now the equation for \( L \) at time \( (t+\Delta t) \), where \( \Delta t \) is a small time increment, is given by the following difference equation

\[
L_{t+\Delta t} = L_t + R_t \Delta t
\]

And, the equation for the inflow rate is some function of \( L \).

\[
R_t = f(L)
\]

Although in more complex industrial dynamics models there are many auxiliary equations which are used to calculate various variables within the rate equations, nevertheless it is contended that all complex systems can be represented by just levels and rates. The levels represent integrations through time and completely describe the state of the system; they are also used to calculate the rates. These represent policy decisions which cause the levels to change; in the example just given, we have discussed a physical flow, but rate variables may refer to other 'flows' such as births and deaths etc. Simple though the example is, it illustrates the fundamental building blocks from which industrial dynamics models of a corporate system are constructed.

The first step in model construction is to identify the goals and problems of the organization involved, followed by a description of the problem situation which must capture the important interrelationships between the factors involved. This would usually involve the...
identification of the system's feedback loops and sub-structures. This verbal description is then translated into a mathematical model which consists of the level and rate equations (and any auxiliaries); this model is then used for simulation experiments.

Obviously, the properties of large aggregates of feedback loops become quite complex. In fact, Forrester stated that the behaviour of an information feedback system was derived from three factors: structure, delays, and amplification. The structure of a system is given by the interlocking feedback loops which interrelate the system levels and rates; delays may occur in a material or information flow and introduce transient responses into the behaviour of a system; and, amplification is the property whereby a small change in one part of a system may produce a large variation in another part. These three factors may also interact with each other to produce further complex patterns of behaviour.

The period from 1956-1961 saw the formation of the concepts of feedback processes upon which industrial dynamics was based and their application to the steady-state dynamics of corporate policies (i.e. fluctuations about an equilibrium state). The years from 1962-1966 were concerned with the consolidation and clarification of concepts and experimental courses were devised for teaching them to management students. Industrial dynamics was extended to cover situations where non-linearities were important and positive feedback processes were also investigated. Both of the examples described earlier contain negative feedback loops where the system fluctuates around a steady-state equilibrium - i.e. they are goal directed. In contrast, positive feedback loops move away from a goal; a good example is the exponential growth of a bacterial population (until it exhausts the carrying capacity of its environment, at which point negative feedback checks the growth rate). In an industrial context the processes studied involved stock-control problems, growth in products and companies. The horizons of industrial dynamics were, however, seen to be much more extensive.

"During this period the view of industrial dynamics was enlarged not only to include the application to enterprise design but also to become a general systems theory to serve as a unifying framework capable of organizing behavior and relationships in areas as diverse as engineering, medicine, management, psychology, and economics." (9) emphasis added

What this indicates is that Forrester had come to see the theory of industrial dynamics as of much more general importance than corporate systems - it was a "general systems theory". This provides a key to the
next phase of the development of system dynamics - namely, the movement into the modelling of other types of social systems such as cities.

1.2.1 **URBAN DYNAMICS**

In 1968 Forrester extended the domain of industrial dynamics to encompass the processes involved in the growth and decline of cities. Funding was again obtained from the Ford Foundation and Forrester believed that industrial dynamics could shed new light on the problems of urban stagnation. He examined policies for urban revival and also sought to explain the failure of past policies which he thought had often merely exacerbated the problems they were devised to tackle.

The cornerstone of Forrester's urban modelling project was the alleged behavioural properties of complex systems; these were now formulated as follows:\(^10\):

1) Counterintuitive nature of complex systems

2) Insensitivity to parameter changes

3) Resistance to policy changes

4) Existence of sensitive influence points

5) Corrective programs counteracted by the system

6) Difference between long-term and short-term responses

7) Drift to low performance

In *Industrial Dynamics* Forrester had stated that at the time of writing it was not possible to generalise about the nature of complex non-linear systems. *Urban Dynamics*\(^11\) represents a departure from this position, since in it these general properties are spelled out. They are therefore worth noting in some detail here but we will leave the analysis of the assumptions underlying them to later chapters.

1) Counterintuitive nature of complex systems

In his earlier work Forrester had suggested that intuition was unreliable in inferring the behaviour of a complex system; now he stated more firmly that complex systems were actually counterintuitive - that
is "they give indications that suggest corrective action which will often be ineffective or even adverse in its results". He argued that our intuitions are formed by exposure to relatively simple systems and were not capable of inferring the behaviour of a complex system with many non-linearities and feedback loops.

"With a high degree of confidence we can say that the intuitive solutions to the problems of complex social systems will be wrong most of the time. Here lies much of the explanation for the problems of faltering companies, disappointments in developing nations, foreign-exchange crises, and troubles of urban areas."  

2) Insensitivity to parameter changes

A complex system is alleged to be insensitive to changes in its parameters; in other words, changes in the value of a parameter do not appreciably alter the behaviour of the system. This leads to the argument that the structure of a system is more important than data, an argument which underscores Forrester's general systems approach.

"The life cycle of companies follows similar patterns in very different industries and even in different companies. Problems in economic development are much the same regardless of continent, social heritage, or even availability of raw materials."  

3) Resistance to policy changes

Complex systems are said to resist policy changes; the system reacts to any change so as to defeat it and preserve its initial state. This property is analogous to homeostasis in living organisms (e.g. maintenance of body temperature) or the equilibrium states in systems of chemical reactions.

4) Existence of sensitive influence points

Although systems are generally insensitive to parameter changes, they often have a few sensitive influence points where the change in a parameter may greatly affect the system's behaviour. This property is related to the notion of amplification in a system (which we referred to earlier).

5) Corrective programs counteracted by the system

Corrective programs tend to displace or perturb corresponding internal processes within a system and thus have less effect than may be
anticipated. As with the resistance to policy changes, the system counters any applied force such as that represented by a corrective program.

"Only applied programs of intrinsic low cost are feasible. Probably no active, externally imposed program is superior to a system modification that changes internal incentives and leaves the burden of system improvement to internal processes." (15)

6) Differences between long-term and short-term responses

This point goes back to industrial dynamics and centres upon the idea that the behaviour of a system may be very different in the long-term than the short term, especially in response to policy changes. Thus, a program which has initial short-term benefits may have disastrous consequences in the long run.

"This conflict between short-term and long-term system response partly accounts for the unhappy state of our present urban systems. As voter pressure and political expediency combine to favor short-run considerations, the stage is set for long-term degeneration." (16)

7) Drift to low performance

The idea here is that complex systems tend to move into a condition of low performance; this is thought to be mainly due to the interplay of the other properties and the intuitive short-term solutions which are designed to alter system performance.

Bringing these system principles into the study of urban problems meant that some of Forrester's views of conventional urban programs, and his alternative policy recommendations, were at odds with much of the received wisdom on the subject. He contended that effective programs required the apprehension of the properties of complex systems - of which an urban system was but one example - and should be tested out beforehand on an explicit computer model which, unlike the human mind, has the ability to map out the behaviour of a complex system.

The number of levels (or state variables) in the urban model was twenty, including three economic classes, three sets of housing categories and three types of business enterprise. These formed three subsystems which were thought to govern the central processes involved in urban growth and stagnation. The model did not correspond to any real city and Forrester relied largely on guesswork to calibrate the dozens of relationships and parameters which were used to describe the
interconnections between the levels and rates. The aim was to focus attention on the entire life cycle of an urban area, and the model simulations were run for a 250 year period. The model shows how growth gives way to maturity and is then followed by decay.

"The area is a complex, self-regulating system that creates internal pressures to modify economic activity and shift the uses of land, structures and people. These changes are dominated by the construction, aging, and demolition of industry and housing combined with concurrent population movements." (17)

1.2.2 WORLD DYNAMICS

The next major extension of system dynamics was the global model WORLD 2 which is described in World Dynamics18. This project grew out of a meeting between Forrester and members of the Club of Rome in 1970. This organization is an international group of scientists, businessmen, and policymakers, founded by Peccei19 in order to draw attention to and study various world problems.

"The members act as private citizens. They are not in governmental decision-making positions. Their orientation is activist - that is, they wish to do more than study and understand. They wish to clarify the course of human events in a way that can be transmitted to governments and peoples to influence the trends of rising population, increasing pollution, greater crowding, and growing social strife." (20)

Forrester believed that system dynamics offered a powerful method of formulating the problems which concerned the Club, and after the initial meeting in Bern Forrester invited Club members to MIT for a two week meeting for which the world model was prepared.

"The meeting included the general theory and behavior of complex systems and talks on the behavior of specific social systems, ranging from corporations through commodity markets to biological systems, drug addiction in the community, and the growth and decline of a city." (21)

The model addressed the global interactions between population, agriculture, industry, resources, and pollution. Being aggregated at a global level it did not differentiate between international and intranational differences, and only contained five levels. The model only contained two empirical data points - the population levels for 1900 and 1970 - all relationships again being guessed by Forrester. The model simulation began in 1900 and ran until the year 2100. From its
behaviour Forrester made the startling prediction that the world system was facing a catastrophic collapse sometime in the next century. The basic message was that the world had fixed limits to growth - it could only support a certain number of people at any given standard of living, it could only absorb so much pollution, and natural resources were finite. Forrester argued that the world must move towards an equilibrium society where the growth in population and industrialization would be permanently halted. He suggested that one way to achieve this would be to reduce world food production, the birth rate, capital investment, the generation of pollution and natural resource usage. Perhaps the most surprising aspect of these suggestions is the idea of reducing food production, for this would obviously greatly increase the death rate amongst the world's population. The model sparked off a very heated debate in many academic circles and in other forums, not only because of the controversial nature of the policy recommendations but also because of the assumptions built into it and the fact that it was based on virtually zero empirical data.

Although the World 2 model contains only 5 levels, the total number of variables is an order of magnitude larger. The flow diagram for the model appears in Figure(1) and the definition of its symbols are as follows:

- level
- auxiliary variable
- rate
- constant parameter
- source or sink
- physical flow
- information flow

The model is actually quite complex in appearance, even though its behaviour is crucially linked to certain key assumptions concerning the nature of the world system - e.g., that the world is undergoing exponential growth in population and capitalization. The standard run of the model is shown in Figure(2). Population and capital investment grow exponentially whilst natural resources become increasingly scarce. Eventually - indeed inevitably, given that it is assumed that resources are fixed - the exhaustion of natural resources precipitates the

*Forrester actually began to talk of the fundamental laws of nature and social systems.
Figure 1 Flow Diagram for The World Model
Figures 2 & 3: Standard run of World 2

P = P, POLR = 2, CI = C, QL = Q, NR = N

Years

1900
1940
1980
2020
2060
2100

0 2000 M 4000 M 6000 M 8000 M P

0 5 10 15 20 25 30 40

0 5 10 15 20 25 50 75 100

Natural resources

Population

Capital investment

Pollution

GDP
THE LIMITS TO GROWTH

The Club of Rome were sufficiently convinced of the potency of system dynamics during their meeting at MIT that the decision was taken to sponsor a much more ambitious project. This was to involve a more complex version of Forrester’s prototype model, to be built by a multidisciplinary team headed by Dennis Meadows - Forrester’s former research student. Financing was obtained from the Volkswagen Foundation and the new model was named WORLD 3. Forrester did not actively participate on the project because he was committed to further urban modelling work. The findings of the team were published in The Limits to Growth in 1972 and largely reiterated those of World Dynamics.

The Limits to Growth was a ‘popular’ report and as such contained no detailed technical information. It sparked off a tremendous controversy - receiving a great deal of media coverage, particularly in the United States. From their scientific audience the World 3 team drew some scathing criticisms; this was partly because they had not gone through the normal channels of scientific publication, but had instead launched the results of the model amidst a publicity campaign without first submitting their work for detailed critical evaluation. The book sold nearly 3 million copies worldwide, with almost 500,000 in the Netherlands alone. The full technical report - Dynamics of Growth in a Finite World - followed in 1974.

THE SYSTEM DYNAMICS NATIONAL MODEL

For the last several years Forrester and his colleagues have been engaged upon modelling the economy of the United States - though Forrester argues that in principle the model is applicable to any national economy. This model is the most ambitious to date, both in terms of size and complexity, and is addressed to the problems of inflation and long-term unemployment. It is financially supported by the Rockefeller Brothers Fund and contains some 1500 levels. Unlike earlier system dynamics models it contains processes which are said to generate three distinct cycles of behaviour; these are the business cycle (3-7 years), the Kuznets cycle (c. 20 years) which arises from factor replacement between capital and labour, and the Kondratieff long wave cycle (c. 50 years) which stems from the growth and collapse of capital sectors. Full details of this model are not yet available and
consequently we will only make brief references to it during the remainder of this dissertation.\textsuperscript{25}

Within the Sloan School Forrester set up the System Dynamics Group which has been a major source of system dynamics research, involving both undergraduate and postgraduate teaching programmes. Also, there are now a number of different system dynamics modelling groups in several countries. In Britain, for example, there is a group at the University of Bradford, and another at the London Business School. Further, the range of subjects to which system dynamics has now been applied is quite extraordinary; the following list gives some indication of the diversity.\textsuperscript{26}

Real estate economies; U.S. energy systems; The search for a policy on heroin; Occupational program planning; Economic development; The cultural structure of pre-Christian Rome; The world cocoa market; Terrestrial ecosystems; Retirement policies within the military; Gypsy moth populations; Dynamics of world peace; Education; Crime; Urban traffic; Regional employment

In order to summarise the main features in the development of system dynamics we can consider it as a theoretical core together with a domain of applications.\textsuperscript{6} We can represent its development by considering changes and expansions in its core in relationship to the different major domains to which Forrester has applied it. The result of this scheme is depicted in Figure(3) where we can see a consistent change and expansion of the theoretical core as each new domain has been tackled; we will return to some of these points in detail later in Chapter Three.

1.2.5 A NOTE ON CONVENTIONS

We wish to introduce the distinction between various stages in the development of Forrester's theory, such as industrial dynamics, and the books which bear the same name - which is this case is Industrial Dynamics. Thus, "urban dynamics" refers to the stage in the development of the theory when urban systems were tackled, and Urban Dynamics refers to the specific book discussing the urban model.

\textsuperscript{6}This idea is taken from the 'non-statement' view of theories.\textsuperscript{27}
<table>
<thead>
<tr>
<th>OCCUPATIONAL SITUATIONS</th>
<th>LIVING SITUATIONS</th>
<th>SOCIAL SITUATIONS</th>
<th>NATIONAL, ECONOMIC SYSTEMS</th>
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<tr>
<td>time scale</td>
<td>250 years</td>
<td>500 years</td>
<td>300 years</td>
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<td>event variables</td>
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<td>sensitive influence points</td>
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<td>better for worse sequences</td>
<td>short-term long-term goal conflict</td>
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<td>counterintuitive</td>
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<td>can improve performance without a trade-off</td>
<td>limited good-improving one factor worsens another</td>
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<td>steady-state dynamics</td>
<td>growth and stagnation</td>
<td>exponential growth transition to equilibrium</td>
<td>growth cycles</td>
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<td>unstable equilibrium</td>
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<td>system modes</td>
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<td>drift to low performance</td>
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<td>realistic goals</td>
<td>must include negative forces</td>
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<tr>
<td>fundamental laws of nature and social systems need for long-term value structures religion</td>
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**Figure (3): The Development of Forrester's Work**

- Multiple behaviour modes - business cycle, Kuznets cycle, Kondratieff long-wave
CHAPTER TWO

SYSTEM DYNAMICS – A CULTURAL ARTEFACT
The general aim of this dissertation is that of gaining a comprehensive understanding of the relationship between system dynamics and the cultural contexts within which it has developed. Specifically, we want to analyse the ways in which system dynamics has co-developed in relation to particular social structures, and to determine the nature of the social role, if any, that it might play. The general problem that confronts us therefore, is the relationship between knowledge and social structures.

Our investigation represents a synthesis of various elements drawn principally from sociology and modern anthropology — our greatest debt being to Douglas¹. The overall perspective of the approach will be to consider system dynamics as a cultural artefact — a product of culture — produced by, in, and for culture*. The form of the relationship between knowledge and social structure can only be interpreted in terms of some specific theoretical model for both 'social structure' and 'knowledge' are theoretical constructs. Accordingly, the project of this dissertation will be based upon a specific model of the relationship which will be outlined shortly.

First, however, it would seem relevant to consider some other ways of conceptualising this relationship because some of the problems that they engender are instructive and lead us to the model to be adopted for our investigation. The approaches in question are predicated on various dichotomies such as that between internal history and external history, science and ideology, or base and superstructure. Our expositions of them will be brief and inevitably somewhat crude; rather than attempting a detailed critical evaluation of each, we will point out some specific problems associated with them and thus set the scene for the approach which we have taken. (References to detailed critiques will however be given.)

The enquiry might begin by trying to establish whether or not system dynamics meets some particular demarcation criterion for 'science' such as that proposed by, say, Popper². Such an approach would, however, be sterile for several reasons.

*The term 'culture' is used here in Douglas' sense, i.e. the traditions, standards and values which are produced by the transactions - negotiations and interactions - between individuals. In other words, culture is actively produced. Social structure is a more precise theoretical concept which is used to describe different patternings of cultural transactions.
Firstly, such an approach would be implicitly underpinned by the notion of a dichotomy between science and pseudoscience, or between science and ideology. In this type of perspective science is seen as being objective and true whilst non-scientific knowledge may be seen as a falsity resulting from the incursion of cultural elements into the production of knowledge. This reduces the sociology of knowledge to the sociology of error, and if applied to our subject, would prevent us from apprehending system dynamics in a proper cultural context.

Secondly, science (or scientific activity), however one tried to define it, is also a cultural product.

Thirdly, system dynamics is addressed to the analysis of both physical systems and social systems. It may be that it could meet some criterion for science when applied to the domain of physical systems, but this of course would not imply validity in application to social systems.

Our view here is that questions regarding the scientific status of theories are really confined to the level of differentiating between different subsets of knowledge. Of course this is not to say that differences between some particular conception of science and system dynamics do not exist or are unimportant; the point is that our focus is deeper in the sense that we wish to draw attention to the cultural factors and conditions which may influence the production of all knowledge.

A second and related dichotomy rests on the idea of distinct internal and external histories wherein a cleavage is posited between internal factors in the context of discovery (cognition, knowledge, rationality) and external factors such as social and political interests, the nature of scientific communities etc. (For a full discussion of the problems involved see de Vries, Harbers.) Further, questions of legitimacy - the context of justification - are thought to be restricted to the internal sphere. The internal/external dichotomy thus allows the idea that external factors may cause the growth of knowledge to deviate from its 'true' course - again tending to reduce the sociology of knowledge to the sociology of error.

Complementing this position we find 'idealistic' or 'individualistic' biases in which the development of knowledge is explained in terms of ideas or an emphasis on the role of specific individuals.

Idealism is a powerful philosophical tradition which conceives of the mind or consciousness (and hence knowledge) as though it existed in a
social vacuum, in a realm of pure thought which is independent of society and the material world. Indeed, idealists have tended to view the world of matter as being organised by mind or spirit and believe that human thought is rooted in certain universals, or 'a priori' principles of cognition, which alone open the way for understanding how the material world is structured.

"The imposition of order upon the chaos of sense impressions was the work of the mind, which was in possession of the true and universal forms of understanding, the categories." Lichtheim (6)

A number of critiques of system dynamics have in fact had a discernible idealist bias. They have therefore placed a strong emphasis upon the importance of the values and assumptions which have underpinned various system dynamics models. These analyses have been directed towards the content of the models, and thus to the content of the modeller's perspective which has tended to be represented as a solely intellectual entity with no basis in the social world. Such studies are also sometimes confounded by an individualistic bias towards the overemphasis of biographical details - which often obscure the social origin and nature of knowledge.

Whilst not denying the importance of a modeller's biography and the values and assumptions implicit in his or her models, we wish to avoid relegating the whole matter to a discussion of these factors alone. For example, Forrester sees his urban model as the outcome of his interaction with several other individuals, the most important of whom was Collins - the former Mayor of Boston who shared an office next to him at MIT. This is exactly the type of biographical information which we believe must be carefully handled and viewed in a broader social context. For, viewed in the absence of a suitable theoretical framework, it can attract more attention than it warrants.

At the opposite extreme from idealism we find economic determinism; this is a crude version of Marxist materialism and is based upon a version of 'reflection theory'. Idealism as a philosophical position was the subject of a sustained critique by Marx and Engels. For them, the problem of the relationship between knowledge and society centred upon the way in which social relations determined the consciousness of individuals. Put in simple terms, Marx posited the idea of a material base (the economic infrastructure) which gave rise to a superstructure of knowledge that reflected the base. Further, the superstructure was thought to embody certain dominant ideas that represented the interests of the dominant class within society.
"In the social production of their existence, men enter into definite necessary relations, which are independent of their will, namely, relations of production corresponding to a determinate stage of development of their material forces of production. The totality of these relations of production constitutes the economic structure of society, the real foundation on which there arises a political superstructure and to which there correspond definite forms of social consciousness. The mode of production of material life, conditions the social, political and intellectual life-process in general. It is not the consciousness of men that determines their being, but on the contrary it is their social being that determines their consciousness." Marx (7)

In versions of economic reductionism, this formulation has been overextended to cover all levels and forms of consciousness and all levels of social reality. All products of culture are then reduced to mere reflections of the underlying economic base. Such a position cannot account for the relative autonomy of thought as evidenced in certain branches of knowledge, modern physics or mathematics for example. We do not wish to suggest that these areas of knowledge are unaffected by material or economic interests but rather, that they are not reducible to such interests.

Some other critiques of system dynamics have implicitly operated upon the premises of some form of the base-superstructure model. For example, certain critics have tied the world models to the interests of multinational corporations. Although such studies have sometimes provided useful insights into the subject, they too often sound like conspiracy theories of history, or articulations of economic determinism. As such, they fail to capture the breadth and depth of the relationship between knowledge and social structures. For example, they tend to equate system dynamics with the content of a particular model (for example, World 2) along with certain economic interests which they associate with it. However, a model may be built with the intention of supporting specific interests or, it may have the effect of supporting them. The distinction between these two possibilities should not be ignored, for in so doing one neglects the fact that system dynamics is related to other areas of culture, such as the movement towards the technocratic control of social systems. This strand of technocratic rationality within the development of system dynamics is not, of course, divorced from economic interests, but it cannot be reduced to them either, any more than the wider development of culture itself can be explained in economic terms alone.

A more adequate interest model is that suggested by Barnes and Bloor of the 'Edinburgh School' in which social or political interests (etc.) are
seen as coherence conditions which maintain the relative stability of classificatory networks - which are seen as the bases of all knowledge systems. This model aims to cut across the internal/external dichotomy. However, it has been charged that in Bloor's so-called 'Strong Programme', a mechanistic causality is posited to account for the relationship between knowledge and social interests. In other words, it would still appear to implicitly cling to the dichotomy between the cognitive and the social. Further, other critics of the interest model draw attention to the role of interpretation - i.e. they point out that scientists not only interpret the world in terms of their social interests, but these too are the subject of interpretation.”

The emphasis on the role of interpretation leads to its own problems - "these interpretations are 'made and shaped in the course of interactions between scientists among themselves and between scientists and their social environment, and...anyone who wants to study the development of knowledge in its social context will have to take this into account" 13. That is, interpretations are themselves socially constituted. Thus, whilst we wish to preserve the usefulness of the interest model, the interpretation model forces us to consider the problem of the interpretation of interests; but further, the question of interpretations must itself be set in a social context.

2.1 AN ALTERNATIVE MODEL OF THE RELATIONSHIP BETWEEN KNOWLEDGE AND SOCIAL STRUCTURES

We will now outline an alternative model which will form the framework for this thesis. The fundamental premises of this derive from the arguments of the preceding section where we identified and discussed various problems arising from other approaches. Only the skeleton of the model is described here but the details will be fleshed out as different parts of the model are deployed in the forthcoming chapters.

The first premise is that the relationship between knowledge and social structures is bi-directional. Knowledge is produced in society and bears the scars of its birth. It is not just a mere epiphenomenon, but something which may reinforce the society or social group from which it is derived, serving as a binding agent that cements people together. It serves to internalise a group's moral code and identity, and thereby 'inserts' people into the group. Knowledge and cognitions are actually

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*For philosophical and other critiques of this position see 9, 10.
**An account can be found in 11, 12.
part of the social bond.

The second premise is that bi-directionality does not necessarily mean that knowledge is an isomorphic reflection of particular economic or material interests, nor is it to be seen as a mere reflection of social and political interests conceived in static terms. Rather, it can have a degree of relative autonomy such that it may prescribe new patterns of social relations or radical changes to existing ones. Changes of social interests will lead to changes in knowledge; or, alternatively, changing interpretations of interests will lead to changes in knowledge. The possibility of relative autonomy does not of course mean that such knowledge is 'neutral' or 'objective'. Indeed, whilst some particular body of knowledge may be more detached than some other system of knowledge it will still impose its own constraints upon human thought and action.

Following Elias\textsuperscript{14}, we can think of a continuum, without absolute end states, wherein knowledge can be more or less autonomous in relation to social structure. Thus, for example, the development from the geocentric cosmology to the heliocentric cosmology represented a change in knowledge in which the socially accepted model of the universe became more independent of people's self-image and began to move away from its role of reinforcing the prevailing social order. It signalled a movement away from man's subject-centredness, anthropomorphism, and egocentricity. Even so, the heliocentric cosmology was constrained by its theoretical framework which was still - though to a lesser extent - tied to the surrounding social structure. Though the Earth was no longer conceived to be at the centre of the universe, the sun and the solar system were. The heliocentric cosmology was later displaced by Einstein's model of the universe - we can see a form of progress in the development of each model, each becoming more detached, but none representing an ideal end state or ultimate truth.

The third premise, again following Elias, is that we must take a dynamic view of the relationship between knowledge and the society in which it develops. A major element in Elias' conception of the sociology of knowledge is that it should not be statically oriented; rather, it should seek to locate knowledge within the context of the wider development of ideas and society. Instead of just relating knowledge to the immediate social context of the group which embraces it, we should also be aware of the longer-term changes (including those in ideas) in the society of which the group and its knowledge are but a part. Referring to the static orientation of some branches of the sociology of knowledge, Elias states:
"the development of society, as that of 'ideas', 'knowledge' or 'consciousness', simply appears as a necklace of here-and-now-situations strung together on an unknown and invisible thread." (14)

We contend also that ideas are not the sole property of individuals, but are the collective products of parts of societies - "our colonisation of each other's minds is the price we pay for thought" (Douglas15). Our focus here, therefore, moves away from individuals and towards the social contexts, including the development of ideas and society, in which they reside. In so doing we will concentrate upon the social roots of knowledge and beliefs, and thus avoid the pitfalls of the more familiar biographies and histories of ideas to which we drew attention earlier. Moreover, Elias' perspective is the basis we need for considering changes or developments in knowledge in relation to shifting interpretations of interests.

One immediate consequence of the first premise is that the material contained in the main body of this dissertation is bifurcated according to the two possible directions of the relationship between knowledge and social structure. Accordingly, Chapters Three and Four will be concerned with the social construction of knowledge, whilst Chapters Five and Six will focus upon the potential impact of knowledge on social structures and specifically on its role as a binding agent whose effect is to establish, or reinforce, or to change, particular patterns of social relations.

This model also finds a predicate in the work of Fleck and the recent revival of his ideas amongst Dutch sociologists and philosophers of science16. Fleck discussed the idea of two circles - one esoteric and one exoteric - which comprise a 'thought collective' who carry a 'thought style'. Within the collective we find the 'scientification' of popular knowledge (within the esoteric circle) and the popularization of scientific knowledge (within the exoteric circle). In de Vries' terms:

"Popularization of esoteric knowledge and scientification of exoteric knowledge are just two sides of the same coin...The development of scientific knowledge, its dissemination and practical use are confined to a thought-style and take place within mutually dependent esoteric and exoteric circles." (17)

Thus, in our terms, the esoteric translation of popular exoteric knowledge corresponds to the social construction of knowledge within the System Dynamics Group; whilst popularization of esoteric knowledge...
corresponds to the social role of system dynamics. The model we shall employ therefore assumes a holistic view of the relationship between knowledge and social structures.

Now let us consider the main features of our model in greater detail.

### 2.1.1 The Social Construction of Knowledge

This relationship between social structures and the specific kind of knowledge represented by system dynamics will be examined from two different perspectives. The first will seek to present a dynamic view of the relationship between system dynamics and the developments in ideas and society from which it has sprung. Such a general perspective is provided by Elias who takes a dynamic view of the origin and development of ideas. Rather than viewing knowledge as a mere epiphenomenon, he treats it as a necessary part of the social bonds between people. Further, he sees it as a power resource by which people can influence the development of social relations within the societies in which they live.

Elias posits the notion of social development which refers to the processes by which social structures (or the social relations between people) change - e.g. through the rising and falling of classes, or the division of labour, or social crises etc. We will consider this notion in relation to Forrester's worldview - which we define as a 'pre-theoretical' construct encompassing his theoretical beliefs, values and outlook. We regard worldviews as part of a cultural tradition shared with other people. (In Fleck's terms, the active connections constructed by scientists to describe nature, are not independent, freely chosen objects, but are part of a cultural tradition.)

We content that it is important to take a dynamic view of system dynamics because it is not a static monolithic position which has been applied uniformly to different domains at different times. Rather, as we saw at the end of the last chapter, it has been expanded and revised during the course of its development and we will seek to explain these changes in relation to various social developments which have impinged upon Forrester during his career. We will argue that these developments

*Interestingly, whilst neither Elias nor Fleck stand as systems theorists - in fact their major contributions were written in the 1930s - it is evident that their work stands as an alternative source of ideas which may support and improve various systems studies concerning social reality.*
not only influenced the choice of applications (the domain extensions) but, via reinterpretation of his interests, the specificities of the core expansions as well.

The second perspective will address the micro-social environment within which system dynamics evolved - i.e. the System Dynamics Group at MIT. This part of our model forms the substrate for the bulk of the thesis. It will draw mainly upon the work of Douglas and will focus on the concept of cosmology, which is a more precise theoretical construct within her theory. Cosmology is used to denote the systems of knowledge that describe people's place in the universe and their relationship to society. Cosmologies are held by social groups who share common assumptions about how the natural world is ordered and how the social world is or should be organized.

Douglas' thesis is that cosmologies are related to the type of social bonds in society, that they are correlated with the prevailing pattern of social relations - i.e. with social structures. This aspect of her work is partly derived from Bernstein and includes his idea that social structures contain various linguistic codes which mediate the relationship between the individual and his or her social environment. These codes set constraints or limitations upon the medium of expression - language - and in more general fashion constrain the knowledge which people produce. For example, the cosmology by which a person lives is actually articulated in language and therefore mediated by a linguistic code. This mediation imparts a specific style to their cognition and this is reflected in the pattern of beliefs and assumptions (the content) which characterise their cosmology.

Each cosmology has its own unspoken assumptions about the ultimate nature of reality, and they remain unspoken because each person takes them for granted. Further, because reality could not be conceived to exist in any other way they are not open to critical enquiry and so the cosmologies by which we live deceive us into thinking about ourselves and our societies in such a way that we are not easily aware of the limitations upon our conceptualizations.

The idea that the media of expression are limited is a crucial point in Douglas' thesis, and it is something that goes against the grain of many other intellectual traditions, particularly those expounding some version of idealism. Indeed, the notion that our cognitive powers are unrestrained often complements the anthropomorphism by which modern man has come to distance himself from the rest of nature.
In line with this view it may be noted that Douglas has argued that we have built a boundary between ourselves and our animal origins and that people have come to perceive a rift between spirit and matter, society and nature. Douglas observes that Marx too viewed the split between spirit and matter as being important; he saw the rift as the product of political and economic developments, but for her as an anthropologist the matter goes much deeper. She argues that we see ourselves and our powers of reason and language as being so much apart from the animals and nature generally. The fences we have built around ourselves are so strong and seductive that we cannot see the limitations which exist upon our power to manipulate symbols in the form of language, ritual, or whatever form they take.

"The human mind, playing freely in symbolic worlds which it creates itself, must bear the weight of its freedom. Smugly tragic, the favourite theme goes on: free to be noble, free to embrace error, free to poison ourselves, free to extinguish our species. This familiar chant nowhere admits that the symbolic life in not entirely free. It works through a medium of expression. The particular limitations set by the medium are worth examining." Douglas (18)

Utilising Douglas' theory we can undertake an analysis of the cosmology implicit in system dynamics which, we hope will enable us to understand how it influences the style and content of the knowledge embraced by the system dynamicists. Thus, Chapters Three and Four will concentrate on the social bonds which unite the people who have produced the cultural artefact 'system dynamics'.

21.2 - THE SOCIAL EFFECT OF KNOWLEDGE

Once this artefact has been created, it may itself serve as a binding agent between people; thus Chapters Five and Six will concentrate on how knowledge may be used to maintain or promote various patterns of social relations. (Or in terminology derived from Fleck, we will consider the popularization and exoteric role of esoteric knowledge.) People deal with each other in their social relations by making appeals about what is right and necessary - which means that they must appeal to knowledge about the fundamental principles of the universe; only then (short of force) may they coerce other people to behave in accordance with their wishes.

We do not wish to imply that system dynamics has actually played an active role in cementing any particular social structures; the point is that the policies which its practitioners have advocated carry
blueprints for social systems. Although these 'plans' may never be put into operation, they are certainly a valid focus of interest. Although this implies that our arguments will enter speculative areas, this will be necessary in order to provide a broad multi-perspective view of our subject matter. For this part of the argument we will employ Douglas' view that cosmologies legitimate social relations. Our focus of interest will be on the mechanisms by which various cosmological elements within system dynamics models serve to legitimate the policies inferred from them.

Douglas' position on this is derived from Durkheim\(^{19}\), and the basic tenet is that cosmologies reflect an interest in social management and control. This idea stems from the connection between the social and natural orders: the classification of the natural environment being an extension of the system of social classifications. Though the social order provides a model for structuring the natural order, it is the context of usage which is deemed to be most important. In fact, people make appeals concerning the natural order - which among other things - can be used in order to place demands on each other; these appeals then have the effect of legitimating social relations. To understand the force of these appeals we must also note Douglas' use of Durkheim's theory of the sacred. This theory is based upon an epistemology which - according to Douglas - can be developed to apply to all systems of knowledge, including science. It does not relate to the validity of knowledge, but to the reasons for which it is held to be true.

"For Durkheim, sacred and profane are the two poles of religious life on which the relation between individual and society is worked out. The sacred is that which the individual recognises as having ultimate authority, as being other than himself and greater than himself...Sacredness inheres in the moral law erected by consensus to which each individual himself subscribes." Douglas (20)

Douglas argues that Durkheim's theory is about socially constructed knowledge of the universe and that it is pertinent to fundamentalist religious doctrines as well as fundamentalist theories of knowledge. (This is actually a more radical version of Durkheim's sociology of knowledge, for he had held that the sciences of his day were special and outside its domain.)

The sacred has two essential features. Firstly, it is dangerous and hedged by protective rules; secondly, its boundaries are inexplicable because the reasons for any particular delineation of them are embedded in the social consensus which protects it.
"The ultimate explanation of the sacred is that this is how the universe is constituted; it is dangerous because this is what reality is like. The only person who holds nothing is sacred is the one who has not internalised the norms of any community." Douglas (21)

Returning to the notion of cosmologies, it is suggested that the conception of the natural order - in which demands are grounded - has the same quality of the sacred and is therefore difficult to evade. The idea of the sacred is one root of our argument concerning the force of appeals to nature; it also pertains to the 'self-evident' beliefs that we will uncover in Forrester's policy recommendations, and is one instance of the binding effect of knowledge.

Douglas' emphasis upon the social interests underlying cosmologies is not the only position on the subject. For example, other anthropologists have drawn attention to the importance of contemplative and expressive interests. However, because of the explicit policy oriented nature of system dynamics we do not feel that these other positions are relevant here. (We will discuss some of the difficulties in Douglas' work in Chapter Four.)

In Chapter Five we will turn our attention to the urban model. In addition to examining the nature of the urban structure implicit in Forrester's policy recommendations, we will also examine the implied role of system dynamics experts in urban management and planning. We will want to ask how the knowledge contained in their policies can cement social structures, and how it legitimates itself in its proposed task.

Chapter Six will be concerned with the debate that surrounded the world models. Of particular interest to us here is the different ways in which people responded to the apocalyptic message of the models. We will argue that their message was in fact interpreted in a number of disparate ways - i.e. there were several exoteric interpretations of the esoteric message - and was built into a variety of correspondingly divergent social cosmologies. These ranged from ideas of world government to small-scale alternative communities.

Throughout these two chapters we will seeking to understand how the different properties of knowledge systems have social ramifications. Taking the view that knowledge is an inextricable part of social relations, we will show how it is linked to social structures in more complex ways than those perceptible to the various approaches referred to earlier.
2.2 A NOTE ON REFLEXIVITY

Given the nature of our task and the fundamentals of the theoretical framework we have laid out, questions must inevitably arise about the social construction of this dissertation itself. In other words, what consequences does our own perspective have for the content of the knowledge contained herein? Of course the answer must be that the general theoretical position we have adopted applies similarly to our own work. But, this does not mean that the arguments outlined here are merely another articulation of sociological relativism. The reason is that it is possible to distinguish between the explanation of the growth of knowledge (the context of discovery) on the one hand, and the justification of knowledge (the context of legitimation) on the other. The first centres on the origin and development of ideas and is therefore the proper concern of the sociology of knowledge - and is the position taken here. The second, in contrast, centres on the validity or truthfulness of knowledge and is the concern of philosophers.

The question of our own perspective raises a related question concerning textual interpretation and we will discuss this in the following section.

2.3 THE INTERPRETATION OF TEXTS

Much of the evidence which will be employed here to substantiate our arguments will take the form of textual extracts. We are not concerned with the history of science as such, and will therefore confine ourselves to the development of system dynamics as evidenced in the formal record - i.e. the books and articles published by Forrester and his colleagues - and we will not draw upon informal sources such as letters etc.

Now, the use of textual extracts begs many questions concerning the problem of interpretation. For example, how does the reader of a text - or for that matter the reader of this thesis, including the extracts employed - know that the extracts are a 'true' representation of the text as a whole? And, further, what standing or meaning does a text have?

In reading a text ones does so from a particular perspective. This perspective is an interpretative framework of which certain elements may be unknown to oneself in that one may not be consciously aware of them. Some exegetes, or interpreters, may place an emphasis on style, authorial peculiarities of terminology, or the grammatical rules
governing the language of a text. Another position - derived from hermeneutic theory - is represented by Mannheim who argued that a satisfactory understanding of a text can only be arrived at if the interpreter can assimilate the framework of meanings from within which the text was written. In opposition to those who advocate the semantic autonomy of a text, Mannheim held that understanding required consideration of the weltanschauung of the writer. The model of the 'hermeneutic circle' of understanding requires not only that a text be analysed with a view to characterising the worldview of the writer, but also that understanding of the text be informed by knowledge of the worldview itself.

![Hermeneutic Circle Diagram]

In seeking to comprehend the context of meanings from within which a text is produced we do not necessarily have to make any evaluative statements with regard to the truth or falsity of the text. Although the identification and characterisation of a weltanschauung logically implies the particularity of a viewpoint and is therefore evaluative, this is not the purpose of the exercise in comprehension. In characterising the worldview of a group or person we inevitably particularise and delimit the extent of validity of the knowledge of that group or person. However, the mere imputation of a statement to say Marxism or Liberalism does not imply the truth or falsity of that statement per se.

Now all this may seem to present us with a paradox because, on the one hand we need to know about the worldview of the system dynamicists in order to interpret their textual output, and yet on the other hand we need the texts to understand their worldview. However, the point about the hermeneutic circle is that understanding proceeds step by step - from text to worldview, back and forth - until the picture gradually becomes clearer.

Having drawn attention to some of the more obvious problems involved in textual interpretation, there is another and deeper problem which centres on the status of texts. We said that our analysis would concentrate on the formal record of the system dynamicists but we have not discussed the standing of the texts in relation to the aims of our

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*A comprehensive discussion is given by Mazzeo.23*
analysis or indeed to the system dynamicists themselves. To address this issue we will discuss Mannheim's ideas a little further.

Mannheim described textual interpretation in relation to three levels of meaning. These meanings are denoted by the terms objective, expressive, and documentary. A text has an objective meaning in that it describes, or states, or argues for or against some state of affairs. It also has expressive meaning in that its author wished to express or communicate something. Further, a text has a documentary meaning which is not the intentional object of the author. Although the author controls the expressive meaning of a work, he or she can not inform the reader as to how the work is to be interpreted. Documentary meaning appears as the context of communication; it is not available to the author; he or she is part of their own socio-historical location and this is reflected in the documentary evidence accompanying the text. Documentary evidence is concerned with the socio-historical context of meaning that is established alongside intentional acts of expression.

"The context of meaning relations which makes communication possible is thus a construct which (like any metalanguage) can only be considered from outside - by a reflexive or retrospective act of consciousness." Simonds (25)

To arrive at documentary meaning, Mannheim set forward certain 'traits' which he used to characterise a worldview. These included the meaning of concepts; the absence of concepts; the structure of the categorical apparatus which is used; dominant models of thought; the level of abstraction; and the ontology that is presupposed.

Another, and very different approach, is that taken by Foucault who would argue that texts can only be viewed in relation to the 'discursive practices' and 'rules of formation' which govern the articulation of specific classes of statements and thereby make texts intelligible. (Another view of the nature of scientific discourse is adopted by Mulkay.) Whilst we cannot pursue these matters here, nor those raised by other writers on interpretation, we must acknowledge that like Mannheim or Foucault we start from a theoretical position. For us it is given by the concepts of worldview and social development, cosmology and social structure. From these we seek to understand the shared knowledge of the system dynamicists via the texts of their formal output. In other words, the 'validity' of our interpretations is rooted more in the 'validity' of our theoretical position than in the problems and contingencies of textual extraction itself.
Although we do not follow Mannheim, there are some parallels in our approach. For example, during the course of our analysis of the worldview and cosmology implicit in system dynamics, we will draw upon elements similar to the 'traits' listed earlier. Moreover, Chapters Three and Four will, in seeking to locate the development of system dynamics within a social tradition and social context, indirectly address the documentary level of meaning. Thus, at the beginning of our analysis the textual extracts will appear 'stark' and perhaps unconnected; however, as the investigation proceeds and our picture of system dynamics becomes gradually more complete, the extracts should become more intelligible in that they will be more easily interpreted in relation to that picture.

Of course this does not provide any final solution to the problems outlined earlier: one can always pose the question as to the representativeness of textual extracts. We can, however, by giving clear references to the sources, provide the opportunity for the falsification of our assertions. In other words, although we cannot prove the validity of our interpretations, by indicating the source of the extracts we can allow them to be refuted.
CHAPTER THREE

FORRESTER'S WORK AS A PRODUCT OF SOCIAL DEVELOPMENT
In this chapter we will draw upon the writings of Elias in order to construct an argument about some general dynamic features of the relationship between knowledge and social structures. In order to set out the problems which confront us, let us first reiterate the major flaw of the 'reflection theory' posited by economic determinism. While accepting the basic premise of such theories - i.e. that ideas do not exist in a social vacuum - nevertheless, we contend that they cannot be reduced to a mere reflection of the economic base of the social structure. Thus, in the case of Forrester, our position is that it is simplistic to see him solely as some 'puppet' of capitalism. Whilst we certainly do not deny the possibility that his models may be used to promote or justify specific features of the social structure - for example, the interests of capitalism - such interests are not in themselves sufficient to explain the development of his work. For instance, although Forrester remains committed to capitalism as such - this being a social interest - we shall see that his changing interpretation of his interests has led him to move from the idea of American style capitalist expansion throughout the world, to the idea that industrial growth must stop. We therefore need a broader model than can be provided by a reflection theory.

The writings of Elias are relevant in this context because he argues that the relationship between knowledge and social structures is neither simple nor static, and in fact contends that they are inextricably intertwined in their development. In order to understand ideas, their role and meaning, we must consider the relationship between knowledge and the social development of the society in which it originates and evolves.

Before we can elucidate this notion of social development we must first discuss Elias' concept of a "figuration". He uses this term to denote the different networks of interdependencies which link people together both within and between societies. This concept does not readily map onto class boundaries alone; rather, classes are but one type of figuration. The linkages between classes (e.g. through the mode of production) are another type. But a family too is a specific figuration, as is the network of families which make up a small community etc. Elias' concept of social development centres on the processes by which the interweavings of different figurations change; for example, through the division of labour; political integration into nation states; or the changing power differentials between different classes. These processes do not just denote material developments in society, but also point to
developments in knowledge and ideas. In fact, shared knowledge binds people together and is a power-resource which may cause people to have more influence on the development of the social relations within the figurations in which they live.

To take an example, it was only at a certain period in history that people came to think that the world contained an economic sphere which was distinctly separate from the realm of politics. This occurred during the rise to power of the entrepreneurial bourgeoisie; they wished to avoid political interference by governments - which at that time were largely made up of the pre-industrial aristocracy - and demanded that the 'separate' economic sphere should be allowed to follow its own 'natural' laws. This contributed to the transformation of political economy and the subsequent birth of economics as a distinct discipline. This view contrasts with that sustainable by a reflection theory. For although the new ideas about the economy are seen as representing the interests of the rising class, they are not seen solely as a reflection of those interests. Rather, they are seen as a product of the social development of the wider society and in particular of the figurational interrelationship between the aristocracy and the bourgeoisie. It was this that helped to shape the bourgeoisie's perceptions of the world - including their notions about the economy - which metamorphosed from the idea that economy ought to be autonomous to the idea that it actually was autonomous and was subsequently perceived as such. Further, as a power-resource these ideas contributed to social development and were therefore not insignificant epiphenomena as economic reductionism often suggests.

At that time the bourgeoisie had a generally optimistic outlook on the world and embraced ideas of progress and development 'for the better'. The pre-industrial aristocracy represented a power that belonged to the past; in contrast, the bourgeois class was in the ascendant and so to them the future looked bright. For Elias, this link between a class' social situation, its outlook, and the knowledge to which it adheres, is an important one. Later, he argues, the social situation of the bourgeoisie changed and so too did their knowledge and outlook. Interstate and intrastate developments - such as the First World War and the Great Depression - helped to blunt the idea of progress. The bourgeoisie became more pessimistic in their outlook and the future appeared less bright. Moreover, it appeared to contain forces - such as communism - which threatened to undermine the whole bourgeois world order. The knowledge they adhered to subsequently changed as well, and theories about progress became replaced by theories which focussed on the present social order and were directed at conserving and defending
Elias's ideas concerning the relationship between knowledge, outlook, and social development suggest the basis for a model which is useful to the study of Forrester and system dynamics. His development perspective suggests that ideas may be viewed in a long-term context, but we do not propose to chart in detail the history of the figurations in which Forrester is located. Rather, the main point for us here is the dynamic aspects of the relationship between knowledge and social development.

Certainly - as we indicated in Chapter One - Forrester's ideas are linked to the social developments pertaining to the rise of engineering, scientific management, and the increasingly dominant role of engineers in American society. But we cannot study the technocracy movement over the past one hundred years. Instead, we propose to concentrate on the short-term social developments which have impinged upon Forrester during the course of his career and examine the theoretical development of system dynamics in that context. This means that our model will not be able to take account of the long-term historical roots of system dynamics, but we will be able to try and explain the course of its development during its application to different domains.

In order to execute our task we propose to draw an analogy between Forrester's work and a particular development within academic sociology. This is the emergence of Parsons' social theory (structural-functionalism) which is of interest to us here for two reasons: firstly, it too is based upon a systems-theoretic view of society; and secondly, the history of structural-functionalism provides an illustrative example of the relationship between knowledge and social development. In fact, Gouldner has provided a detailed critique of Parsons which attempts to demonstrate the relationship between his social theory and the social contexts in which it evolved: we propose to consider this critique as a case study of the type of approach advocated by Elias.

Like Elias, Gouldner focuses upon the changing fortunes and outlook of the middle-classes and uses this to chart the evolution of Parsons' social theory.

Given that we can establish the plausibility of the analogy we will be in a position to use Gouldner's conclusions to make inferences concerning Forrester's own work. Our aim in doing so is to sketch the

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Elias himself has drawn attention to the development of sociology and has singled out Parsons' work as an example of social developments which have impinged upon the middle-classes during the past century (5).
rich texture of social development without the necessity of a detailed long-term study of Forrester's social location. The comparison with Parsons will enable us to go into detail concerning Forrester's theoretical position (and its development) and relate it to short-term social developments and his changing outlook. In order to structure the comparison we will consider the worldviews of both theorists - which we take to consist of theoretical beliefs, values, and general outlook.
In order to establish the similarities between the worldviews of Parsons and Forrester we will consider several features which are discernible in their respective systems theories. These features not only illustrate their theoretical beliefs, but also inform us with regard to their value orientations. We will focus on the following:

Process-reduction

The oneness of the world

Conflict

Common interests

System interdependence

System requisites

1.1: PROCESS-REDUCTION

The models of social systems which are postulated by structural-functionalism and system dynamics can readily be seen as examples of process-reduction i.e. they reduce the processionary nature of society - its long-term social fluxes - to a state. For example, Parsons partly relied upon an organic analogy for describing social systems; he thought of society as a living organism in which social processes corresponded to organic processes. Despite its obvious attraction, this analogy has the drawback that it forced him to refer social processes back to some static framework which corresponded to the organism itself. This turned out to be the dominant institutional infrastructure of society at the time. Further, though processes are indeed present in Parsons' model, they are seen as intrinsic to the system. In contrast, social change is perceived as a perturbing force which is extrinsic to the system.

"Social change thus appears as a phenomenon resulting from the accidental, externally activated malfunction of a normally well-balanced social system. Moreover, the society thus disturbed strives, in Parsons' view, to regain its state of rest." Elias (8)

The organic analogy has surfaced in Forrester's work too, and he accordingly perceives the dynamics of systems in relation to an unchanging structure which again largely reflects dominant values and
institutions. System dynamics models purport to simulate future time but their structural features remain fixed. The 'present' is therefore projected into the future and the ensemble of processes that pervade the fabric of societies - and which in fact make them societies - have been frozen into an unchanging concrete structure.

Parsons and Forrester regard social systems as 'real world' entities which exist above and beyond the individuals within them. In other words, systems have an ontological status in their respective frameworks. Systems theory is not just seen as a way of gaining knowledge about the world (a matter of epistemology): for Parsons and Forrester it is a way of revealing the properties of a world that is actually systemic. This helps to reinforce the effects of process-reduction, for if society is a system and - through the organic analogy - has an institutional core which is unchangeable in essentials, then long-term social processes will be ignored as extraneous to the system as it is construed in the here and now.

3.1.2 THE ONENESS OF THE WORLD

System dynamics and structural-functionalism share a similar metaphysical conviction about the "oneness" of the world. Thus, a social system is not merely a unity of elements - an integration of separate parts - it is a whole, and its elements express this oneness.

"Its oneness, Parsons believes, is the world's most vital character. Its parts, therefore, take on meaning and significance only in relation to this wholeness." Gouldner (10) emphasis added

This conviction can be seen in system dynamics by the way in which analysis proceeds; whether it is a corporation, a city, a nation, or the whole world that is being studied, each is seen as a totality and it is the total system which provides the point of departure and the frame of reference for analysis.

With Forrester, one immediate consequence is that the causes of social problems - as well as prescriptions for their solution - are sought solely in terms of system properties. For example, some problems are attributed to the pursuit of short-term goals, or to the counterintuitive nature of complex systems. The converse of this approach is that theories based upon the notion of class conflicts or contradictions (e.g. Marxist theories) are excluded from any debate concerning the nature and origin of social problems.
This exclusion-tendency can be seen also in structural-functionalism. In fact, Gouldner argues that Parsons was motivated to counter the model of society posited by Marxism. Marx too had conceived of society as a system; yet for him the divisions in the social world - its conflicts and contradictions - were its deepest reality. In contrast, Gouldner suggests that for Parsons it is not the cleavages in the social world that are real, but rather, its unbroken oneness.

The vision that the world is one contributes to a distinct view of subsystems. Simply stated, Parsons' approach entails a study of social relations in terms of the functions they have or perform for some larger structure - hence the name 'structural-functionalism'. For example, an organization may be conceived as a cluster of functional relationships which are ordered so as to produce a self-maintaining entity. Further, the organization is seen to have a common pattern of values and norms which integrate its separate elements or subsystems into the organizational whole. This idea of the functional integration of system elements underpins system dynamics; for instance, in several places Forrester adopts the term "functional" to describe organizational activities - which he looks upon as a contribution to the working of the total system.

3.3 CONFLICT

Given that they are committed to the notion that the world is one, Parsons and Forrester - not surprisingly - discuss conflict in a distinctive way. Anything which is functional is thought to be implicitly good; with structural-functionalism this bias is derived from its positivist heritage. The 'positive' orientation of that philosophy meant that social phenomena were to be explained in terms of some functional operation in a larger system; they were therefore seen as something 'positive', something which contributed to the integration and maintenance of the system. This connects with the idea that conflict is bad, for it is seen to be 'dysfunctional' - it threatens the disintegration and breakdown of the system. Forrester adheres to a corresponding view and his consequent commitment to social order (i.e. the absence of conflicts) is clearly seen - for example - in the following extract.

"Our most challenging intellectual frontier of the next three decades probably lies in the dynamics of organizations, ranging from the growth of the small corporation to development of national economies. As organizations become more complex, the need for skilled leadership
becomes greater. Labor turmoil, bankruptcy, inflation, economic collapse, political unrest, revolution, and war, testify that we are not yet expert enough in the design and management of social systems." (11) emphasis added

Though Forrester does perceive the possibility of goal conflicts between different subsystems, he does not believe that conflict is a structurally inherent feature of social systems. Much the same can be said of Parsons, and in fact his neglect of conflict is frequently cited as an important flaw in his social systems model.

"By no feat of the imagination, not even by the residual category of 'dysfunction', can the integrated and equilibrated social system be made to produce serious and patterned conflicts in its structure." Dahrendorf (12)

Neither theorist can accept that conflict may be part and parcel of the social world.

3.1.4 COMMON INTERESTS

The belief about the world's oneness, coupled with the functional perception of subsystems, leads both men to embrace the idea of common interests or common system goals. The argument seems to be that if the world is one there must be certain goals which unite all of the subsystems within the system. Parsons is concerned with the importance of value consensus - which he sees as vital for the integration of the system; this is only possible if common goals exist. In Forrester's case we find an argument that (in the long run) only the pursuit of system goals (i.e. common interests) can benefit the system as a whole. He therefore calls for the subordination of subsystem goals to the system goals which alone serve the common interest of all. His view of conflict surfaces again here: conflicts of interest are seen not only as threats to system stability, but also as blocks preventing subsystems from achieving long-term benefits through the integration and stability of the total system.

Moreover, it has been suggested that Parsons' concern with social order is basically a moral one (13). In connection with this we may also note that Forrester has advocated an important role for religion in maintaining a future global equilibrium society - thus evincing a similar moral dimension in social order.
The concept of system interdependence is a central feature in many systems theories. Basically, the idea is that a system's elements are in reciprocal interdependence with each other and there are therefore no 'single-factor' deterministic elements - no simple causes and effects. This concept has three problems associated with it: namely - the measure of interdependence; its ontological status; and the perception of interdependence vis-a-vis system elements. By examining these problems we can see the overlap between Parsons and Forrester in contrast to other systems theories.

In Parsons' work the problem of the varying degrees of interdependence is not raised. In part, Gouldner tells us, this was due to the lack of a body of mathematics which would be required to address the problem. A measure of interdependence implies quantification and therefore calls for a mathematical approach. Turning to Forrester, we can see that although he uses mathematical modelling techniques and computer simulations, the model variables are enclosed in feedback loops - where everything influences everything else - and he does not raise the question of the differential degrees of interdependence between the variables. Indeed, this has been left to some of his critics who have shown that despite the apparent complexity of his world model, its essential behaviour is determined by key assumptions concerning the growth of population and capital. Thus, these elements in his model are its basic driving force and other elements are largely dependent upon them.

Surprisingly though, despite their common emphasis upon the importance of interdependence, and in contrast to ideas of multiple causality, they both tend to emphasize single-factor explanations in accounting for the behaviour of social systems. In Parsons' case there is a primary emphasis upon the role of shared moral values and beliefs; whilst in world dynamics, for example, Forrester too stresses the need for long-term value structures to maintain system stability.

This first problem is in fact closely related to the problem of the ontological status of interdependence. When dealing with a system, whether physical or social, we are not necessarily dealing with a real system, but something which may display a greater or lesser degree of systemic properties such as interdependence. In other words, interdependence is not an a priori exhaustive description of the relationship between system elements. However, as we observed earlier, Parsons and Forrester view systems as real-world entities and so
interdependence in social systems is seen rather as a fact.

In order to illustrate the third problem we will consider a different systems model, one which will show us a further distinctive bias in their conception of interdependence. In contrast to conceiving of systems in terms of interdependence, Gouldner has outlined an alternative model based upon the idea of the functional autonomy of system elements. According to his model, systems can be seen as an assembly of elements which have a varying degree of functional autonomy with regard to each other. Thus, some elements may be highly autonomous—meeting most of their own needs—whilst certain other elements may have a low degree of functional autonomy and therefore depend upon interchanges with the other elements for the satisfaction of their needs. In this model a system is seen as a group of elements whose interchanges restrict their functional autonomy.

Conceptualizing in terms of interdependence—as Parsons and Forrester do—focuses on the whole and the close-connectedness of its parts. This therefore emphasizes the oneness of the whole and the parts are seen in relation to their systems character. Conversely, conceptualizing—as Gouldner does—in terms of functional autonomy, sharpens focus upon the parts themselves. In this alternative model the system elements are not seen merely as 'parts' but have an existence on their own and their connectedness actually becomes problematic because it restricts their autonomy. And whereas the positions of Parsons and Forrester lead them to concentrate upon the mechanisms that protect the system in its totality, Gouldner's approach leads to a consideration of the mechanisms that protect the autonomy of the parts.

3.6 System Requisites

The crux of Parsons' theoretical framework revolves around the idea of four system requisites (or system problems) which are all involved in the protection of the system and its persistence. These system 'needs' are: adaptation, goal attainment, pattern-maintenance, and integration.

The idea of adaptation is concerned with the manner in which a system responds to changes in its environment. Given a situation of scarcity and contingency, it is necessary for the system to adapt to environmental conditions by allocating personnel and resources in the best possible configuration to pursue its goals. Related to this, goal attainment is the problem of ensuring that the system is actually directed towards its goals.
The notion of pattern-maintenance is used to describe the way in which a system tends to maintain its equilibrium state through homeostasis. As we suggested earlier, the steady state is seen as the normal condition of the system and change is perceived as being extrinsic - a transient phenomenon as the system moves from one equilibrium state to another. The patterns which the system maintains are constituted by shared norms and values which obtain various 'patterns of action' - the pattern variables. With reference to this, Dahrendorf equates Parsons' social systems model to a utopian "village pond".

"Homeostasis is maintained by the regular occurrence of certain patterned processes which, far from disturbing the tranquility of the village pond, in fact are the village pond." (17)

Lastly, integration is the problem of maintaining value consensus, or a shared value system, which facilitates goal attainment and pattern-maintenance.

In system dynamics we can find ideas which are analogous to these four system requisites though they are not given the same formal role.

In world dynamics it is suggested that physical limits to growth are being encountered by the world system and that continued growth in population and industrialisation represents a threat to the system's viability. This points to a problem in the relationship between the world system and its environment and is therefore a problem concerning adaptation. The proposed solution to the problem is said to lie in a global equilibrium society where growth in industry and population would cease. Forrester discusses the problem of maintaining long-term operating goals (which are necessary to achieve and preserve equilibrium) in the face of short-term desires - this parallels the Parsonsian problem of goal attainment.18.

Forrester believes that systems are purposive, by which he means that they are goal-seeking. Further, that goal is conceived of as an equilibrium state where the growth tendencies of the system's positive feedback loops have been arrested (or checked) by its negative feedback loops. In fact, we can actually consider negative feedback to be a type of protective mechanism for the system; indeed, positive loops move away from a goal whilst negative loops move towards a goal. It may also be noted that Forrester advocates the use of "negative forces" in order to bring about an equilibrium society. What he actually has in mind is the strengthening of the system's negative feedback loops which, in analogy with the concept of an organism, is similar to the idea of mobilising the
Parsons views equilibrium in more sociological terms – through the operation of the pattern variables – but despite this difference in the exact phenomena implicated in equilibrium the central core of each conception is the same, i.e. order and the absence of structural change are considered to be the normal or preferred conditions of the system. Moreover, it is not difficult to envisage how the engineering conception of equilibrium can be translated into a social or political concern for order and stability; for equilibrium implies the absence of large scale structural change or conflict. This is borne out if we turn to the foreword of Forrester's Collected Papers where Brown, who is a distinguished engineer and a superior of Forrester in his earlier career, states:

"Worldwide efforts to stabilize political, economic, and social structures frequently fail...Scholars in many disciplines have addressed themselves to seeking solutions to these dilemmas...New and more powerful approaches are urgently needed, and it is my belief that the system dynamics methodology developed by Professor Forrester is one such approach." emphasis added

Forrester argues that complex systems are insensitive to policy changes, because they react towards such changes so as to defeat them and thus preserve their original state. As with Parsons' concept of pattern-maintenance, this idea is derived from the notion of homeostasis and so the overlap here is not surprising.

These 'protective' mechanisms are not the only ones to be found in Forrester's work; in fact, as with structural-functionalism, other mechanisms turn out to be rooted in the role of value structures, and so the problem of integration also surfaces in his theory. Forrester's ideas on values are primarily confined to his later work, from the period of urban dynamics onwards. This marked a very interesting change in his theoretical position, for in addition to the cybernetic feedback properties of systems he now began to re-focus his theory to include the role played by individual value commitments in securing system equilibrium and stability.

Forrester has asserted that long-term value structures determine what society may be like up to one thousand years from now, so these structures are obviously perceived to play an important role in system stability.
The long-term value component in an operating goal is an enduring standard that transcends adversity and short-term pressures. It is deeply embedded in the collective character of the system." Forrester (21)

This compares with the Parsonsian perspective, where value structures contribute to goal attainment by ensuring system integration.

Secondly, Forrester contends that many of society's present values, such as humanitarianism, are only oriented towards short-term interests. In contrast, he believes that there are certain long-term values which are oriented towards long-term interests such as the viability of the system as a whole.

"Morality and ethics must focus on how we are to make the choice between that which is favourable to us in the present and that which is right for humanity in the future." Forrester (22)

Not only do Parsons and Forrester share a similar concern about value consensus, they also treat some values - namely order and stability - as transcendental. With Forrester, these values would presumably be judged to be "right for humanity". The notion that some values are transcendental and not culturally specific, is really another extension of their conviction of the world's oneness - thus, their conception of a social system is like a universal form, unbroken in its oneness it is protected by certain transcendental values to which all lesser values such as humanitarianism must be subordinated. The notion of transcendental values also underscores their fixation on the present order of things - they can see no alternative to it because it rests on immutable values.

This brief survey of Parsons and Forrester has been based upon a cluster of common theoretical beliefs which, far from being 'obscure' or insignificant, have provided us with a useful picture of how they perceive the world. Interwoven with these beliefs we have discerned a number of value orientations. Thus, for example, both place a similar value on the moral basis of social order (as well as social order itself) in contrast to non-moral bases of social order (e.g. material gratifications).

Our contention is that the root of the similarity between Parsons and Forrester does not lie in their adherence to a particular form of systems theory - as if this could exist in a social vacuum - but rather in the social developments which have shaped the formulation and use of systems theories as descriptions of society. In other words, they both
draw upon similar conceptions of systems theory as a knowledge resource to promote their interpretations of their interests - these being related to their class position and the tradition in which they stand. Our next task therefore, is to discuss Gouldner's thesis that Parsons' work is a product of the changing fortunes of the American middle-classes. This will help to consolidate the model of the relationship between knowledge, outlook, and social development to which we referred in our introduction. We will then be in a position to make inferences concerning Forrester's work, and in the final section we will discuss the development of his theoretical framework in relation to these inferences.

3.2 Parsons' Work as a Product of Social Development

Some of roots of structural-functionalism can be traced back to the sociological positivism of Comte, but whilst the latter had an evolutionary perspective the former has been more oriented towards the present. Gouldner argues that this change in outlook was already evident with Durkheim.

"While Comte had raised the motto of 'Order and Progress', Durkheim, in contrast, felt constrained to place even less emphasis upon 'progress' than had Comte; he came to invest his energies almost exclusively in the analysis of 'order'. In short, Durkheim began to truncate the future orientation of Comtianism in the course of his polemic against the conceived future projected by Marxism and socialism. He thus began the consolidation of sociology as a social science of the synchronic present, which came to culmination in contemporary Functionalism." Gouldner (24) emphasis added

In Comte's time the middle-classes had embraced a forward-looking utopian vision that sought to sweep away the power of the old elites who opposed the rising tide of industrialisation. In contrast, the middle-classes of Parsons' society upheld a very different outlook; for them, the future appeared far from bright.

"Unlike the Positivists, the middle-classes of Parsons' society was not threatened by an old elite which was identified with a drew attention to the past, and thus did not need to look forward to a future in which it would be rid of that incubus. The forces threatening the modern middle class are themselves very future-oriented and look forward to a radically different society. Parsonsian Functionalism, therefore, is grounded in a class experience that has no stimulus to focus upon the past and little desire that its future be radically different. Its impulses are fundamentally conservative: they want more, but more of the same", Gouldner (25)
Thus, Parsons' theory is to be seen as part of a long-term change in the outlook of the middle-classes; its sentiments are focused upon the present whilst the future is seen to contain potential dangers to the social order. Gouldner views Parsons' early work as a theoretical response to the Great Depression of the 1930s. He also notes that it developed at a time when the world had witnessed the growth of communism after the Bolshevik Revolution; the rise of fascism in Germany and Italy; and the shattering, by the First World War, of middle-class confidence in the idea of progress.

It must be noted that Gouldner's thesis is rather controversial within sociological circles and we do not wish to imply that the matter is cut and dried. However, we do not propose to evaluate Gouldner's position vis-à-vis his critics. Our justification is twofold. Firstly, much of the controversy arguably does not address any substantive issues bearing upon whether or not Parsons' thought was influenced by social development; instead, it tends to revolve around semantic differences— for example, discussions of whether Parsons was a 'conservative' or a 'liberal' thinker. This criticism misses Gouldner's point for it ignores his definition of 'conservatism'. Though he allows that Parsons may indeed have been liberal in a narrow political sense, he was 'conservative' in that in the face of the threat to social order his overriding concern was the conservation of society's dominant institutions. A second—though weaker—reason is that the very existence of controversy is of no value in reflecting upon the worth or merit of any particular thesis. Indeed, the history of science provides us with numerous examples of why this is so.

Gouldner's thesis is that Parsons' work reflected the international concern of the world's middle-classes with the problem of maintaining social order.

"The empirical emptiness and abstractness of the Parsonsian analysis of social order reflected an effort to respond to the existence of an international crisis that simultaneously threatened the middle class in capitalist countries on different levels of industrialisation and within different political traditions." Gouldner (29)

He argues that Parsons evinced a conservative optimism in the status quo.

"It is pertinent to note that Parsons himself has referred to some of these points, and he remarks that his first book - The Structure of Social Action - marked a major turning point in his professional career because it clarified the development of his thought concerning the problems of the state in Western society (26)."
and in society's institutions; realising the extent and depth of the
crisis he focused on the problem of social order rather than the
contemporary social problems of the everyday world at that time. During
the Great Depression the economic system had broken down with
catastrophic consequences, it could no longer provide the things which
had held American middle-class society together. Thus, Gouldner asserts,
because Parsons dearly wished for society to be held together he was
forced to find a non-economic source of social integration.

"In the time-worn manner of the conservative, Parsons looked to
individual moral commitment to cement society. Parsons' voluntaristic
sociology did not consider the crisis soluble in terms of the New Deal's
welfare efforts, so, in effect, it concerned itself with what was
necessary to integrate society despite mass deprivation." Gouldner (30)

Parsons thought that society could be held together by morality and that
it would require neither changes in its economic institutions, nor
redistributions of income or power. Also, he was suspicious of the New
Deal and it was only during the post-war expansion of the welfare state
that he came to accomodate his theory to the idea of the need for the
state to take an active interventionist role in society.

Parsons' later work took on a more sophisticated systems-theoretic
perspective in the 1950s. Since the Second World War, the state had acted
in the name of national security; war-induced solidarity was
complemented by the integration of the unions and the working class into
mainstream society and the threat of social disorder receded.

"To see society in terms of firm, clearly defined structures, as Parsons' new theory did, was not now dissonant with the collective experience, the
shared personal reality, of daily life." Gouldner (32)

It was at this time that he came to perceive society as a self-
maintaining homeostatic system; going beyond the integrative function of
shared values he came to focus on the mechanisms which internally
contribute to the stability of the social system. Parsons' work at this
time also developed in the context of what he believed to be a dangerous
threat imposed by the Soviet Union; and, Gouldner argues that this
concern, particularly in light of the Marxist prophecy that capitalism
contained the seeds of its own destruction, acted as another important
influence upon his theoretical output.

"At the very source of Parsons' whole intellectual effort, then, was an
effort to combat this death prophecy; to seek or formulate a social
system so general in character that it need never die; to endow it richly
with a perpetual, self-maintaining character; to remove or iron out all
His work subsequently changed its emphasis from the central problem of order, and its solution in voluntarism (spontaneous individual value commitments), to the complex mechanisms of pattern-maintenance and self-regulation. This represented a further increase in the influence of process-reduction on the perception of the social world.

Finally, Gouldner argues that although Parsons did move some way towards the welfare state, functionalism still adopted a characteristic moral attitude towards social problems.

"Sociological Functionalism's emphasis on the role of moral values and on the significance of morality more generally, often leads it to locate contemporary social problems in the breakdown of the moral system; for example, as due to defects in the systems of socialization and as due to their failure to train people to behave in conformity with the moral norms." Gouldner (34)

Functionalism, therefore, did not advocate the kind of technocratic rationality - and the technocratic conception of social problems - that came to play a predominant role within the welfare state35.

32.1 THE PERTINENCE OF GOULDNER'S CONCLUSIONS FOR THE CASE OF FORRESTER

We can draw several conclusions from Gouldner's critique which suggest inferences about Forrester and system dynamics. Firstly, there is the idea that Parsons' social theory reflects a middle-class concern about maintaining social order, coupled with a conservative impulse to preserve dominant values and institutions. Particularly in the face of crisis (when there was a threat to social order) Parsons' main concern was the preservation of the status quo; not wishing to alter society's controlling institutions, he concentrated upon the non-economic sources of integration.

Secondly, he believed that social order could be secured by morality alone i.e. by individual value commitments and conformity to moral norms. This moral view of social order also had the ramification that social problems were seen as a reflection of a failure in society's moral systems.

Thirdly, the affluence and social cohesion of the 1950s led to the elaboration of his more sophisticated systems model. Now that the threat to social order had seemingly receded - and his faith in society's
The institutions appeared to be vindicated— he embarked upon a theoretical program to map out the mechanisms by which the social system protected itself. This period of his work also coincided with a growing threat perceived to be posed by the Soviet Union; in the face of this threat, Parsons' systems model effectively disproved the Marxist death prophecy and showed that the social system of the United States was richly endowed with self-equilibrating mechanisms which would ensure its survival.

Let us now see how these inferences might apply to Forrester. In fact, there are a number of plausible reasons for viewing Forrester in the same light as Gouldner views Parsons. For example, Forrester developed his early ideas on social systems during the 1950s when Parsons was working on his more sophisticated systems model. Secondly, each of Forrester's later modelling efforts have been addressed to some form of crisis in society; thus—as with Parsons—he has faced the problem of social order.

In the next section we will actually examine the development of Forrester's work, focussing in particular on the theoretical shifts which have marked the extension of system dynamics to different domains. If our analogy with Parsons is reasonable, then we should be able to explain these shifts—as well as the overall development of his work—in relation to the inferences made above.
Forrester developed industrial dynamics during the late 1950s and early 1960s; one of his reasons for the formulation of the approach was that it would contribute towards the United States' challenge for world leadership.

"We see already that the international struggle of the 1950s that was based on military technological competition is changing to a struggle to achieve economic strength and sufficient understanding of economic change to form a new basis for world leadership". Forrester (36) emphasis added

Forrester's earlier work on military systems* indirectly supported the "military technological competition" to which he refers, and his work on industrial dynamics was intended as a basis for improving the strength of American corporations - something which would presumably aid the United States in its struggle for global leadership. He did not believe that this would be won by the space race underway at the time but rather, thought that success lay in the control of economic systems.

"It is in management and economics, not on the moon or Mars, that the current international competition will be won. The American corporation is the heart of the American economic system. How well we fare will depend on how well American corporate management understands its job...For the last twenty years, international competition has been in the area of force supported by scientific advances. The rules of the contest are now changing. The test is now of leadership in showing the way to economic development and political stability". Forrester (37) emphasis added

Thus, Forrester held up the United States' economic development and political stability as a model for the rest of the world to follow. Though he did not specifically refer to the Russians by name, it was of course the Soviet Union which was the other main contender in the competition to which he refers. In other words, we can conjecture that the ideological confrontation with the Soviets left its imprint on his work, for its aim was to help the United States win the international competition. In fact, a similar view of the necessity for understanding the workings of the economy was later taken by President Kennedy.

"What is at stake in our economic decisions today is not some grand warfare of rival ideologies which will sweep the country with passion,

*During the 1940s and early 1950s Forrester had worked on various military projects concerning weapons control systems and the SAGE continental air defence system.
but the practical management of the modern economy. What we need are not labels and cliches, but more basic discussions of the sophisticated and technical questions involved in keeping a great economic machinery moving." Kennedy (38)

Turning now to the urban modelling project, we have already noted Forrester's view of the emergence of this stage of his work. The factors he points to are biographical details: for example, he refers to his contact with the ex-Mayor of Boston, Collins, and also lays great emphasis upon the fact that he had his own computer terminal at home - thus allowing him to expeditiously carry out the programming required for the urban model.

But of course this view is only one possible interpretation, or description of the emergence of the urban model and it contrasts with the inferences made earlier. For example, it notably does not take into account any of the various theoretical shifts that can be unearthed within the urban model. Another interpretation is that we should not see urban dynamics merely as a technical elaboration of industrial dynamics - i.e. a technical adjustment of the theory to fit a new domain - but as a 'new' theory which, in part, was forged beneath the hammer of the threat to social order. It is this second interpretation which we will pursue here, and we will do so in relation to the relevant theoretical changes.

Forrester had definite views on government intervention in the urban crisis and the responsibilities of local administrations. He was, for example, opposed to massive influxes of government money to tackle urban problems for he believed that they could only be solved by changed internal practices. He took the view that a city should be a master of its own destiny - that, in other words, it should be a self-regulating system. Of course, the idea that systems should be self-regulating was not new; the point of interest is in the way Forrester drew his system boundary. His choice is in fact resonant with a common feature of American culture - namely the notion of individual freedom which has evolved amid suspicion of the Federal Government. (This parallels Parsons' hostility towards the New Deal during the Great Depression. Then (and now) proposals for government intervention to solve social crises were often perceived by the middle-classes as a further destabilising threat to social order and were debarred from the agenda of possible solutions.)

*This formed part of our discussion in Chapter Two.*
In *Urban Dynamics* we find that Forrester makes the assumption that underemployed Negroes (his term) should be integrated into the economic framework of the city.

"This study assumes that extreme concentration of economic and social groups is detrimental and that success will be more easily achieved in a single economic system than in two separate and parallel systems." Forrester (39)

Interestingly enough, he provides no systems-theoretic justification for this assumption although it represents an expansion of his theory of social systems and one which apparently contradicts his thesis that a city should be master of its own destiny. For, if a city can be a self-regulating economic entity, then why not part of a city?

There is, however, a way of understanding this contradiction, for in fact it exemplifies an argument we made in Section 3.1.5. There we discussed Gouldner's idea of functional autonomy in order to reveal the bias in Forrester's notion of interdependence. This same bias is evident here, and we can see that he ignores the fact that the social and economic integration of Blacks (into the mainstream social and economic system) would restrict their ability to build a functionally autonomous system of their own.

Although there is the possibility that Forrester was only expressing some humanitarian desire for racial harmony, another plausible explanation lies in the prevailing threat to social order. We suggest that he was merely expressing a concern for order and stability - factors which were deemed to be more important than functional autonomy for Blacks.

At the time there was great concern over the urban problem, and in particular its racial dimensions. For example, Conant warned of "social dynamite" in the cities.

"The building up of a mass of unemployed and frustrated Negro youths in congested areas of a city is a social phenomenon that may be compared to the piling up of inflammable material in an empty building." Connant - quoted by Harwood (40)

Harwood argues that the aims of the poverty programmes, such as the Ford Foundation's community action programme, were never intended to eliminate American poverty. Rather, he contends that they were designed to try and re-establish the social order that had been disturbed by the effects of economic change upon Blacks after the Second World War; the
aim was to integrate them into the economy and thus restore order. This is one possible implication of Forrester's position, and his objection to the extreme concentration of social groups can be seen as expressive of Conant's concern about the "piling up of inflammable material" - he was responding to the threat posed by the urban problem and his abiding priority was the restoration of social stability.

Forrester also talked about the need to stop low-cost housing projects because of their allegedly detrimental effects on the city. This policy option is supposedly derived from the behaviour of his model, and yet the movement away from such housing schemes had already begun at the time his model was formulated.

"Prior to the new directions of 1968, low rent public housing was the dominant component in terms of national production...The importance of these programs declined markedly in favour of the more recent (1968) rental and homeowner subsidy programs." Mercer and Hultquist (42) emphasis added

Further, it should be noted that Forrester suggested that the political power of the poor was too strong, and that his proposed housing policy would effectively serve to constrain that power. On the one hand, he purports to be discussing the properties of feedback systems, yet on the other he conflates this with openly political value judgements. Might it not therefore be that his policy explorations on housing are not so much a purely theoretical matter, but simply another means of seeking the restoration of social order, and a theoretical reflection and legitimation of a change that was already underway at the time the model was being built?

The theoretical changes which we have been discussing are not the only ones that can be seen in the urban model; others centre upon the concept of limited good and the role of pressures and stresses in maintaining system stability. In Industrial Dynamics Forrester had been optimistic about being able to improve the performance of a system without a tradeoff.

"Since most industrial systems seem to operate so far from a hypothetical ideal, it is reasonable to hope that system improvements can first be obtained without requiring any compromise. Improving one factor may not require a penalty elsewhere." Forrester (43)

However, with the advent of urban dynamics his outlook had somewhat changed. Forrester now exhorted his readers to differentiate between the possible and the impossible (or the utopian) and he implied that there
was only a limited or fixed amount of good that the urban system could provide for its subsystems. He took the view that the goals which may benefit one subsystem may cause another subsystem, or even the system as a whole to decline. Ideas about value commitments began to surface and he talked of the "responsibility" of urban residents. Thus, he implied that order in cities could not be secured by economic incentives alone, but also required the allegiance to certain values. Moreover, he also implied that the urban crisis was partly caused by the breakdown of 'responsible' values amongst the poor. (We will return to these points in Chapter Five.)

Forrester's concept of limited good is related to his belief that no sustainable system mode can be free from pressures and stresses. In fact, systems are said to actually need pressures as restraints to stop the system from drifting into undesirable behaviour modes, i.e. out of equilibrium. So, pressures and limited good (scarcity) can be considered to be further types of protective mechanisms for the system. His new outlook which is reflected in these theoretical concerns is therefore sharply distinguished from his earlier work.

The idea of limited good did not appear in *Industrial Dynamics* where he had been concerned to pave the way for American economic leadership in the world economy. In the political climate of the time, such a notion could conceivably have been construed as a statement of a fault or limitation inherent in the capitalist system. However, with the onset of the urban crisis the idea came to the fore, for if it hadn't, other goals - 'utopian' goals which certain sections of American society firmly wished to resist - might have become predominant.

The next phase in the development of Forrester's work was his world model; by this time the imputed generality of industrial dynamics led him to adopt the term "system dynamics". The building of the model took place in cooperation with the Club of Rome, and the burgeoning environmentalist movement provided a blackcloth to the project. The main points made by this study were that there were fixed "limits to growth" in the world system and that it was necessary to undergo a transition to an equilibrium society if the system were to avoid a catastrophe.

Implicit in Forrester's theoretical development was a changing emphasis on the role and importance of individual and collective values. Here again we find an interesting parallel to Parsons, who during the Great Depression had advocated the potency of individual effort in contrast to collective solutions. Similarly, the need for individual action is evoked by Forrester - in his case to avert world catastrophe - and he
urged people to change their values so that they might derive satisfaction from an equilibrium society.

"To make the best of the future requires restraint, self-discipline, and intentionally increased pressures in the present." Forrester (45) emphasis added

Forrester's new theoretical emphasis and Parsons' early work both evolved amidst dangerous threats to social order; notably, both thought that such threats must be solved without changing the fundamental economic structure. With the urban crisis the challenge to order was present in many cities; with the world modelling project the perceived threat lay in the future but was potentially more devastating.

Forrester's idea of stopping industrial growth stands in stark contrast to his work in *Industrial Dynamics* where he had stated

"Capital formation, education, and the aspirations of the people must grow in synchronism if revolution and war are not to overtake economic development." (46)

In *World Dynamics*, however, we find a rather different position.

"We may now be living in a 'golden age' when, in spite of a widely acknowledged feeling of malaise, the quality of life is, on the average, higher than ever before in history and higher now than the future offers...There may be no realistic hope of the present underdeveloped countries reaching the standard of living demonstrated by the present industrialized nations." (47)

These ideas are also expressed in terms which have important theoretical ramifications for his systems theory. He has now 'discovered' fundamental 'laws' of social systems.

"When ultimate limits are approached, negative forces in the system gather strength until they stop the growth processes that had previously been in control. In one brief moment of time the world finds that the apparent law of exponential growth fails as the complete description of nature. Other fundamental laws of nature and the social system have been lying in wait until their time has come." (48) emphasis added

Thus, the system will ultimately protect itself and establish an equilibrium condition, but will not do so with the wishes of human beings in mind. Forrester observes the fact that values are acquired through socialisation and he believes that man has not evolved fast enough to cope with a world system that has now become so complex. Growth oriented values are seen as transient phenomena that are an
erration in present contexts, whilst the values consistent with an equilibrium society are more basic. In functionalist style, Forrester continues to look for the root of social problems in the breakdown of a moral system.

In the past several years Forrester has been preoccupied with modelling the American national economy. This work began during a mounting concern with the problems of inflation and unemployment, when the social order faced more crises and potential disorder. Although details of the model are not fully available at the time of writing, we can note his claims that the system dynamics structure of the model can reproduce the inflation and unemployment crises which many capitalist countries have been experiencing. He views these crises rather as system properties which have hitherto been misunderstood and mismanaged, and he has looked to the concept of long-wave economic cycles (e.g. the Kondratieff cycle) in order to explain them.

I believe the System Dynamics national Model is beginning to provide the first coherent theory of how the long wave is generated, and that theory to the historical evidence for the long wave, thus unifying many observations previously thought contradictory. We see these waves as the source of much of today's rising unemployment in industrial economies.
We have now looked at the general evolution of system dynamics, including its inherent theoretical shifts, and sought to explain them in relation to specific social developments. Our discussion of these developments has mainly centred upon various social crises but we have also referred to other features clustered around them. For example, we noted the question of the political power of the poor and the autonomy of Blacks in relation to the urban crisis. These issues, of course, are connected to the changing power differentials between different groups and classes in American society and are therefore specific strands of social development in their own right. Forrester as responded to each crisis with a modelling project which has sought to solve it. In each case, the restoration of social order has been paramount in his thinking, and his proposed policies do not challenge the established order.

We have seen that Forrester's worldview - like Parsons' - represents a traditional middle-class concern with social order. Further, his allegiance to the American social system, to capitalism, and indeed to social order generally, is not just a conscious matter in the sense that he explicitly values them. They are also rooted in the theoretical beliefs which structure his perceptions and the way he thinks. And these beliefs are themselves grounded in his social background and together with his values and general outlook have shaped the development of his work in relation to the social problems he has sought to tackle.

Forrester's outlook has become more pessimistic over the years and this too has influenced his theoretical position. For example, not only has he come to look for a moral solution to social problems, but he has also come to perceive such problems as being rooted in deficient value structures i.e. in failures of the moral system itself. Further, we have seen how the blunting of his optimism has led him to advocate the necessity of "pressures and stresses" in order for social systems to maintain their stability. Thus, what was once construed by some people as a social problem may now - according to Forrester's position - be seen either as a value problem, or as a system necessity (or perhaps even a system property in the case of the causes of unemployment and inflation).

Though we have seen that Forrester is committed to capitalism, his increasingly moral perspective cannot be explained in relation to capitalist interests, alone - i.e. as a reflection of the economic base. Indeed, his position is noticeably different to the technocratic perception of social problems, which ironically, other critics see also
as a reflection of capitalist interests.

Our analysis of Forrester's worldview has shown that it has entailed a number of shifts in his theoretical position - in other words, his actual interpretations of the world have changed. Although we have argued that he is committed to social order we have established that his interpretation of how that interest may be secured has shifted. Indeed, this has ramifications for his other interests and we have shown that he moved from the promotion of the hegemony of American capitalism to the idea that growth must end. If we had adopted only a simple static model of the relationship between interests and the development of knowledge, we would not have grasped these important changes - this bears out the utility of the developmental model posited by Elias. This model has afforded us an explanation of Forrester's shifting interpretations of his interests - in order to secure the goal of social order; it has illuminated the expansion of the domain of application of system dynamics; and it has enabled us to comprehend the various theoretical shifts which mark the expansion of its theoretical core. Moreover, by locating the development of Forrester's work in a cultural tradition we have - in Fleck's terms - shown that a number of his systems ideas such as the stand against massive financial programmes etc., are really esoteric variants of more general exoteric knowledge. In other words, knowledge within the traditional ideas of the American middle-classes has been transformed into an esoteric systems-theoretic variant. Thus, had we predicated our investigation on a simple dichotomy between internal and external history we could not have arrived at an adequate explanation for both the core and domain expansions within system dynamics. Such a dichotomy could well allow for social influences on the choice of domain extensions, but could not explain the theoretical shifts too.

In this chapter we have focused upon the general macroscopic relationship between knowledge and social development; in the following chapter we will consider the specific micro-social relationship between the cosmology of the members of the System Dynamics Group and the social bonds which unite them. We need to understand how social relations shape their values, outlook and theoretical beliefs - not just in times of crisis, but also during the ordinary mundane world of experience and, most importantly, in the context of the System Dynamics Laboratory. In other words, we need to know how the elements of a worldview are transmitted and constantly re-formed in the consciousness of individuals. To flesh out the bones that we have laid bare we now need tools of greater precision. Their provision will be the subject of the next chapter.
CHAPTER FOUR

COSMOLOGY, KNOWLEDGE AND SOCIAL STRUCTURE
The aim of this chapter is to develop a picture of the co-development and interrelationship between system dynamics and the micro-level social structure of the System Dynamics Group. Using the anthropological concept of cosmology we will endeavour to connect the shared professional outlook of the system dynamicists with their social experience as a group. In addition to social structure and cosmology (with the focus on the content of knowledge such as beliefs about man, society and nature) we will also consider cosmological style or thought style as evidenced by their methodological orientation, including their approach to modelling and response to theoretical anomalies.

We will undertake a comparative analysis and argue that differences in social context at the micro-level can be used to illuminate the differences in the shared knowledge - both in terms of style and content - of the System Dynamics Group vis-a-vis a control group.

Beginning with the work of Bernstein and the relationship between cosmologies, linguistic codes and the social bond, we will consider two elaborations of his work. The first, due to Douglas, is directed towards the content of knowledge, of shared beliefs about man and the cosmos. The second, due to Bloor, is a development of the first via the work of Lakatos in which the focus is on method and the form or style of knowledge (or thought style). In Douglas' work it is argued that the style and content of knowledge are connected but for the purposes of our analysis here we shall keep them separate during our investigation. It is of course not necessarily the case that the content of knowledge should be the same as style, particularly as we will take a methodological view of thought style.

Thus, we shall endeavour to show that on three different levels - social structure, the style of knowledge or thought, and the content of knowledge - the System Dynamics Group manifest a systematic difference in contrast to our chosen control group.
The anthropological concept of cosmology is of a system of knowledge encompassing shared beliefs about how the universe is construed. This system includes knowledge about the fundamental 'building blocks' of the cosmos, including the relationship between the self and society which in fact constitutes the thread by which the other beliefs are held together. Each cosmology has its own characteristic style of thought, determined by the nature of the system of boundaries and classifications that make it up.

Cosmologies are constructed with systems of classifications in which the nature of the boundaries (or divisions) between classes may vary. For example, some cosmologies may have a strong tendency to maintain boundaries, whilst others may have a weak tendency. In the first instance we might expect sharp distinctions between cognitive classes or categories, as if everything were 'black and white'. In the second case we could expect many shades of grey and a willingness to revise existing classifications. The first treats classifications as 'God given' and immutable - celebrating the purity of categories - whilst the second treats them more as provisional entities - celebrating the mixture of categories.

Douglas is an anthropologist who has developed some widely discussed ideas about cosmologies and how they are related to social structures. She views cosmology as being related to the type of social bond in a society - a line of reasoning related to that of Durkheim and Mauss. The basic idea is that the social relationships in a society provide a prototype for the logical relationships between things. Thus our social boundaries are said to influence our cognitive boundaries and therefore how we make sense of the world and endow it with intellectual coherence.

"The first logical categories were social categories; the first classes of things were classes of men into which these things were integrated. It was because men were grouped and thought of themselves in the form of groups that in their ideas they grouped other things." Douglas (3)

This aspect of Douglas' thought is also derived from the work of Bernstein. In particular she incorporates his ideas that social structures include various linguistic codes which mediate social relations and, most importantly, set constraints or limitations upon the medium of expression i.e. language. Symbolic expression is therefore said to be constrained by the nature of social experience. In order to develop the idea of such constraints we need to elucidate the idea of
LINGUISTIC CODES

Bernstein's thought on linguistic codes is derived from Durkheim's sociology of knowledge and Sapir's work on the influence of language as a cultural control. His focus of interest is upon the role of speech forms in encoding the patterns of social relations, and in mediating and reinforcing those patterns.

The basic idea is that when a child is socialised it learns a language that is encrypted in a linguistic code that reflects the social structure within which it resides. Linguistic codes not only define the concepts used by the child, they also set limits on what is perceived and on how perceptions are structured into meaningful patterns.

"...different speech systems or codes create for their speakers different orders of relevance and relation. The experience of the speakers may then be transformed by what is made significant or relevant by different speech systems. As the child learns his speech, or, in the terms I shall use here, learns specific codes which regulate his verbal acts, he learns the requirements of his social structure. The experience of the child is transformed by the learning generated by his own, apparently voluntary acts of speech. The social structure becomes, in this way, the substratum of the child's experience essentially through the manifold consequence of the linguistic process. From this point of view, every time the child speaks or listens, the social structure is reinforced in him and his social identity shaped." Bernstein (6) emphasis added

The "different orders of relevance and relation" impose different constraints upon the child's perceptions and experiences, and these have their correlates at a linguistic level. There has actually been a great deal of debate on this matter, especially with regard to the precise mechanism of the codes - e.g. do they operate through syntax or semantics? Whilst we wish to acknowledge the controversy surrounding these points we do not intend to become bogged down with them here. In order to illustrate the difference between codes it is sufficient to introduce the idea that language may have two distinct functions: one is to transmit information, and the other is to express the social structure from which it emerges and to reinforce it.

Bernstein posits the idea of two distinct linguistic codes, one restricted and one elaborated. The restricted code is seen as having a narrow range of syntactic alternatives that are rigidly organised.
Socially restricted speech conveys information, but also expresses and reinforces the social structure; the second function dominates the first. This code relies heavily upon the prevailing social context to convey meanings and therefore affirms the unchallenged metaphysical convictions upon which the social structure rests.

In contrast, the elaborated code is more detached from its social role and is more of an independent tool of thought. It has a wide range of syntactic alternatives that are flexibly organised; it requires more complex planning and can be used to articulate generalised abstract principles; it organises thought processes and distinguishes and combines ideas. This code carries a much smaller burden of implicit meanings for its aim is to make everything explicit - it elaborates meanings verbally.

"In its more extreme, elaborate form it is so much disengaged from the normal social structure that it may even come to dominate the latter and require the social group to be structured around speech, as in the case of a university lecture." Douglas(8)

Each type of speech code is found in different social structures, each is generated by a particular social matrix. Bernstein has used the idea of family control systems (the way that adults control their children) as a way of characterising these differences. He posits the idea of two opposite systems, positional and personal, corresponding the restricted and elaborated codes. With positional control, the restricted code reflects the statuses, roles, and hierarchy of the surrounding social context.

"The child in this family is controlled by the continual building-up of a sense of social pattern: of ascribed role categories. If it asks 'Why must I do this?' the answer is in terms of relative position. Because I said so (hierarchy). Because you're a boy (sex role). Because children always do (age status). Because you're the oldest (seniority). As he grows his experience flows into a grid of role categories; right and wrong are learnt in terms of the given structure; he himself is seen in relation to that structure." Douglas (9)

However, with personal control the value of the individual is celebrated rather than the fixed social pattern. The child here is sensitised towards the feelings of others and uses the elaborated code to articulate his own personal feelings and emotions. When this child asks a question its mother feels obliged to give as full an explanation as possible.
"The curiosity of the child is used to increase his verbal control, to elucidate causal relations, to teach him to assess the consequences of his acts. Above all his behaviour is controlled by being made sensitive to the personal feelings of others, by inspecting his own feelings. Why can't I do it? Because your father is feeling worried; because I've got a headache. How would you like it if you were a fly? or a dog? The child tends to be controlled by person oriented appeals." Douglas(10)

Now let us see how these ideas tie in with the concept of cosmology. Douglas summarises Bernstein's insights in the following terms.

"He is deriving cosmology from control systems, or rather showing how cosmology is part of the social bond, according to the following principles. First, any control system, since it has to be made reasonable (be justified, validated or legitimated as Weber put it), must appeal to ultimate principles about the nature of man and the cosmos...Second, that the control system interacts with the media of control (speech, ritual). Third, that certain characteristics hold between the coding of the medium and the character of the control system." (11)

Each speech form transmits not only information, but also a concealed "baggage of shared assumptions". These assumptions are the "ultimate principles" of different cosmologies. Thus the nature of the social environment is perpetuated in speech forms and cosmology, and these in turn tend to reinforce that environment.

The transition from positional to personal control and from restricted to elaborated speech codes, is argued to be a result of industrialisation, particularly through differentiation (e.g. the division of labour) and increased social mobility. It shows

"the way that patterns of family control are progressively detached from the immediate social structure of the family and local community and progressively coordinated with the demands of the wider industrial social structure." Douglas(12)

However, the pressures of industrialisation do not produce the same combinations of responses in control and speech in all areas of industrial society. Douglas and Bernstein have suggested a tentative model to distinguish different cosmologies according to the differences in codes and control schemes. Figure(1) shows a fourfold classification of cosmologies; the cosmological elements in each case are cardinal sins and virtues, the idea of the self, and art forms. Let us consider some of the properties of the diagram.

In sector (A) speech has a solidarity-maintaining social function. Here are many so-called 'primitive' tribes where the social structure has a
FIGURE (1) GENERAL COSMOLOGICAL IDEAS (from Douglas' 'Natural Symbols', p. 50)

(1) CARDINAL VIRTUES
(2) CARDINAL SINS
(3) IDEA OF THE SELF
(4) ART FORM

SPEECH SOCIALLY
RESTRICTED

A

(1) PIETY, HONOUR
(2) FORMAL TRANSGRESSIONS AGAINST SOCIAL STRUCTURE
(3) SELF, PASSIVE, UNDIFFERENTIATED ELEMENT IN A STRUCTURED ENVIRONMENT
(4) PRIMITIVE: STRUCTURAL ELABORATIONS UPON SOCIAL CATEGORIES

FAMILY CONTROL SYSTEM

B

(1) TRUTH, DUTY
(2) FAILURE TO RESPOND TO DEMANDS OF SOCIAL STRUCTURE
(3) ACTIVE AGENT, INTERNALLY DIFFERENTIATED, RESPONDING TO ROLES
(4) CLASSICAL: TRIUMPH OF STRUCTURE OVER INDIVIDUAL

SPEECH ELABORATED

C

(1) Sincerity, Authenticity
(2) Sins Against Self
(3) Internally Differentiated Agent, Attempting to Control Unstructured Environment
(4) Romantic: Triumph of Individual Over Structure

D

(1) Personal Success, Doing Good to Humanity
(2) Generalized Guilt Individual and Collective
(3) Subject Alone
(4) Professionalism: Overriding Concern with Techniques and Materials of Creative Process
strong grip on its members. In sector (B) speech has been elaborated as a specialised tool for decisionmaking. However, the social structure still retains a grip and individuals here do not tend to challenge the social categories or assumptions which surround them. Douglas suggests that this would be the sector for Aristotle.

"Elaborated speech in this case is still in the service of the social structure, but uses the philosophical reflections at which it has become adept for examining and justifying those assumptions." Douglas (13)

In sectors (C) and (D) the grip of the social structure has been weakened. Sector (C) is thought to be a transitory state and (D) is an area where many people in industrial societies would be found - this is the sector for existentialism. In fact, Douglas suggests that in modern societies people are spread between (B) and (D).

If we think again in terms of the boundary maintenance characteristics of cosmologies, then we can envisage a sharp distinction between (B) and (D). With (B), boundaries would appear to be well-defined, permanent, and mutually supportive. They would be the separate graded compartments of the whole social structure. Positional control requires unambiguous boundaries, with the social structure being perceived as a concrete reality rather than as a provisional man-made entity.

In contrast, with (D) we would find a readiness to revise boundaries; the only ones that would be maintained would be those pertaining to the rights or qualities of individuals.

The diagram shows that the elaborated code can be distinguished in two forms: with positional control it is oriented towards the relationships between objects or abstract concepts; with personal control it is oriented towards the relationships between persons. It is interesting to note that Douglas locates engineers in section (B) along with lawyers and the military.

"The work of engineers, concerned primarily with abstract relations between material objects, does not lead them to use the elaborate code to reflect critically on the nature of social relations." Douglas (14)

Now, these suggestions concerning engineers are relevant to our analysis because they lead to speculations about Forrester who of course was himself an engineer. Would it be accurate to say that Forrester does not "reflect critically" on the nature of society? It is noteworthy that many of his critics have charged that he has a simplistic view of the political processes in social systems15. Moreover, we have the evidence
of his theoretical beliefs - e.g. his belief that systems are real-world entities - which can be seen as theoretical refractions of positional control, structured by an object-oriented elaborated code.

A further illumination of why Forrester could be located in (B) can be seen by comparing him with the type of people found in (D). Here are people such as social scientists (including psychologists and anthropologists) and artists etc; people who

"live by using the elaborated speech code to review existing categories of thought. To challenge received ideas is their very bread and butter...The professions which deal with the expression of personal feelings rather than abstract principles are also found here. This is the square in which ideas about morality and the self get detached from the social structure." (16)

Of course referring to cosmological differences amongst the professions begs questions about education. It is therefore useful to note that Bernstein moved on from linguistic codes to develop the idea of educational codes - which also set constraints upon thought and persist beyond the school into the child's professional life. (This is something we shall return to later.) Indeed, although we have been talking about family control systems, this has only been a means of illustrating how the social bond between individuals may be constituted in more general social contexts.

"For each type of family there is its necessary manner of validating coercive demands. For each distinct type of social environment, likewise, there its its necessary manner of justifying coercion. Through the classifications used, the furniture of the universe is turned into an armoury of control. In each social system human suffering is explained in a way that reinforces the controls." Douglas (17) emphasis added

The social bond is a system of control in which there are various ideas about what is right and wrong, and about the role of the individual vis-a-vis the social structure etc. These ideas are sanctified by an ideology - a cosmology which justifies the control system. Taken together, these features mask the power vested in the social bond and the power relations within it. Codes, whether linguistic or educational, are qualities inherent in the social structure; the range of codes available to an individual in a particular location constrains his or her range of conceptualization - thus, the experience of social relations sets limits on symbolic cognitive relations.
Douglas has sought to generalise Bernstein's work, to shift the focus from family control systems to the wider control systems of society. Her theory concentrates upon the control aspects of cosmologies, so for the moment we can leave aside the ideas about how the media of control vary and come back to them later. Douglas focuses upon a comparison of control systems which contrasts a personal form - unstructured by fixed principles - with a system that is equivalent to the positional family of the code-control scheme.

"We can concentrate, it seems, upon the interaction of individuals within two social dimensions. One is order, classification, the symbolic system. The other is pressure, the experience of having no option but to consent to the overwhelming demands of other people." (18)

The two dimensions are referred to to as 'grid' and 'group' respectively. Grid is a property of the shared classifications of society that bond individuals to it, and group signals the social pressures that impinge upon each individual. The grid-group diagram is depicted in Figure(2).

A classification system may define the whole of existence or only a selective part of it. The absence of classification represents confusion, "rulelessness". The greater the degree of classification in the social environment, the more stable it may tend to be. The grid dimension refers to the degree of rank or scope of shared classification systems.

Hierarchical groups where rank and classifications are very explicit are high grid - e.g. a military regiment or a bureaucracy. At low grid there may be competing systems of classification describing different aspects of the social field. Hence overall coherence is low here. Alternatively, there may simply be an absence of classification. The group dimension defines the strength of the boundary that surrounds an individual or group. An isolated group which is internally cohesive is high group; a fragmented group with unstable membership is located more towards zero on the horizontal line. At zero the individual is under no pressures from others at all.

In this view grid and group are seen as two independent variables that define social structure. Cosmology is the dependent variable and the different ways in which grid and group reinforce each other gives rise to different cosmologies.
FIGURE (2)  DOUGLAS' GRID-GROUP DIAGRAM
"Shifting from left to right, the view of the universe becomes progressively less benign. The world is less friendly; a more punishing, difficult place to survive in...From top to bottom, false appearances begin to emerge as we move down. Diverse classifications compete. There is less coherence. A gap between reality and formal appearance is observed. In a tribal society, a man will worry whether his neighbours are what they seem, honest humans, or man-eating witches in disguise. Among ourselves, philosophers become dubious about the possibility of knowledge of the external world...So there we are...our minds structured by the cosmologies which are generated by the ways we deal with one another, our categories reinforcing our social choices." Douglas (19)

Within the diagram Douglas distinguishes between four different social environments and their corresponding cosmologies: 1) high group/low grid (small group); 2) high group/high grid (high classification); 3) low group/high grid (insulated); 4) low group/low grid (individualist). Examples of these are as follows:

1) **social structure**: isolated groups without a clear distinction of roles, strong boundary between insiders and outsiders.

**cosmology**: dualism, preoccupied with the idea of good versus evil - pollution conscious

2) **social structure**: military, aristocratic, or bureaucratic systems; grid strongly identified with the social body, a clear category of rejects

**cosmology**: pious, ritualistic towards authority and its symbols, belief in a punishing moral universe

3) **social structure**: sections of industrial society where people are oppressed by a grid of impersonal rules - they have no choices and the wider society offers no rewards, they are insulated from other people

**cosmology**: eclectic, insulation limits social experience and therefore the theoretical elaboration of the concepts of nature and the self is impoverished

4) **social structure**: highly competitive individualistic environments; no fixed cognitive or social boundaries

**cosmology**: humans experienced as anonymous and merciless; time is an individual resource that is always in short supply; rules are abstractions which govern individual transactions
One particularly interesting feature of cosmologies is the different characteristic ways in which people may respond to anomalies. Anomalies are objects or events that do not fit into our usual systems of classification; they present a threat to our cognitive coherence and security.

"In a chaos of shifting impressions, each of us constructs a stable world in which objects have recognisable shapes, are located in depth, and have permanence. In perceiving we are building, taking some cues rejecting others. The most acceptable cues are those which fit most easily into the pattern that is being built up. Ambiguous ones tend to be treated as if they harmonised with the rest of the pattern. Discordant ones tend to be rejected." Douglas (20)

So far we have been concerned with the content of a cosmology but now we must consider its form or the style of thought. Following Bloor, we wish to consider thought style in a methodological perspective and in the case of SDG we will refer to their approach to modelling and response to anomalies. The style of a cosmology - thought style - is related to the system of boundaries and classifications by which our cognitive field is put together and our view of the universe mapped out. Anomalies may threaten to break down the sacredness of those boundaries and hence we can see that it is the nature of the boundaries that determines the range of response to anomalies.

Anomalies may come in many forms; an animal that does not fit into the local taxonomy; pollution or dirt; a deviant who disregards the moral norms of some particular group; or as Bloor has argued, even a counterexample to a mathematical theorem. If we return to Douglas' four cosmological types we find an interesting range of responses to anomalies. Firstly, with small groups, we find pollution conscious tribes where people are constantly prone to fears of evil. The lack of structure in their social environment leads to a pervasive dread of anomaly; here we often observe strong notions of taboo. Secondly, with high classification, the strong grid provides for a distinct category of rejects - those who break the moral rules. The elaborate nature of the grid also allows the redefining of boundaries, hence anomalies can be easily adjusted or excluded. Thirdly, we have the insulated cosmology where the high degree of insulation means that anomalies pose no serious threat and exist comfortably alongside of the public categories. Lastly, with the individualist cosmology, there are no stable social categories because boundaries can be constantly made and broken. Hence, there are no stable cognitive categories and so anomalies are the basis for
innovation and novelty.

At this point it would seem appropriate to pull together the threads of our argument concerning the nature of cosmologies. A cosmology is a system of knowledge about how the universe is construed; it has a particular style of thought associated with it and this is governed by a system of classifications and the boundaries which delimit them. Its content includes beliefs about the relationship between the self and society, nature, knowledge and time etc. Corresponding to style of thought, each cosmology is characterised by a distinctive response towards anomalies - the objects or events which transgress the system of boundaries and classifications. Cosmologies are correlated with specific types of social structures, and their unspoken assumptions concerning the ultimate nature of the cosmos are the source of a legitimating ideology which justifies the pattern of social relations within each social environment. Cosmologies are articulated in language and are therefore constrained by linguistic and educational codes which are qualities inherent in the social structure.

In the following section we will discuss some of the problems associated with the grid-group theory before going on to undertake a comparative cosmological analysis between the System Dynamics Group and a selected control group. Our aim will be to characterise the shared cosmology of the system dynamicists and apprehend its significance for the development of their knowledge. For instance, given the importance of their conception of nature within their outlook, we wish to enquire as to whether it is rooted in their micro-social environment - in other words, does their view of nature represent a symbolic expression of the social location in which they find themselves?

A comparative approach is necessary because of course the four 'ideal types' of social environment and cosmology have a limited practical utility: it is not possible, for example, to state that a specific group is high classification per se, but only that it is high in comparison to some other group. Contrasting the differences in cosmological content and thought style between SDG and a control group, we will invoke the grid-group theory to explain them in terms of differences in their respective social experiences.

1.1.4 PROBLEMS WITH THE GRID-GROUP THEORY

It would seem fair to say that the grid-group theory is regarded as a promising but nonetheless controversial contribution to the sociology
of knowledge. There are a number of reasons which may be suggested as contributory factors in this and it is worthwhile discussing some of them here.

Firstly, a careful reading of Douglas' writings shows that her theory has shifted its theoretical locus; from essentially Durkheimean ideas concerning collective representations and isomorphic interconnections between social and natural orders, she has moved more towards the social interests side of the thesis in which the focus is on the usage of the natural order as a resource for legitimating social institutions. In her earlier work, particularly Natural Symbols, where the grid-group theory was enmeshed with the ideas of Bernstein, cosmologies appeared as collective phenomena which constrained thought - the constraints being generated by social relations. However, with the advent of Cultural Bias we find a preoccupation with the "negotiating individual" in which cosmology is conceptualised in much more fluid terms: changing social experience is quickly followed by changing cosmology. The problems involved in this theoretical shift are compounded by the fact that Douglas has not sought to reflect on it, nor has she set the development of her work in context.

The earlier formulation allowed greater account to be taken of tradition, both at the social level of value orientations, allegiances and commitments, and at a cognitive level in terms of the persistance of codes. Bernstein's arguments about the coding and transmission of educational knowledge is supported by Douglas herself when she contends that the patternings of relevances and relations which are learnt as part of the curriculum are carried beyond the classroom and through life. Now whilst we do not wish to subscribe to a deterministic fixity which does not allow for, and indeed cannot accommodate social change, we feel that some compromise must be struck between Douglas' original and later positions. Certainly for those individuals who have had exposure to a variety of contrasting social environments we can perceive the possibility of the almost instrumental manipulation of cosmological elements in the furtherance and legitimation of specific interests. However, linguistic or educational codes are characteristics of cognitive structuring and performance which can not change so easily. For example, imagine how difficult it is for someone trained in say physics (especially within the highly specialised British educational system) to change directions as it were and become a historian, or for an artist to become a mathematician. Such transitions will have implications in terms of shifting cosmological perceptions but they will be accomplished only after much effort, unlearning and relearning.
Secondly, both Douglas and a number of her interpreters have apparently defined and utilised the concepts of grid and group in related but nonetheless divergent ways. At times it is not clear whether this is due to the lack of evidence concerning a particular case where the theory has been applied, and consequently grid and group have only been used to designate previously known aspects of social context. Caneva and Rudwick, for example, brought the theory to bear on materials they were already cognizant with\textsuperscript{23,24}. Other shifts in the usage of these concepts can be seen in the questionnaire oriented empirical thrust developed by Hampton\textsuperscript{25}.

In the programmatic \textit{Natural Symbols}, grid is defined as the "scope" or "degree of rank" of shared classifications, it is the "order" inherent in the symbolic system. However, in \textit{Cultural Bias} we find that grid is described as a "cross-hatch" of rules, and a set of insulations. Moving on to Caneva, we can observe that in his framework, grid "measures the extent to which people classify themselves according to socially objectivated roles and are then controlled by an appeal to behavior appropriate to a given role."\textsuperscript{(26)}

Parallel to this diversity in the interpretation of grid, we find a range of referents in the use of group. For instance, Bloor used university settings as the referents of social environment in which to locate the mathematicians he studied; in other words, group was taken to be the institutional academic bodies within which the different mathematicians resided. Others, such as Caneva, stretched the concept of group to cover the social environment within particular national contexts.

"German society within which these individuals came to maturity was a relatively stable, highly differentiated society with the individual well integrated into the social fabric via his particular corporate identity."\textsuperscript{(27)}

Because of this range in the usage of concepts in the case studies within which grid-group theory has been applied it is difficult to construct an overall picture of either its development or status in terms of empirical corroboration. Thus, it is evident that the concepts of grid and group are not established; grid is not theory dependent but, rather, it is an intuitive construct. Therefore, given a reasoned position, we can choose an operationalization of these concepts which matches the requirements of our analysis.
In the case of the system dynamicists we are interested in their professional cosmology and we take group to be the System Dynamics Group within the institutional setting of MIT. As for grid, we prefer to retain the more abstract and general definition set out in Natural Symbols. Our reasoning is as follows: this general level is such that each of the particular conceivable referents of grid such as role differentiation, rule governed behaviour, hierarchy etc., may be considered as dimensional variables which interrelate to set the overall value of grid (which is therefore considered to be a multidimensional construct). We would argue that the designation of grid as multidimensional is useful because it may be a mistake to assume that it was some simple additive function of each referent - as implicitly assumed on occasion by Bloor and Hampton. This view of grid has the further advantage that it allows the specificity of each social location to remain in focus. Rather than blurring the 'individuality' and particularities of each social context beneath the rigidity of a single formula, it requires us to allow for the differential weighting that each dimension may take in any given social environment. The overall nature of an environment is what counts in the last instance (i.e. whether it is high or low grid) but a multidimensional construct prevents the prejudging of what is to be taken as the most important indicator of grid for any particular context. This implies that we do not support the use of questionnaires as indicators of grid - at least not in isolation and certainly not if a simple scalar measure is employed.

To illustrate the potential utility of this more cautious approach we may consider the following example. Suppose one considered the hierarchisation of two institutions by looking at the formal structure of status positions within each institutional hierarchy - information on such structures being commonplace features of university prospectuses or yearly reports. The problem involved in such a comparison of griddedness is that it is difficult to know whether the hierarchy has an impact upon each individual within an organization or whether there are pockets of individuals or sub-groups who largely escape the formal channels of decisionmaking and the public grid of rules which support them. We are not thinking here of those actors who occupy positions at the upper levels of such hierarchies, who wield power through the organizational rules and classifications, so much as those who ignore or operate outside the rules, or those who occupy a social context in which the overt statuses are little respected. What we are driving at is that one must distinguish between the 'objective' institutional structure of statuses and hierarchy, and the actual
subjective manner in which they actually impinge upon different groups or individuals. The problems implied by this may be particularly acute for those cases involving historical material in which such a distinction may be hard to investigate. (We will have to return to this point when we discuss the institutional setting of SDG.)

We should also note that support for our position can be found in Douglas' own comparative analysis where it is reported that the division between the sexes in an otherwise weak boundary culture - the Hadza - has important cultural ramifications. In other words, this particularity of the Hadza, in contrast to the Mbuti pygmies, requires a flexible approach to grid; the overall bias of Hadza culture is towards low grid but the importance of this specific social distinction can not be overlooked if one wants to understand their culture. This implies that the weighting one might ascribe to the symbolic division of the sexes - which is one possible referent of grid - will depend on the other referents and therefore the particular context in question.

The relevance of this for our own study is that small differences in grid or group can have substantial significance for the comprehension of different cosmological systems. Compared to certain pre-literate peoples the cosmological differences between some scientific groups in western societies may appear quite small. However, we are not concerned with such a comparison but rather one between different western groups and we seek to explain divergences in their cosmologies by reference to possibly small differences in grid and group. Given the spirit of the comparative method set out by Douglas our intentions are not in dissonance - indeed they are in keeping with the professed subtlety of the whole approach.

When we look at the level of detail in the theories concerning the nature of society which are held by different academic groups it would be difficult to explain their differences in terms of divergent paradigms or problematics; or for that matter to argue that system dynamics was simply engineering applied to society. This would not solve the problem concerning the question of what characteristics of social environment influenced the development of system dynamics. Also, we must remember that system engineering itself developed in a specific social location - that of a military-industrial setting. In any case, rather than a diversity in content - e.g. physics or engineering - we are more interested in the diversity of styles. For example, we want to understand how a slightly higher-gridded social context, with its concomitantly greater profusion of social essences, becomes 'translated' into a theory containing relatively more platonic essences - often within its
implicit theoretical core, the assumptions upon which it stands - and therefore sustains a different view of the universe than a context at lower grid.

Similarly, in relation to group we want to inquire into the process by which a slight increase in group dependence - forced from within or without - can shift the centre of gravity of a theory such that it becomes defended in a manner which could have been considered unthinkable earlier and in which actors seemingly infringe elements of their previously stated methodological positions. Put another way, we want to consider the possibility that small changes in group (a strengthening of the boundary between the established and the outsiders) have the effect of enhancing the threat of anomalies or monsters - this will be particularly important when we come to consider how SDG responded to criticisms of their work. These points bring us to more fundamental problems; for in addition to the shifting theoretical orientation and divergent - though related - uses of the conceptual terms of Douglas' theory we must also consider the limitations which are inherent in the whole approach. Several criticisms have been articulated in 'Essays in the Sociology of Perception' and elsewhere 30,31,32, but we will only focus on those difficulties which are judged to have particular relevance to our own study.

The most significant problem would appear to be its rather static framework and the consequent lack of depth concerning the nature and causes of social change. It provides the basis for recognizing changes in cosmology in respect of changes in social context but does not directly address the mechanisms which, say, push a group towards higher grid or group. There are however certain clues or hints as to what is involved in such changes but a substantial theoretical caveat remains. Of course the concept of social change itself is problematic, particularly with regard to class-based, stratified cultures. Indeed, very disparate processes may be involved depending upon the societal resolution and time scale in which we are interested. In this thesis we are interested in any short-term changes such as might be nascent in the debate between SDG and its critics; particularly in view of the frosty, if not openly hostile reception meted out to system dynamics in various circles and organs of more established disciplines within the scientific community. We are also interested in the development of system dynamics in relation to the very formation of SDG and the processes thereby implicated. To pursue this line of enquiry we will have to expand upon Douglas' clues and hypothesize about the nature of the processes involved.
Despite the difficulties of theory and interpretation arising from the problems concerned in conceptualizing these types of changes certain advantages may accrue. For instance, it would constitute the addition of a longitudinal element to our analysis and would therefore buttress the case against those critics who might suggest that the differences between SDG and our control group are located in factors not addressed by the theory. This is perhaps particularly advantageous in view of the fact that the theory is rather sensitive to charges that it lacks detailed empirical corroboration. It should however be clear that our contribution in this direction is more concerned with establishing the consistency of our analysis here and not with the substantiation of the grid-group theory itself.

4.2 COMPARATIVE METHOD

4.2.1 CHOICE OF CONTROL GROUP

Before our comparative method can be carried out we need to discuss the problems which are indigenous to the choice of a control group and the reasons for the particular selection made here. There are many possible groups with whom SDG could be compared and all would display similarities and differences. Following the axiom that everything is both similar to and dissimilar to everything else, no a priori choice of control group can exist - there will be both advantages and disadvantages in whatever choice is actually made and our selection must therefore at least be based on a substantial argument.

If we took any two given groups it would be possible to compile a formidable inventory of factors - social, religious, political, economic and ecological - which could all have a bearing upon the beliefs held by them. However, the whole crux of Douglas' theory rests upon the claim that it is cross-cultural: that is, it purports to reveal specific patterns of social relations which may arise in different contexts but which are justified by similar sets of beliefs about man and the cosmos. However, in order to argue that differences in intergroup beliefs are due to differences in grid and group, the groups in question should be comparable. For example, in Douglas' own test cases she selects neighbouring Nilotic tribes. This is not a constraint of the theory, rather it is methodological requirement which pertains to all cases of comparative method. Comparative approaches are beset by the problem of many variables (i.e. sources of cultural variation) combined with only a small number of cases. Choosing comparable cases helps to filter out extraneous sources of variation but other possible strategies are to
increase the number of cases; or reduce the property-space by means of combining similar categories; or by constraining the analysis to what are considered to be the key variables.\textsuperscript{33,34,35}

We are interested in the professional cosmology of SDG and so the first requirement in our choice of control group is that it should be concerned with similar professional matters such as modelling socio-technical systems and policy formation. This requirement should circumvent any problems which might arise due to the glare of inter-professional differences and which would necessitate a task beyond the scope of this enquiry. Paradoxically, it may be that in seeking to choose a comparable control group we automatically restrict ourselves to groups with relatively similar grid-group environments - relative that is to the disparities evidenced in the ethnographic record.

A second requirement is that we should compare sets of beliefs about the world as it is. This is because groups from different social locations might well support similar programmes for social change, all being drawn by the lure of a particular alternative cosmology. Therefore we must be careful about referring to what might be stated about wished for social arrangements. (The particular beliefs we are interested in include those pertaining to man and society.)

Thirdly, the control group must be a genuine group in the sense that the individual members give consensus to shared public knowledge - we cannot merely compare SDG with isolated individual utterances emanating from a source who are only a group in name. We can of course allow for intra-group variation but it is the overall style of public knowledge which concerns us here. This latter point has been spelled out by Bloor in his study of mathematicians:

"Individual evidence is always to be treated by putting it in a context where its typicality and its contribution to the overall pattern can be assessed. This overall pattern is precisely the system of boundaries and classifications - it is the style of knowledge - and this is what the theory is about." (36)

\textbf{2.2 CHOICE OF COMPARATIVE ELEMENTS}

Douglas' programme for analysing cosmologies appears to have the potential for addressing an extremely diverse range of cultural elements; from attitudes to old-age and sickness, to millenarianism and
gardening, it offers a kaleidoscopic picture of culture. However, this very diversity poses the question as to what particular cluster of cultural elements we may consider in our comparative analysis - especially if we are to forestall the charge that our choice is selective. To answer this question we propose the following points.

Firstly, with comparative analyses it is an accepted tactic to select those variables which are considered to be important. As we are interested in the professional cosmology of SDG we will select those elements which form central features of their outlook. We will be comparing clusters of elements in which SDG and the control group will be closer together on some points and further apart on others - see Figure(3).

Secondly, the selected elements can themselves be regarded as clusters of sub-elements and we will therefore be grouping together similar variables and reducing the property-space. We will however seek to point out any non-uniformities within each element. Such disparities should be expected because any selection of elements - and thus the sets of sub-elements - must be an arbitrary one in that the clusters of sub-elements are not expected to reflect any real sub-divisions of culture.

Thirdly, the elements will have a certain degree of independence and therefore any systematic bias towards higher or lower grid-group will be all the more persuasive.

The elements we have chosen are 1) response to anomaly 2) modelling 3) knowledge 4) nature 5) man and society 6) time. The first two will be considered together as indicators of thought style, whilst the remaining four reflect the content of cosmologies.

In discussing knowledge we will refer to questions concerning ontology and epistemology, both the source and the justification for the knowledge which each group subscribes to. The concept of nature is a fundamental element of cosmologies: it may be seen as part of, or separate to society, to be venerated or controlled. Beliefs about man and society represent other fundamental pieces of the cosmological jigsaw. Is man changeable or static, is he a modifier of the ecosystem or only one species along with all others? Lastly, time is perhaps one of the more difficult elements to get to grips with - uniformly immersed in 'clock-time' as we are in modern societies. Though we cannot endeavour to tackle the depths of enquiry undertaken by many anthropologists, we can look at the conception of past, present and future, the temporal extent of obligations and the temporal character of the dynamics posited in
Note: of course at the outset we do not know which is group A and which is group B.
system dynamics.

One reason for the choice of these six elements is that they pertain to the professional outlook of SDG. Secondly, there is a pragmatic reason too in that more citations are available concerning these elements than say for SDG's attitude to religion.

2.3 SCIENCE POLICY RESEARCH UNIT

The control group which has actually been selected is the Science Policy Research Unit (SPRU) based at the University of Sussex, England. The following points discuss the reasons for our choice.

1) SPRU and SDG share a number of important professional interests centring on the nature and future developments of socio-technical systems and the problems they engender - they are part of the international scientific community who have focused upon similar societal and environmental issues. In parallel with this they share a commitment to the furtherance of policymaking. SPRU profess to take a systems approach in the study of problems and they are broadly interdisciplinary; they have a considered policy of bringing together natural and social scientists to work on shared projects. Like SDG, they have also experienced an influx of international scholars.

2) As a central feature of their work we find that the definition of problems and the formation of possible policy alternatives are determined by their beliefs about the nature of society: in other words, their work explicitly reflects their view of the present.

3) SPRU qualify as a group in so far as they issue joint papers, reports and books, and were also involved in the establishment and subsequent editing of the journal Research Policy. We can therefore speak of their shared professional outlook. Further, in their project work they are arranged into teams who - at least during the critique of world modelling - were in continuous close collaboration.

"In the early years of the programme all members of the team worked on their special assignments with one goal in mind: to contribute to a major common theme"(40)

We should also note that their livelihood as a group depended upon them 'making a name' for themselves and thus establishing an increased position of respect vis-a-vis funding bodies.
Like SDG they have been involved with outside consultancy work, including contracts with governmental agencies, corporations and international organizations. Indeed, their work on world modelling has been funded by similar bodies to those which sponsored SDG.

Both groups engage in the teaching of graduates and undergraduates, in addition to containing postgraduate research programmes.

SPRU entered into a professional dialogue with SDG. This stemmed from a contract in which they were requested to evaluate system dynamics as a technique, as well as the world models. This dialogue involved meetings and the exchange of letters but there were also formal interactions at international conferences and through the media of books and journal articles. It is out of this dialogue that we find a clear expression of the beliefs held by SPRU and to a certain extent we also find a clarification of those sustained by SDG - in other words, the exchanges made their beliefs explicit.

Moreover, this interaction contained not only technical issues but also focused on arguments concerning nature, man and society, and therefore highlighted the very types of belief necessary for our comparative cosmological investigation. The fact that the dialogue occurred also lends force to our contention that although SDG and SPRU are ostensibly located in different cultural settings (North America and Britain) they are part of an international scientific culture and we are therefore not in contravention of Douglas' methodological strictures.

Of course it could be objected that SPRU's criticisms of SDG do not really represent shared beliefs so much as opportunist responses. This challenge can be dealt with by reference to SPRU's earlier and later work. In fact, they share some considerable expertise in the very areas such as pollution and natural resources which were addressed by SDG and their criticisms were therefore a genuine reflection of their beliefs.

The threads spun through the dialogue reflect the moves of each group in wishing to secure or enhance their status and credibility; we assume that each articulated those beliefs which reflected the self-evidence implicit within their style of thought, and therefore their social context, and used them to buttress their respective positions. Later we will see how this illuminates the difference between SDG - modellers defending their intellectual products and sense of proper order - and SPRU, hired critics who seek recourse to a different sense of intellectual order. This is particularly of interest in view of the fact that SDG subscribe to a shared philosophy and methodology - system
dynamics—whilst in the case of SPRU no such single, concise, routinised approach is to be found.

7) Within the dialogue between SPRU and SDG there arose arguments concerning certain anomalies in connection with the behaviour of the World 2 model. This part of the interaction between the two groups—which we will refer to as the 'backcasting debate'—illuminates the difference in style of thought and response to anomaly which is manifested by each group. Indeed, the short history of this debate will form a major part of the following comparative analysis; whilst it enables us to apprehend each group's treatment of monsters it is also sufficiently detailed to allow us to pinpoint individual variations amongst SDG and therefore supports the possibility of both individual and sociological interpretations of the grid-group theory as proposed by Bloor.

1.2.4 OTHER POSSIBLE GROUPS

Other potential candidates for the control group could have been institutions such as the Hudson Institute or the Rand Corporation but these have been rejected for a number of reasons. The Hudson Institute is a private think-tank and is perhaps most notable for the work of Kahn, an ex-member of Rand and a futurologist whose books and articles include *The Next 200 Years* and *Year 2000*. His work takes the form of projections concerning likely technological developments and concomitant speculations about the potential social ramifications. It therefore does not meet the essential requirement of comparable professional interests or practices.

Although it is another private think-tank the Rand Corporation is perhaps much closer to MIT. Born out of close collaboration between the military and civilian experts during the Second World War it is famous for its pioneering work in systems analysis. Its earlier work in systems engineering later gave way to the predominance of cost-benefit style systems analysis during the 1950s but largely remained tied to the study and planning of military systems. However, in the 1960s certain Corporation members did look at planning in urban and governmental systems.

The aim of Rand systems analysis is to devise alternative techniques or instrumentalities by which specified objectives can be met. The selection of any particular alternative is related to criteria of economic efficiency and resource availability. The approach is not of
the formal modelling type practised by SDG; rather, mathematical models are used only as a means for investigating the relationship between the objectives and the techniques or instrumentalities. Moreover, simulation modelling is viewed as being only one of a range of possible techniques for evaluating alternatives within the cost-benefit framework.

Arguably, the Rand Corporation's work has much more in common with Forrester's work in the 1950s than the later work on urban and global systems. In fact, it would appear fair to say that Rand systems analysis remains essentially technocratic whilst system dynamics has developed its additional moral tinge. This difference notwithstanding, however, it may well be that both approaches are fundamentally similar. Indeed, a contrast between Rand and SDG would be an interesting history in itself - particularly when viewed as parallel strands of the systems movement which have developed from common origins in a military context. Having said that, we are faced with the problem that there does not appear to be a clear articulation of beliefs concerning the cosmological elements in which we are interested; for instance, Rand have not been involved in any extensive model based programme concerning population, resources and the environment. Moreover, we do not have any information concerning the style of response to anomalies which members of Rand might share. Because of these difficulties it is not feasible to develop an adequate account of the cosmological orientation which could be attributed to them.

4.3 THE CULTURAL SETTING OF SDG AND SPRU

The aim of this section is to present some evidence concerning the relative grid-group characteristics of the cultural settings within which SDG and SPRU reside. More specifically, we seek to describe the nature of the institutional location of each group. The major period of interest centres on the time of the world modelling debate (1970-1974) but we shall also consider the broader time span associated with the tradition of each institution. With each group we are concerned with their nascence within a tradition. In the case of SDG it is the period of almost 30 years including the 1950s and 1960s when Forrester and his colleagues moulded the ideas of systems engineering into system dynamics. In SPRU's case we have the very short period from 1966 when it was formed and the tradition built up mainly in the early 1970s. Moreover, the tradition behind system dynamics evolved within an institution which already had a distinguished reputation. These differences in historical extension and institutional setting of each tradition are reflected by the level of detail we can cite concerning
Before we embark on the descriptions of each institutional location it is important that we point out the relevance of the general liberalization in western societies - and in particular the radical changes in university environments - during the late 1960s and early 1970s. In fact, most of the evidence we shall cite concerning SDG pre-dates this and so our remarks should not be construed as being in any way well-founded in relation to the later institutional setting of the group. The evidence we will present is also subject to the reservations discussed earlier in section 4.2. However, by referring to different sources we hope to gain an overall flavour of each institution and set the micro-location of the groups in that context. Further, as the evidence is not based upon direct detailed observation of each group it will not constitute the basis for a stringent test of the grid-group theory but rather, is offered as auxiliary evidence on which to base our later comparison of cosmologies.

**SDG**

SDG reside within the Sloan School of Management at MIT. This is a private, and one of the most prestigious institutions within the American education system, and indeed it enjoys a worldwide reputation. Founded in 1865, MIT is a very large organization - in 1966/67 there were some 969 members of faculty (of which 26 were women), 3,857 undergraduates (200 women), and 3,718 graduates (201 women). Further, there were 935 foreign students (201 women). The Sloan School's chief benefactor was A.P. Sloan, the former head of General Motors; originally named the School of Industrial Management, it was established in 1950. In 1960 some 12 persons were engaged on the programme in industrial dynamics but by 1968 some 120 graduates and postgraduates took industrial dynamics as a first-term subject; in addition some 100 men in the Sloan Fellow and Senior Executive Development Program also took the subject. Many of the graduates within the system dynamics programme are former engineering students - this being an approved route for the graduate study of the management of complex systems.

MIT is a very exclusive institution and its entrants are restricted to those who are amongst the highest performers on various official verbal and mathematical tests - so much so that it has been said that students often stand in awe of each other. MIT has a long tradition of contacts with the military and different industrial concerns - particularly through the design of military systems and co-ordination of private sub-
contractors. Indeed much of the research at MIT is sponsored by the military.

Largely vocational in orientation, MIT is governed by moral considerations pertaining to education for the filling of societal roles and meeting professional responsibilities.

"All members of the M.I.T. family, administration, faculty, and students, must be able to feel a sense of belonging to a great institution with a high moral purpose."

The links with the military, government organizations and business indicate that it is well-integrated into the dominant ideology of the country. The sense of vocation is coupled with that of social responsibility; particularly in engineering, from whence many Sloan School graduate students originate, we find much stress on these factors.

"It is essential that the modern engineer be able to organize and direct men. His success depends as much upon his understanding of human relations and his skill in handling men as upon his technical competence. Full achievement in his profession requires that he be a man of broad culture with a deep sense of social responsibility." (emphasis added)

"Each student must be prepared to accept individual responsibility for leadership in his profession, his neighborhood, and his nation; this implies his acceptance of the moral and ethical burden relating not only to his own acts but to the acts of the society of which he is a part."

"Since we attract some of the best youth of this and other countries, the Institute is obligated to educate them to be not only capable technical men, but professional men aware of their responsibilities as citizens."

It is widely acknowledged that the student atmosphere at MIT is extremely competitive and demanding, with little time outside of teaching and studying; for the professors too, student demands on their time would appear to carry a heavier burden than at other institutions.

*This accent on the social responsibility of engineers would appear to be a general cultural characteristic and is not peculiar to MIT. Indeed, it is reported by several commentators.*
"The Institute has a demanding curriculum which dominates a large part of the student's working hours. Its severe selectivity insures that it admits only highly able and, on the whole, highly motivated students...the demands it makes, and the rewards it offers, both in the present and in promise, have profound effects on the lives of students". (54)

With the vocational courses in particular, the curricula are marked by much routinised learning and practice - "learning by doing" is a hallmark of MIT education. This often centres on laboratory practices and notably, system dynamics is taught in the System Dynamics Laboratory.

The students are continually assessed and ranked, and it is the rewards of high grades - such as scholarships and graduate fellowships - which helps to stimulate competition.

"At the centre, of course, are the grades. Not only do they certify accomplishment, but many future rewards are dependent on them" (55)

The heavy load of the curriculum, combined with a large student body (which therefore requires complex time-tableing) and regularity of testing all point to a high degree of punctuation and sequencing within the temporal dimension of social life. Following Zerubavel56, we can suggest that the complex time-tableing sets up a corresponding temporal structure within social life with consequent intricate patterns and rhythms. With greater organizational complexity, time becomes increasingly identifiable by one's particular location; the differentiation of time matching the division and integration of social practices such as lectures, laboratory work, seminars and study periods. The punctuation or differentiation of time is also evidenced in a historical sense too. For instance, in Wylie's MIT in Perspective57 the names of MIT staff are post-fixed by the year of their graduation (or receipt of their Masters) - e.g. Robert R. Everett'43. This practice is observed in MIT's institutional journal Technology Review where we also find frequent reference to specific classes - e.g. the class of '23. This is particularly so in the final section of the journal in which readers are kept informed of notable achievements (honours, citations, medals), but also deaths, of MIT alumni - these being arranged according to class year. It is of further interest to note that the journal also carries advertisements for consultancy organizations comprised of MIT graduates and these too carry the year of graduation convention. (Outside of these sources however, we have only found one article in which the convention was observed58.)
We find that a rigid network of rules and regulations govern the social conduct of the students:

"the rules are spelled out so that the university can function in a parental role, particularly with respect to the conduct of women students." (59)

Writing in 1970, in his study of MIT, Snyder observed that the strict regulations were beginning to be relaxed at elite colleges but that "many universities still maintain close surveillance on the manners and mores of their coeds"60.

At a departmental level, social relations would appear to be formal; quoting one professor, Snyder records:

"the individual departments operate in a traditional pattern, the format of which is too authoritarian to my way of thinking, although the individuals aren't." (61)

This is not an isolated observation for several sources observe the conformity and subordination of MIT students62. Indeed, Wylie notes that for a long time MIT had seemed "immune" to the violent protests that occurred at Berkeley and elsewhere during the late 1960s and early 1970s. What is important in this respect is that although violence did erupt at MIT, it lagged behind that at other university institutions. In relation to SDG and the Sloan School we may usefully note that a number of investigations testify as to the more conservative attitude of management and engineering students amongst the general student population63. Further, Snyder argues that competence rather than creativity has become the keynote of MIT education - this is arguably a contributory factor in the conservatism of the institution. Competence is a requirement of the vocational orientation of much of MIT's curricula and is ultimately assessed by others in the practising professions and industrial organizations.

"The concern for competence lies behind the work overload and expropriation of leisure that are the most immediately visible marks of difference between M.I.T. and liberal arts colleges." (64)

As for the staff, Snyder talks of distraction because of outside commitments and the demands of those people who have a legitimate claim for attention.

"The norms of scholarship require a relatively free exchange of information; moreover, they presuppose that within the very broad fraternity of scholars, men will be as helpful as possible to others who
seek their aid in pursuit of some legitimate professional enterprise... The result is that the commonest complaint, at every large university, is of an academic man's difficulty in doing his own work in the face of the constant distraction by others." (65)*

It would appear that the conformity, competition and regulation of social life constitute an oppressive grid for the students at MIT. They are, however, a distinct elite and are trained to be leaders in their field - they therefore become socialised into the experience of the exercise of authority. Their sense of obligation is not only to MIT but also to the professional and social responsibilities which pervade the vocational orientation of the institution. Thus, it is within this culture that Forrester, his colleagues and students, came to embrace system dynamics. With SDG itself the net of perceived duties is cast even wider for they consider themselves to have a responsibility for the future of mankind. Indeed, system dynamics is now an internationally embraced philosophy; there are international conferences, an international society is being formed and an annual Forrester Prize has just been instituted.

Other evidence concerning the group boundedness of SDG comes from their own self-perceptions. We find a number of statements in which it is clear that they consider themselves to be cognitively set apart from others, and in particular social scientists whom they allege lack a proper understanding of system dynamics66.

Each social environment will usually have a range of codes - in high group social locations we would especially expect to find instances of restricted codes. In so far as system dynamics becomes a lens through which the system dynamicists orientate themselves in the world, we should expect that it gives them a common sense of identity. In fact, they tend to see themselves as pioneers standing at a new frontier in knowledge, and they perceive their abilities as something which sets them apart from outsiders. For example, speaking with regard to those specialised in the profession of automatic feedback control, Forrester has stated

"The profession has been through a hundred years of developing appropriate theory and concepts. No one has a better professional background for understanding today's important social and economic forces...Knowledge imposes responsibility. If no one is better able to deal with the important world and national issues, those with training

*In line with this observation we may note Forrester's remark that the computer runs for the urban model had to be completed from his terminal at home.
and ability inherit an obligation to step into the void." (67)

Bernstein conjectures that a restricted code will emerge amongst any group which shares a common identity. Thus, as the theoretical framework of system dynamics becomes more and more consolidated amongst SDG, so we should expect that communications amongst its members become 'shorter' - to be less elaborated, and to carry a greater burden of implicit meanings - to become more like a restricted code. To a certain extent these points overlap with the questions raised by Kuhn in relation to paradigms68. To the extent that the system dynamicists know each other and interact as a social group, they do not just share common intellectual tools for the restricted code affirms a set of common values and sense of identity as well. In reference to this we may note that many of the publications in system dynamics (between urban and world dynamics) became increasingly dependent on cross-referencing amongst the group - i.e. they came to rely more upon other works in system dynamics rather than drawing upon different intellectual sources. This reinforced both their commitment to system dynamics and the group boundary which increasingly set them apart from outsiders.

This sense of apartness is of course rooted in the whole elitist ethos of MIT but it came particularly to the fore when SDG sought to defend themselves against the often vehement criticisms which stemmed from the physical and social science communities. Forrester, for example, has even suggested that the nature of this criticism has educational implications for the teaching of social scientists.

We conjecture that group boundedness may not arise solely from internal social bonding (i.e. cognitive bonding through a shared philosophy, group commitments and interests) but also from external pressure. The response of journals such as Nature was an exercise of the public grid which constitutes the received view of scientific work.

For example, one editorial in Nature asserted that World Dynamics was "a somewhat dangerously over-simple document"69. Another in The Economist argued that The Limits to Growth report

"represents the highwater mark of an old-fashioned nonsense, because the MIT team has pumped into its computer so many dear, dead assumptions. It falls with both eyes open into the central trap before all futurologists, and is thus in danger of discrediting the germ of truth that should make more considered researches of this sort worth while." (70)

Yet another editorial, this time in Science, carried the following
"Enthusiasts can easily lose sight of the limitations of computers." (71)

Particularly with respect to the World 3 project team, who had published a popular account of their work long before any detailed technical description was available, we observe that the accepted procedures of scientific publication had been violated. The response of many in the scientific community was to denounce the MIT work and to re-affirm the grid of rules which conventionally govern publication; at the same time this also served to insulate SDG, to push them further up grid. In effect, the response of established scientific groups and others such as economists was to assert that SDG must articulate their case within accepted rules or not at all.

Douglas argues that social structure can remain fairly stable unless counterpressures impinge from outside, or if new knowledge weakens the credibility of classifications.

"In either case, the social change will be wrought in the other dimension, that of action or pressure." (72)

Thus, it is conceivable that the grid-group rating of SDG actually shifted slightly during the period of intense criticism - we will return to these points in greater detail when we discuss SDG's response to anomalies.

In our earlier discussion of problems concerning the grid-group theory we suggested that it was important to keep the role of codes in focus, that they indicated constraints and sources of resistance to changes in cosmology. In relation to this point we can cite certain parallels between Forrester's early and later career.

Forrester attributes his view of systems to his experiences when working with military systems, and indeed, we contend that there are important continuities between those experiences and the subsequent development of system dynamics. For example, in a history of the Whirlwind Project it is reported that Forrester's investigative techniques were the product of his experiences since 1940 in the Servomechanisms Laboratory.

"They were not intuitive, unexamined procedures that he was unaware of and could not explain. On the contrary, he took it for granted that he should analyze and make explicit as possible the useful techniques that 'came naturally' from his experiences. He preferred to know where he
stood and why, at all times and was committed in a very self-aware way to understanding and rationalizing and systematizing the procedures of his mind..." (73)

Now the relevance of this for our understanding of his work on system dynamics is that there too we find the same ideas and concern about explicitness, only now it is to be found in the realm of formal computer models.

The Whirlwind Project was conducted in a building which was closed to outsiders because of military security measures and it was run as a tight, well-oiled machine.

"Drawing together as it did young men of ambition, ability, and spirit, and reinforced by a habit of daily operations that stressed, and for the most part obtained, intelligently planned and coordinated operations, this policy produced an unusually high esprit de corps." (74)

In this social context, then, were a common purpose united all, the seeds were sown for the later ideas of the purposive nature of social systems, the need for subsystems to subordinate their sub-goals to system goals etc. The social essences which pervaded a tightly organized research team, were mirrored by the platonic essences which suffused the material objects (and their abstract relations) which were integrated within the project and actually enabled that integration to proceed. In other words, the social organization of the laboratory was a precondition for the eventual material organization of Whirlwind's components.

As leader of the project, Forrester was described as "the Chief, cool, distant, and personally remote in a way that kept him in control without ever diminishing our loyalty and pride in the project" (75). In this regard he stood in contrast to his deputy - Everett - who was "relaxed, friendly, understanding" (76). Thus, although he was the "Chief" his social interactions were more prescribed by a grid of rules than those of Everett. However, it would appear that Forrester was remote only in a personal sense - i.e. he maintained strict self-control - and in terms of technical issues he was continually involved in problems at a workbench level (77).

A second continuity between his earlier and later work is that Forrester has continually found himself marching to a different beat. With Whirlwind he was under pressure from the military authorities because of his and Everett's unorthodox research practices - particularly as regards their overspending. Forrester was convinced that the experimental computer then being assembled was of much greater
importance than many realised - he saw that a new threshold or frontier was being crossed - and he considered that he had to protect it from those who, not realising its importance, could interrupt its progress.

"He saw himself as best carrying out his directorial function by shielding his men from potential outside interference." (78)

The project came under repeated criticism from different agencies as well as other groups who were also engaged on similar projects, and so the experience of being in a threatened group was not new to him. When his later work came under attack however, it was not just an important project which was under threat; indeed, we shall argue that it was his sense of proper order which was at stake.

There were also charges that his group did not cooperate fully with others in the field - though it is accepted that certain groups avoided involvement because the project was classified - and again this arguably served to consolidate the sense of apartness. At a more symbolic level, we find that the security regulations, which differentiated the insiders on the project from outsiders, were reinforced by the ordering of social space:

"[O]ffice walls were to be kept clean and bare of cartoons and frivolous pictures" (79)

In other words, a strict sense of purity of categories prevented the contamination of the inside of the laboratory by the "frivolous" objects from outside. This information concerning Forrester's early career not only informs our understanding of the style of thinking which later manifested itself in system dynamics, it also helps to illustrate the deep cognitive commitment he has to it and the subsequent training of his students.

3.2 SPRU

SPRU are based at the relatively new (1961) University of Sussex. This institution is rather small in comparison to MIT and only had 4,500 students in 1977. The ratio of the sexes is much more equal at some 1.28:1 males to females (compared to 20:1 at MIT) and in 1982 contained some 425 foreign students - a somewhat smaller percentage than at MIT. It is far less selective than MIT which in this regard is more strictly comparable to Oxford or Cambridge. In 1967 SPRU contained 8 members of staff and 1 visiting fellow; by 1976 there were 39 members of staff, 8
visiting fellows and 14 postgraduates who were distributed amongst 6 project teams\textsuperscript{81}. Notably, most of the staff members of SPRU came from other universities and institutions\textsuperscript{82} and they were drawn from a variety of disciplines.

One source of information concerning Sussex is Riesman who spent some 6 months there (c.1965). He is a well-known social scientist with an international reputation and can not therefore be regarded as a naive observer. In his comparison of American and British universities he notes that the planners of the university (amongst other new institutions) were:

"insistent that institutions not grow too large, not beyond human scale, nor grow too fast to permit the induction of students and faculty into their own collegial and more or less experimental climates." \textsuperscript{(83)}

In terms of university organization he observes that British universities are more decentralized, with faculty members being much involved in new appointments - a task which remains an administrative function in American institutions. He argues that British academics pay a price for their greater democracy through time spent in meetings; interestingly, he comments that this loss was "excessive" at Sussex, partly because of its "newness" and the "belief in equality"\textsuperscript{84}.

As for the students, Riesman contrasts the "playfulness", "experimentation" and "joie de vivre" he found amongst those at Sussex with the "intense meritocratic competition" often found in the U.S. Moreover, he contends that the relatively smaller portion of people who attend universities in Britain partly contributes to a greater sense of ease and the "appearance of being relaxed and less bustling and busy than its American counterparts"\textsuperscript{85}.

The experimental nature of Sussex is manifest in the introduction of new ideas into curriculum planning and the interaction of disciplines.

"What I found at Sussex was an exceptional energy of faculty members talking with each other about education, visiting each other's lectures, and bringing undergraduates into their discussions. One has to see in daily unfolding the details of the Sussex curriculum to realize the tenacious ingenuity: the framework of contextual courses, the grouping of people and topics into schools, the search for intellectual cement to relate the specialities in new and interpenetrating ways, and hence to alter them." \textsuperscript{(86)}

Briggs, the former Vice-Chancellor at Sussex, also refers to the innovative nature of the Sussex experiment.
"From the start Sussex...has been thought of as a centre of innovation... The freedom to work along new lines and the power to plan new combinations of subjects and new curricula have proved great attractions in recruiting academics from universities where curricula can be changed only with the greatest difficulty." (87)

This experimental spirit was an important element in the foundation of SPRU in 1966: there was a deliberate attempt to bring together natural scientists and social scientists to work on shared projects. The aim was to develop cross-fertilization rather than the development of a single philosophy such as system dynamics. However, Freeman notes that it is difficult to assess how far cross-fertilization - as opposed to mere juxtaposition of different views - was achieved. The plurality of opinions amongst SPRU appears to be reflected in a comment in Thinking About The Future where Jahoda's guidance of the world modelling project team is acknowledged:

"she made it possible for a diverse and sometimes unruly group to cooperate fruitfully." (89) emphasis added

And later, Freeman notes:

"It included people of very diverse political views ranging across the whole spectrum from Conservative to Marxist, and some of no identifiable political complexion. It included members from very different disciplines, and we were not united, as were the MIT group, by a common faith in system dynamics. But we were, and are, agreed on the urgency of many of the social and political problems raised by The Limits to Growth, and the belief that satisfactory solutions can only emerge as a result of a continuing process of research, political debate, and social experiment." (90)

In comparison to what we stated about restricted codes and SDC, we can assert that this diversity prevented the consolidation of a similar sense of identity. Indeed, we may note that SPRU made many references to other works and bodies of knowledge and did not, therefore, maintain professional or disciplinary boundaries as rigidly as SDC.

The evidence we have presented concerning the social locations of SDG and SPRU suggests that the former should be regarded as further along the axes of grid and group. The greater level of conformity at MIT indicates stronger social control and this is complemented by the degree of ranking (including grading and historical age status), vocational orientation, the routinization of learning, complex punctuation and

In other words, SPRU were not a conservative academic island within an otherwise radical educational sea.
sequencing of institutional life, and the centrality of organizational power. To these points should be added the larger organizational size, much longer historical roots, and division of the sexes - with the virtual exclusion of women at MIT. All of these factors indicate a higher grid position. As for group, we have seen that the vocational orientation of MIT is aimed at inducing a sensitivity to professional and social responsibilities, and therefore a sense of group identity. As a group within an institution which cultivates the sense of being part of an elite, SDC's group boundedness is further enhanced by their shared philosophy and position vis-a-vis the threat of criticism from large sections of the rest of the academic world. In Fleck's terms, SDC are more clearly bounded as a thought collective, an esoteric circle who share a thought style. For in addition to shared interests the social bonds amongst SDC are also constituted by the exchange of cognitions within the framework of the thought style (or as we argued earlier, they share a restricted code) and a 'harmony of illusions' - that which distinguishes a thought collective - constrains their conceptions. In defending the theory of system dynamics in the face of criticism, they also defended the social bonds which united them. In contrast, SPRU did not share a theory of the world and so we can state that this lack of a strong cognitive bond indicates a lower rating of group experience. In addition, SDC are constituted by a core of members who have developed their professional outlook under the supervision of Forrester - the inventor of system dynamics from whom they have learnt - and have accepted his teachings on authority. SPRU, on the other hand, do not share a similar learning experience.

The evidence we have presented in this section can not be construed as a definitive account of the social location of SDC and SPRU. It is, however, perhaps more detailed than that offered in other applications of grid-group theory. Without direct observation we can not know the precise nature of the social relations behind the walls of the System Dynamics Laboratory or SPRU, but by considering the different institutional traditions within which SDC and SPRU reside we have offered an interpretation of their social experiences in terms of grid and group.

In the following section our attention will turn to their respective thought styles and we will seek to present evidence which will be more detailed and exhaustive.
In this section we seek to compare the thought styles of SDG and SPRU from a methodological point of view: we want to detail their response to theoretical anomalies and approaches to modelling. To this end, the backcasting debate provides a good opportunity to see how they react to the same kind of phenomena. We will employ Lakatos' ideas about how mathematicians deal with counterexamples in order to illuminate the strategies by which SDG and SPRU responded to the anomalies which arose in the context of backcasting and thereby throw light on their thought styles. We do not advocate the general use of backcasting simulation models, nor do we explore its ultimate legitimacy. Moreover, it must be said that neither of these two groups regarded backcasting as being in any way fundamental to the wider debate on world simulation models. This does not however detract from its usefulness for our purposes here.

4.4.1 INTRODUCTION TO BACKCASTING

Backcasting is the name given to the technique of running a simulation model backwards in time (retrodiction) in order to try and test its assumptions and parameter values. Its proponents contend that retrodiction is likely to drive a model's variables to unrealistic values and may thereby indicate implausible assumptions in its formulation. In a review of the world models of Forrester and Meadows of the System Dynamics Group at M.I.T., Cole and Curnow of the Science Policy Research Unit (SPRU) at the University of Sussex - suggested the potential usefulness of the technique and demonstrated it with those models.

Here we will concentrate on Forrester's model - World 2. This model contains a series of non-linear, non-probabilistic, first-order difference equations and its structure represents a complex array of interconnected feedback loops; it is used to simulate the behaviour of global interactions between population, resource depletion, capital investment, pollution and agriculture (these being the model's state variables). The model contains almost no empirical data but it was adjusted so that its 1900 and 1970 population figures accorded with the accepted statistics.

Starting with initial values for the state variables in 1900, the model is run until the year 2100; it predicts a global catastrophe within the coming century, a catastrophe which is marked by overpopulation,
pollution and the exhaustion of natural resources. The so called "standard run" of the model is shown in Fig.4 and from these state-variable trajectories Forrester concluded that the world must move towards a global equilibrium society in which the growth in population and industrialisation would cease.

The difference equations are integrated by using the Euler rectangular method and in backcasting the model the solution interval is assigned a negative value. The backcasters argue that a system dynamics model may be run either forwards or backwards in time - at least theoretically.

To take a simple example, consider a given trajectory of a variable (P) representing population through time (t).

![Graph showing population trajectory](image)

This trajectory is given by the following difference equation:

\[ P_{n+1} = P_n + P_n(BR - DR)\Delta t \]  

where BR = birth rate and DR = death rate. The retrodiction of the variable is given by:

\[ P_n = P_{n+1} - P_{n+1}(BR - DR)\Delta t \]  

Of course some people - particularly members of the modelling fraternity - may well object that backcasting is not a valid technique, that it requires a model to behave in a way that the real world does not. From such a perspective as this backcasting would appear to be nonsensical. Now, to be sure the world cannot be run backwards - because of thermodynamic considerations for instance. However, models are mathematical objects and in backcasting one is attempting to explore the pre-history which is consistent with the original starting values of a model. Thus, given the state variable conditions at time t=0 we could ask what were the conditions at time \( t-\Delta t \) which preceded it etc., thereby exploring the view of history projected by the model. For this reason it can be argued that we should not reject the claims of the backcasters.
Figure 4 STANDARD RUN OF WORLD 2

Figure 5 BACK CAST OF WORLD 2
out of hand; if something cuts against the grain of common sense then perhaps we should examine that grain - at the very least it may aid the understanding of one's position.

There is another and stronger reason too: this lies in the fact that some - but not all - members of the MIT group later accepted that backcasting was a theoretical possibility and different model improvements were put forward in light of a certain model 'error' which was uncovered by the SPRU backcast of World 2. In any case, we are not interested in judging who was 'right' or 'wrong' about backcasting in any absolute sense. In other words, it is no use attempting to understand the debate by asking what was the true position to take. Rather, we assume that each group holds its own beliefs on the matter rationally; therefore, what they each take to be the truth is the focus of attention here.

In fact, there are practical difficulties with backcasting. In particular, numerical errors affect the dynamic calculations and models may then generate spurious histories. However, Cole and Curnow argued that provided such errors are strictly controlled (through the use of a small - but not too small - solution interval) backcasting can yield useful information about a model. For example, they found that World 2 predicted anomalous population figures when backcast and from this they concluded that the model was incorrectly formulated.

Cole and Curnow clearly saw the errant population figures as an anomaly which challenged the system dynamicists' claim that the model adequately represented the global system. It also - in their eyes - cast doubt upon the model's post-2000 predictions. Subsequently they proceeded to modify the model. The members of the System Dynamics Group did not share their conclusions; in fact, some (but not all) rejected the anomaly and they unanimously upheld the model's predictions.

Having briefly discussed the idea of backcasting we will now continue with a sketch of the history of the debate which surrounded it, then we will discuss Lakatos' work on counterexamples in mathematics before going on to use his ideas in order to analyse the debate in more detailed terms.

The debate is reconstructed from the principal exchanges in the literature between the groups at MIT and SPRU. In reality there were of

It should also be noted that not all difference equations can be backcast; for example, the SPRU team cite the case of Bessel's difference equation for certain parameter values.
course other less formal interactions through the media of personal letters and meetings as part of the overall SPRU critique of the system dynamics world modelling effort. However, this paper will confine itself to the explanation of the development of the formal record.

1.42 RISTORI OF THE DEBATE

The controversy over backcasting originally arose when Cole and Curnow noted that the World 2 model projected a population decrease between 1900 and 1904 and subsequently suggested running the model backwards before 1900 in order to see where this trend had developed from.

"Death rate is quite different from the historical trend in the vicinity of the year 1900. One obvious thing to investigate, therefore, is what the model has to say about the period before 1900." Cole and Curnow (96)

This population dip had not drawn much attention earlier because the output from the model had been presented in graphical form with a rather crude scale. Although Forrester had actually commented that the death rate at 1900 was "equal to or greater than the birth rate", he implied that it was due to incorrect initial conditions which caused a "small transient readjustment".

"Such questions raised by the behavior of a model system cause us to re-examine and improve the model." Forrester (97)*

Cole and Curnow argued that the model's mathematical relationships were time reversible and that since the credibility of the predictions produced by the model depended to a certain extent upon its ability to reproduce trends between 1900 and 1970, extending its time scale backwards would provide the opportunity for a better test of the fit between history and model trajectories.

Setting the solution interval to a negative value they found that the model retrodicted an exponentially growing population which reached a value of some 3.9 billion by the year 1880. (See Fig.5) In their words:

"The curves are curious - they seem to indicate that the 20th century lies in the aftermath of a catastrophic population collapse..." (98)

Further, the value of the pollution variable became negative - due

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*In the light of what was to follow his remark was most significant for we shall see that several distinct ways of improving it emerged.
principally to instabilities in the numerical calculations. However, it then also became effectively de-coupled from the rest of the system and did not interfere with the calculation of the other variables.

Cole and Curnow argued that at low levels of industrialization the model yielded poor estimates of death rates; in particular they contended that one variable - known as DRMM (death rate from material multiplier) - overestimated the death rate whenever material standard of living was low. When backcast the level of population becomes augmented by deaths and depleted by births: hence the errant values for the death rates caused the population values to grow exponentially as the model retrodicted.

DRMM is a weighting factor which adjusts the death rate in accordance with the level of material standard of living - MSL - which is itself related to the level of capital investment. Thus:

\[
\text{DEATH RATE} = P \cdot DRN \cdot DRFM \cdot DRCM \cdot DRPM \cdot DRMM \quad \text{equation (3)}
\]

where \(P\) is the level of population, \(DRN\) is a nominal value for crude death rate and \(DRFM, DRCM, DRPM\) are other weighting factors representing food consumption, crowding and pollution respectively. Fig.6(a) shows the curve that had been chosen to represent \(DRMM = f(MSL)\).

Cole and Curnow decided to experiment with this curve and subsequently constrained the range of \(DRMM\) from 1.5 to 0.5 instead of 3.0 to 0.5 as Forrester had done - Fig.6(b) shows the modified curve. (Interestingly, Forrester himself had suggested that the curve might be somewhat too steep on the left-hand side.)

This single modification enabled retrodiction of the model beyond 1880 to the year 1850 (though other variables also become negative by this time, not due to numerical errors but simply because the model trajectories reach zero and then become negative).

"If this variation [in DRMM] is reduced to a factor of three, the peculiar behaviour of the model before 1900 disappears and it is possible to run it back to before 1850." Cole and Curnow (99)

Back to 1850 the population history of the model remains quite plausible and when the model is run forward from 1850 it generates smooth population growth. This ceases in the 21st century and the subsequent fall in the level of population is due more to falling birth rate than increasing death rate as had been the case with the original model. Thus,
Figure 6 ALTERNATIVE CURVES FOR DRMM

Figure 7 CRUDE BIRTH AND DEATH RATES

CRUDE BIRTH AND DEATH RATES (per 1000)

MATERIAL STANDARD OF LIVING

death rate

birth rate

(1970=1)
the model's prediction (on population at least) was no longer as pessimistic.

Of course, modifying the DRMM multiplier was not the only possible way of enabling retrodiction with World 2. In fact the SPRU team also suggested possible changes to the level of capital that is devoted to agricultural production - by this means a high value of DRMM due to a low level of MSL may be compensated by a low value for DRFM because of increased food per capita (see equation (3)).

The main conclusions which they drew were that Forrester's guesswork in initializing the model was in error, and that it gave poor estimates for death rates whenever material standard of living was low - or in other words, that the model was not correctly formulated in this regard. They also advanced another - and perhaps more subtle - point, which was that had the model been initialized in 1880 on the basis of Forrester's arguments in World Dynamics, then the predicted collapse would occur some 20 years earlier. Similarly, if it had been initialized in 1850 the collapse would occur in 1970! The reason for this is that the model exhibits exponential growth within fixed limits: thus, starting the powerful growth forces 20 years earlier brings the clash with those limits forward too. Therefore, seen as a practical and heuristic model testing tool, the questions raised in the context of backcasting illuminated the model's incorrect initialization, poor component formulation with regard to death rates, and also threw light onto its basic behavioural characteristics. These findings raised questions about the rest of the model, particularly in the light of the almost complete absence of empirical data in the model and the controversial conclusions Forrester had drawn from it.

However, the results from the SPRU backcast were not entirely conclusive. The problem lies in the fact that SPRU did not explicitly discuss the possibility of a confluence of histories: there could be many histories for World 2 which all converge on the 1900 starting values and the SPRU backcast could therefore be just one history amongst them. As it turned out, their backcast was indeed genuine - that is, it had uncovered the legitimate history of World 2 - but let us leave the reasons for this to be discussed in greater detail later. For the moment, let us continue by considering the implications of the SPRU backcast and how the MIT group responded it.

According to Forrester, a good model is distinguishable from a bad one in the extent to which it "captures more of the essence of the social system that it presumes to represent" 100. Further, he states:
"Given the assumptions about how different parts of a complex system affect each other, the computer can then trace the operation of the system through time. It can carry through the arithmetic tasks and follow the rules of behavior as set down in the model description. The computer gives the correct implications of the assumptions that went into the construction of the model." (101)

Now, the dip in population between 1900-1904 and the retrodicted population for 1880 of more than 4 billion are surprising features of the model's behaviour and represent anomalies which must ultimately be explained. They are anomalous because they conflict with generally accepted history; put another way, pre-1900 history and the period between 1900-1904 are outside the scope of World 2. Therefore, it cannot be accepted that the model captures the "essence" of the global system; or at least there could be an improved model which captured more of its essence.

The reactions to the anomalies from the System Dynamics Group provide arguments which can be seen as embodying distinct strategies for coping with them. These responses are not strategies in the sense of deliberate moves to avoid or sidestep problems, but are rather examples of the almost unconscious, ingrained - though rational - reactions which attend a particular style of thought. Later we will analyse these responses in terms of Lakatos' ideas about how mathematicians cope with counterexamples in the hope that they will illuminate the nature of the model modifications proposed by SPRU and the system dynamicists.

The response from MIT was not uniform; initially it was unequivocal, with the backcast being totally rejected. Later, however, the response from other members of the group was more measured and the backcast was seen to be genuine, though the model's predictions were still upheld.

The first response came from Meadows et al who denounced the SPRU work on backcasting for a number of technical and other reasons. For instance, they argued that reversing the solution time increment "must radically alter the entire dynamic character of the model" that normally insignificant errors would tend to accumulate - with model elements exhibiting "completely spurious excursions". They charged that the SPRU backcast was such an excursion:

"The discovery of one such excursion in the World 2 population is cited as an imperfection of the model. In fact, the World 2 population will also explode under reverse simulation from many different starting points. For example, if the model is initialised in 1940 with characteristic values for that date, and run backwards, population explodes by the year 1920. Since World 2 does not always backcast its own
behaviour, should we conclude that World 2 is not even a good model of World 2?" Meadows(104)

For these and other reasons the MIT group saw backcasting as "completely meaningless". However, aside from the above points - which undoubtedly have some relevance to the problem of backcasting - irrelevant factors were also cited. For example, Meadows argued that delayed relationships would be asymmetric in time and that any stochastic influences on the model's behaviour in the forward direction would not be recaptured when it was backcast. These points are irrelevant to the case because the World 2 model did not contain any explicit delays nor did it contain any probabilistic functions - in fact the predictions of a system dynamics model are completely determined by the choice of initial values. Finally, Meadows concluded:

"Running a system dynamics model backwards tells us nothing about the model's utility in understanding the world. The meaning Sussex automatically assigns to backcasting illustrates the influence of analytical habits gained in the context of substantially different kinds of models. The Sussex authors suggest it is important "to examine the great catastrophe of 1880" in World 2. We believe it is more important to first understand the relation between the mathematical properties of multiloop feedback models and the dynamic attributes of real world systems." (105)

Now, arguably the main plank in the MIT retort was the charge that the SPRU backcast merely uncovered a spurious history. Whilst SPRU did accept the possibility of spurious excursions - as we noted earlier - they argued that if errors were kept under tight control this need not be a problem and that whilst the MIT backcast from 1940 to 1920 was unstable because of numerical errors in the computation, their own backcast exploded because of wrong assumptions in the model.

In a later article by another member of the MIT System Dynamics Group - Wright106 - whose own response will be dealt with in detail shortly, it was accepted that the SPRU backcast was indeed unique: it "had shown the legitimate predecessor state of the model". This has also been corroborated by Erickson and Pikul107 (of the Naval Underwater Systems Centre, Newport USA.) who thought that backcasting was a legitimate technique, that all models should be expected to have realistic

Meadows did acknowledge though that if the 1940 values were entered with extreme accuracy (i.e. in error by less than 0.001%) then the model would backcast over limited ranges. However, he further noted that the approximation errors in the computer simulation language used with system dynamics models - Dynamo - were of the same order of magnitude.
histories.

"With this article, which shows how all objections can be dismissed or bypassed, we would like to return backcasting to the armamentarium of those who test and develop global models." Erickson and Pikul (108)

To show that a confluence of histories does not occur they computed a series of different model trajectories between 1880 and 1900 based upon a well-distributed set of starting values near to the 1880 values derived from the SPRU backcast.

"We found that no other nearby histories came close to matching Forrester's model at 1900." (109)

Further light on this matter can be shed by a comparison of crude birth and death rates as functions of MSL. Fig.7 shows that (other things being equal) as MSL decreases the crude death rate rises much more sharply than the birth rate - and in fact increasingly so. Thus, when backcast, the level of capital investment falls - followed by MSL - and so the population begins to explode.

Although Wright accepted the legitimacy of the SPRU backcast, he did not accept their conclusions with regard to Forrester's model. Whilst acknowledging that backcasting with system dynamics was indeed theoretically possible, and providing an example of a simple system dynamics model which would retrodict unproblematically, Wright argued that practical difficulties limited its usefulness and he viewed the SPRU backcast as "lucky" in this respect.

"A retrodictive test of Forrester's World Dynamics ... is shown to have found, fortuitously an inconsistency in the model, but to have drawn incorrect conclusions about the importance of that defect for future behaviour and policy alternatives, to have suggested inappropriate and incomplete model improvements, and to have added nothing to understanding of the model." Wright(110)

In order to try and solve the difficulties with the World 2 model he began by changing the 1900 initial conditions for capital investment; however, despite the fact that the model then exhibited smooth growth from 1900 in a forwards direction and yielded trajectories close to the original ones, the model still would not retrodict satisfactorily. He then turned his attention to the model's formulation.

Though admitting that something was wrong with the model, he rejected the actual SPRU modification of the DRMM function. Instead, he altered
the range of DRMM from 2.4 to 0.5 (see Fig.6(c)). He based his argument for this on the fact that the model misbehaved when MSL<0.25; the SPRU modification altered DRMM throughout the interval 0<MSL<0.5 whilst his was restricted to 0<MSL<0.25. In addition, he also chose to modify another variable, one which influences capital investment rates. His purpose in doing so was to slow down the model's growth in capital investment when MSL<0.25; the effect of this was to overcome the problem pointed out by SPRU with regard to the timing of the model's collapse. The question as he saw it was:

"can these assumptions be modified to support reasonable 1880 values without damaging predicted future trends." (111)

In extending the modification of DRMM over a larger interval the SPRU team had also altered its values for post-1900 computations and indeed, this accounts for the less pessimistic post-2000 trajectories. In challenging their modification Wright asserted:

"It may be that their formulation is correct; but it certainly does not follow that a discrepancy observed in the 1880-1900 range of operation (MSL<0.25) demands revising the formulation in other ranges." (112)

Beginning with "reasonable" 1880 values, Wright argued that his modified model passed "close" to Forrester's 1900 values and mapped out a path "very similar" to the original World 2.

A second reason why Wright rejected the SPRU modification and the conclusions they drew concerning World 2 was grounded in his different view of model purpose:

"A model need be accurate only for ranges of operation over which it will be exercised...A nonlinear model will retrodict its referent system if its formulation is reasonable for the range of operation that occurs in the earlier period. It is possible for a model builder to choose, rationally and deliberately, component formulations accurate over the operating mode occurring after a starting point but inaccurate in ranges expected before that initial time. The model cannot be faulted if it remains in the acceptable operating range." (113)*

A similar position was taken by Britting (also from the MIT group) 114. He too saw backcasting as theoretically possible but thought that models were constructed only "to be valid within a particular time span of interest". Further, both Britting and Wright pointed out that Forrester

*This last sentence could be interpreted to mean that the model was in fact unfalsifiable!
id himself noted the erroneous starting behaviour of World 2; however, I shall argue later that the two groups did not perceive the same error at rather, different errors were socially constructed.

In 1974 Forrester again made reference to the misbehaviour of his model at the start of its simulation. He suggested that the model was incorrectly initialized and recommended changing its initial values; leaving the value for population, capital investment, pollution and natural resources at the previous levels he argued that the value of CIAF - which represents the fraction of capital devoted to agriculture - should be increased from 0.2 to 0.4. However, whilst the trajectories of the other variables mimic those of the original model (except that population no longer dips between 1900-1904) that for CIAF decreases for the first 37 years before following a path similar to the one of the original. Though Forrester's conclusions remained the same he did not offer any hypothesis to account for (nor did he even note) the peculiar behaviour of this variable.

Moreover there is actually a more crucial point to be noted here, for Wright too had accepted Forrester's assertion that the original model was not correctly initialised. But he chose to alter the initial value of capital investment. The obvious question then, is what is the set of correct initial values for the model? Further, if both changes are tenable, then why could the fault not equally lie with the formulation of the model itself? In fact, there may be numerous combinations of initial values or, equally, numerous parameter formulations which could result in smooth population growth from 1900 onwards. This throws into sharp relief the dilemma and problematical nature of global modelling of this kind, for without basing such models on an adequate empirical foundation we have no way of choosing whether to alter the initial values, or modify the parameters such as DRMM which SPRU had done, and yet the predictions of the model may be quite sensitive to such changes.

In 1976 Forrester argued that backcasting was "apt to be meaningless" unless very special conditions were fulfilled. Though citing the work of SPRU he did not acknowledge any achievement or valid criticisms on their behalf. Instead, he referred to Britting's paper where it was argued that backcasting did not reveal anything useful about the model.

At this point it would seem appropriate to summarise the main features of this debate.

The groups at MIT and the SPRU differ distinctly with regard to the basis and utility of backcasting. There are also some differences
amongst the system dynamicists themselves, though they are united in their agreement that the SPRU backcast did not invalidate Forrester's conclusions. Other groups were also for or against backcasting; e.g. Erickson and Pikul were for the technique. Another modeller - Brewer - was against.

Originally the MIT group saw the backcast as meaningless and irrelevant but later Wright and Britting saw it as legitimate. Thus, the debate shifted from one of whether the SPRU backcast was legitimate to a consideration of its implications together with possible improvements to World 2. Again, this shift underscores our position that the ultimate validity of backcasting is not relevant to our understanding of the debate.

Given that the model was supposed to capture the essence of the global system, the backcast represented an anomaly which needed an explanation. Similarly, the behaviour of the model between 1900-1904 was also anomalous.

Each group holds a different view of the purpose of a model and what should be expected from it.

The SPRU offered a simple modification of the DRMM parameter which was rejected by Wright in favour of a less 'extreme' modification together with a modification of a parameter influencing capital investment.

Forrester thought that the 1900-1904 population dip was due to incorrect initialization but his modified set of initial values were different to those of Wright. Thus even within the MIT group there were different positions on precisely how the model should be modified.
In order to understand the different moves within the backcasting debate we need some concepts about how anomalies are dealt with. These are provided by Lakatos in his analysis of strategies for dealing with counterexamples to a mathematical conjecture. By utilising Lakatos' conceptual scheme we will be better able to comprehend the different strategies pursued by SDG and SPRU and thereby flesh out their respective thought styles.

In his book 'Proofs and Refutations' Lakatos set out to describe the logic of mathematical discovery. A fundamental tenet of his position was that mathematicians did not discover different domains of some pre-existing mathematical universe; rather, they invented them - he viewed mathematics as the product of social 'negotiations', of argument and counterargument between different groups. This did not mean that mathematicians could invent anything but rather that mathematics was logically underdetermined. To illustrate his view of mathematics he took the example of the controversy surrounding the Euler-Descartes conjecture and polyhedra. This conjecture states that the relationship between the number of edges, vertices and faces of a polyhedron is given by the formula:

\[ V - E + F = 2 \]  

where \( V \), \( E \), and \( F \) represent vertices, edges and faces respectively.

Lakatos discusses how various mathematicians adopted different attitudes towards polyhedra and counterexamples to the Euler-Descartes conjecture. At one extreme some thought that the conjecture captured the essence of all real polyhedra; at the other were those who saw the conjecture rather as a statement about those objects which were conventionally ascribed the status of a polyhedron (i.e. that met some definitional convention). In the face of putative counterexamples, different mathematicians consequently embarked upon disparate strategies in order to deal with them. Ultimately, these strategies reflected different styles of thought and they lead to different contents in mathematical knowledge. We will now proceed by giving a very brief and much simplified account of some of the strategies discussed in Lakatos' analysis before employing them to understand the moves within the backcasting debate.

First of all, imagine that we have some conjecture and a suggested proof for it. What are we to do if someone proposes an anomaly or...
counterexample? Such a case may be either local, global, or both a local and global counterexample, by which Lakatos meant a counterexample which refutes specific lemmas in the proof, the conjecture, or both respectively. Local counterexamples usually give rise to the refinement of lemmas in the proof, but with global cases the responses are more complex. Looking at the history of the dispute surrounding the Euler-Descartes conjecture, Lakatos distinguished several distinct approaches for dealing with such counterexamples but here we will only consider the four major possibilities.

Firstly, there is the strategy of monster barring in which the counterexample is declared to be a monster or "pathological" case: it is said to be of no significance because it does not fit the definitions embedded in the proof. For example, in the case of the Euler-Descartes conjecture some mathematicians proposed counterexamples which adherents of the conjecture refused to accept as genuine polyhedra. This strategy often evokes shifting definitions.

A second and more sophisticated strategy is to accept the counterexample as genuine but to make a distinction between the 'correct' domain of application of the conjecture and the counterexample - which is thought to fall outside it. Other defining lemmas are added to the proof and though the conjecture's domain becomes restricted its underlying validity emerges intact. This strategy is called exception barring. The re-drawing of the domain is, however, ad hoc, for it only depends on the particular counterexample and is no guarantee against there being others within the new domain.

A third strategy - one which is related to the last - is that of monster adjustment. Here, the counterexample is 'adjusted' by arguments which disinvest it of its threatening potential for - it is asserted - when seen in 'correct' terms or from the vantage point of the 'right' perspective it is no longer a monster at all. In fact, certain mathematicians - again when presented with a counterexample to the Euler-Descartes conjecture - suggested that there were hidden edges (etc.) which only those with a trained eye could see. When these were taken account of the conjecture was upheld.

Finally, there is the strategy of proofs and refutations in which counterexamples are welcomed and used to improve the conjecture. By inspecting the proof, a lemma which conflicts with a counterexample is incorporated into the conjecture; thus counterexamples are assimilated and the conjecture becomes restricted to the domain of the errant lemma which any given counterexample challenges.
Before we proceed any further we must acknowledge the difference between Lakatos' mathematical example, the case of modelling and the backcasting debate. However, we contend that the applicability of his scheme in our analysis can be defended on at least two counts. Firstly, Lakatos raised the issue of the strategies in his discussion of physics: he saw structural similarities between mathematics and experimental science and indeed, his Methodology of Scientific Research Programmes may be seen as 'proofs and refutations' applied to the history of physics. (The latter point is also mentioned by Feyerabend.) This similarity can be more easily grasped if we consider the following comparison:

<table>
<thead>
<tr>
<th>MATHEMATICS</th>
<th>EXPERIMENTAL SCIENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>conjecture</td>
<td>conjecture=hypothesis</td>
</tr>
<tr>
<td>proof=embedding conjecture</td>
<td>corroborating experiment=embedding hypothesis in a set of basic statements</td>
</tr>
<tr>
<td>in basic statements</td>
<td></td>
</tr>
</tbody>
</table>

The different strategies found within mathematics are considered to be part of scientific research programmes too: such programmes comprise negative and positive heuristics, progressive and degenerate problemshifts etc., which have parallels in Proofs and Refutations. In other words, the strategies described by Lakatos were not seen as being exclusive to the domain of mathematics but were construed as rather general properties of intellectual and methodological thinking.

Now, we would place modelling between the two poles of mathematics and experimental science - which if accepted, supports our use of Lakatos. A second reason is that we have no evidence against using Lakatos' scheme for the case of modelling.

We stated earlier that the backcast undertaken by SPRU had generated an anomaly and it is suggested that the debate which ensued contains similar strategies to those identified and described by Lakatos. The basis for drawing this parallel can be further substantiated if we reflect for a moment upon the mathematical 'game' that Lakatos was describing.

For Lakatos, conjectures and proofs are closely related. A conjecture can be seen as a statement about a given class of objects, whilst a proof procedure can be viewed as a series of sub-conjectures (or lemmas) derived from the main conjecture. (In fact Lakatos regarded a proof as a thought experiment for proving a conjecture.) Following Feferman, the
Euler-Descartes conjecture can be written as follows:

$$\forall x \left[ A(x) \rightarrow B(x) \right]$$  \hspace{1cm} \text{equation (5)}

where $A$ represents certain conditions and $B$ is a conclusion. Thus, for all objects $(x)$, for which the conditions $A$ are met, then the conclusion $B$ is true - i.e. the formula holds. Conversely, given an object $(x)$, if $A$ and $B$ are true then the object must be a polyhedron. The conditions - $A$ - actually varied during the history of the controversy, but one example was the requirement of convexity. Thus, conjectures can be seen as statements about the classification of objects: a conjecture embodies a classificatory scheme. Following this line of reasoning, anomalies can be seen as objects which violate a system of classifications.

Turning to the world simulation model we can see that the trajectories mapped out for the state variables are a form of conjecture about the behaviour of the world system. However, the focus on the world is only one particular instance of the application of system dynamics - which Forrester claims is a general systems theory (i.e. it is applicable to "all systems that change through time"). Thus, let us consider the conjecture, subconjectures and proof which I take to be analogous to Lakatos' case.

(A) conjecture: for all systems $(x)$ that change through time, their behaviour is given by that of their referent system dynamics system

(B) sub-conjecture: the behaviour of the world is given by its referent system dynamics system

(C) sub-conjecture: the behaviour mode of the world system is exponential growth followed by collapse

(D) proof of (B) and (C): the simulation exercise with WORLD 2

The referent system dynamics system is that system which is constructed to represent $(x)$ in accordance with the principles of system dynamics.

Now, conjecture (A) is what I take to be ultimately at stake in the debate in the sense that it is the basis of the system dynamicists' sense of proper order. (B) embodies the claim that the world is a system that belongs to the class of systems specified in (A) and therefore its behaviour is given by its referent system. (C) is a sub-conjecture about the behaviour of the world system which stems from the alleged
properties of all feedback systems. Thus, (A), (B) and (C) are concerned with the classification of the world as a system which is describable by system dynamics and has the properties of a feedback system - as with Lakatos then, the debate contains a problem of classification.

The world modelling exercise is not concerned so much with (A) or (B) - the long experience and laboratory practice tells the MIT team that these must hold, they are almost self-evident. Rather the exercise centres on the question of how the world behaves: MIT believe that it is undergoing exponential growth and will experience "overshoot and collapse". The sub-conjecture (C) is of the form

\[ \exists x \left[ A(x) \rightarrow B(x) \right] \]

there exists a system (x), which given conditions A (e.g. exponential growth within a system containing negative feedback), will overshoot and collapse

This can be seen to be a particular instance derived from a statement of the form of equation (5)

\[ \forall x \left[ A(x) \rightarrow B(x) \right] \]

which is the general format of the conjectures studied by Lakatos and therefore brings us back to a problem of classification again - i.e. does the world system belong to the class of systems (given A) for which B is true. In this case we contend that the implied derivation is legitimate because MIT are not of course just defending one particular set of trajectories; rather, they are defending a sense of proper order concerning the behavioural properties of feedback systems.

Turning to the proof, this we take to be the simulation exercise with the model. The exercise of simulation is an attempt to reproduce a referent system dynamics system and simulate its behaviour on a computer. In analogy with Lakatos' thought experiment, simulation is an orderly exercise which attempts to show that (B) and (C) hold - for MIT, simulation represents a laboratory experiment. It also reflects upon (A) but doesn't prove it. The simulation exercise can be seen as a series of sub-conjectures derived from (B) or (C); it is used either to show that the model (the referent system) does capture the "essence" of the real

\[ \text{In fact, it may be that many other forms of conjecture could be treated in this way. If so, it could open up many debates to the Lakatosian approach.} \]
system because it describes its behaviour, or to show the exponential growth followed by overshoot and collapse. In fact, (B) must be taken as part of the 'proof' of (C). MIT attempt to prove (C) by a series of simulations which purport to show that even with a wide range of alternative assumptions and policies the world system still faces collapse. The portion of the 'standard run' 1900-1970 which allegedly reproduces historical trends, stands as the 'proof' of (B).

CONJECTURE \[ (C) \]
PROOF \[ (B) + 1970-2100 SIMULATIONS \]

CONJECTURE \[ (B) \]
PROOF \[ 1900-1970 SIMULATION \]

Necessarily, given the above, we make a distinction between the WORLD 2 model considered as a formal system - the referent system - and particular simulations with it. The referent system incorporates all the relationships and parameters used in describing the interactions between the state variables (i.e. the levels and rates); it captures the 'essence' of the real system. Forrester argues that any system can be represented by only two types of variables - levels and rates - linked in a structure of feedback loops. Levels are accumulations or integrations within the system and rates are flows which cause the levels to change. Thus, not only is it claimed that the referent system dynamics system can generate the same behaviour as the system (x), but it also has the same properties - i.e. those of a complex system such as an equilibrium seeking nature. At the heart of this notion is the tenet (which the system dynamicists take to be true) that systems are real world entities. This tenet is not just a practical metaphor for it gives substance to the system dynamicists' conception of the world. System dynamics models are not posited as black boxes which merely mimic some observed behaviour; rather, they are meant to capture the essence of the 'real' system generating that behaviour.

"What structures are capable of giving the behavior modes that characterize real-life systems." Forrester(122)

In other words, system dynamics is not so much an epistemological framework but rather an implicit ontological statement about the world.

All of the assumptions implied by the referent system are considered subconjectures within the 'proof'. The model in the simulation is
discrete and approximates to the real and referent systems which are of course continuous; there is no analytical solution for the referent system, hence the need for simulation.

Given this scheme, what do counterexamples look like? Firstly, a local counterexample is found when the model's behaviour (and therefore the referent system) does describe the behaviour (actual or expected) of the real system but a particular model assumption is found to be in error. Or, a simulation error is made. For example, a given assumption (either in the model or the simulation technique) may be invalid under certain conditions but does not affect the behaviour of the model and so (B) or (C) hold.

Secondly, a global counterexample would be found where the simulation output and the real or expected behaviour deviate. If no error can be found in the model or the simulation then a system has been found which lies outside the domain of (A).

Thirdly, a local and global counterexample would be a case where the simulation output again deviated from real or expected behaviour and the source is located in a model or the simulation error.

What of the anomalies in the backcasting debate? Well, the population dip 1900-1904 is a global counterexample to (B) because clearly the referent system does not describe the history of world population. (It is also a local counterexample if we can find an error in the referent system (model) or the simulation.)

The backcast anomaly is also a global counterexample to (B). Ultimately, (C) is neither provable nor disprovable - only the future will show this. However, (C) depends on (B) and so if the latter fails both anomalies must be considered local counterexamples to (C) - it would remain a conjecture without proof.

4.4.4 COPING WITH THE WORLD 2 ANOMALIES

The first thing to notice is that the SPRU team deliberately set out to test the World 2 model. In doing so they thought that better models would emerge. Observing the anomalous behaviour at the start of the simulation they generated another anomaly by running the model backwards. They suggested that the anomalies indicated that the model was in need of some reformulation. Had they thought that only an initialization problem was involved the error in the DRMM parameter would have gone unnoticed.
They subsequently reformulated the parameter in order to uphold (B) - the referent system being modified - but at the same time this refuted (C). In other words, the model was changed so that it did indeed describe history (B) (or at least a greater portion of it) but the original trajectories did not remain the same - the model trajectories no longer overshot and collapsed (C).

Of the strategies discussed above, that of 'proofs and refutations' appears to be the closest to ascribe to them for they were prepared to assimilate the anomalies.

Turning now to the response of Meadows et al, it is clear that the SPRU anomaly was not given the status of a genuine counterexample; rather, it was perceived as a "spurious excursion". Further, whilst some of the MIT group's comments were apposite (and actually accepted by SPRU) others were red herrings. More importantly, the SPRU backcast was claimed to be "completely meaningless" and Meadows made verbal recommendations about the important issues in question - of which backcasting was clearly not seen to be one - as if such recommendations alone could 'solve' the problem posed by the model's anomalous behaviour. Further, much of Meadows' technical argumentation may be viewed as a definitional flurry which by seeking to consolidate the distinctions between forward and backward running models thereby upholds (B) and by implication (C). The strategy here is monster barring, the anomaly is roundly rejected as a "monster", and we observe the articulation of a previously hidden lemma - the definition of what is taken to be a system has shifted. Implicitly, (A) and (B) become:

(A) for all systems that change forwards through time, their behaviour is given by their referent system dynamics system

(B) the forward running behaviour of the world is given by its referent system

Notably, sub-conjecture (C) also remains intact.

In contrast, Wright's response was both more complex and interesting. Remember that he accepted the backcast as genuine: he therefore accorded the anomaly the status of a true counterexample, so clearly he cannot be said to have been monster barring. Notably, he described the problem as a "bug", and he viewed the anomaly as "grotesque". He admitted that the model needed reformulating for the case when material standard of living was low but he did not think that the anomaly countered the main conclusions which Forrester drew from the model. In other words, the
backcast anomaly is accepted as genuine but it is barred as an exception to (B) and is not seen as a challenge to (C). The domain of (B) is reduced by extra conditions, both with regards to time and the levels of MSL. Thus, (B) becomes:

the behaviour of the world between 1900 and 2100, when MSL > 0.25, is given by its referent system

Rejecting the SPRU modification he stated:

"One of the symptoms of whatever is wrong appears in the World Dynamics base run as a small population decline 1900-1904. At least, one wants to revise the 1900 initial values to erase that transient without affecting 1905-2100 behavior... At early stages of industrial development, Forrester's original model over-estimates death rate and capital formation. An appropriate query is: can these assumptions be modified to support reasonable 1880 values without damaging predicted, future trends?" (123) emphasis added

In upholding the predicted trends, and therefore (C), Wright was affirming (B); for the original trajectories only have plausibility insofar as they are taken to represent the real world system. He realised that for (B) to stand the model must be able to replicate 1880-1900 history.

So, the adopted strategy was to modify the model without affecting its original trajectories: or in other words, to add to the defining 'lemmas' without changing (C). He admits that death rate and capital formation estimates are in error when MSL < 0.25 and he sets out to bring pre-1900 history into the domain of the conjecture. A closer look at Wright's modifications shows why this is a good description of his strategy. Again referring to Fig.6, we can see that Wright's respecification of DRMM arguably gives the function a rather curious appearance. If MSL < 0.25, DRMM is set to the value of 2.4, otherwise it is calculated in accordance with Forrester's original curve. Further, Fig.8 shows Wright's effective change to the capital investment function - CIH - and again for MSL < 0.25 the parameter is changed (to 0.16) with the original curve holding for MSL > 0.25. It is evident that this implies a discontinuous change at MSL = 0.25. In fact, the discontinuity ranges between values of 0.16 and 0.32 for CIM, which effectively means that capital investment doubles when MSL reaches 0.25. Alternatively, capital investment would suddenly double between 1899 and 1900. All this obviously begs crucial questions about the possible mechanisms which could account for such a discontinuous change.
Figure 8 CURVE FOR CIM (capital investment multiplier)
Now, these extra conditions are arbitrary because they are stimulated by the particular counterexample involved and do not guarantee against others. (Wright, however, believes that he has found a safe domain—hence his remark that the "model cannot be faulted if it remains in the acceptable operating range.";) Wright asserted that a model need only be accurate for the range over which it is intended for use; although he allowed that Forrester did not make this range clear in the case of World 2, he himself firmly limits the original model to 1900-2100. This is a modified form of exception barring: first of all the simulation of pre-1900 history is barred as an exception to the domain of World 2; secondly, he claimed that the pre-1900 anomalous trajectories could be avoided by incorporating his model revisions; thirdly, he argued that the validity of Forrester's conclusions—based as they were on the 1900-2100 predictions—were unaffected by the anomaly. (We can also discern the thread of monster adjustment here—i.e. the argument that when seen in 'correct' terms the anomaly poses no threat.) Thus Wright upheld (B) by barring the exception which it did not cover—he was trying to delimit a safe domain for the model. He then proposed to change the model so that the exception could be accommodated. (B) then becomes the behaviour of the world between 1880 and 2100, is given by its referent system the referent system in question being different to the old one.

His modifications alter the model in a piecemeal way in order to bring the exception within its domain. This yields what has been described as characteristically "segmented" or "additive" knowledge: certain conditions hold for pre-1900 (MSL<0.25) whilst others hold for post-1900 (MSL>0.25). Notably the switch in these conditions centre on a rather arbitrary boundary (either the 1900 boundary in time or the 0.25 value of MSL) and—as we argued above—imply a problematic discontinuity.

This arbitrary boundary is related to our earlier point concerning the difficulty in deciding what is wrong with the model and which was exemplified by the different sets of initial conditions specified by Forrester and Wright. As Wright would have it, the model is not correctly formulated for MSL<0.25 or, for pre-1900 values. But what is the reason for the choice of 0.25? For, upon closer examination (see Fig.5) it can be seen that the retrodiction of World 2 does not yield a value for MSL which is less than 0.25 until 1898. So by his criteria could we not claim that the model is valid at 1899? In fact it isn't because the level of population in 1898 is greater than that at 1900 even with Wright's initial values. Thus, we can only conclude that the choice of MSL>0.25 or
1900 is an arbitrary boundary which leads to extra 'lemmas' in the model's formulation and merely functions to preserve conjectures (B) and (C).

Britting accepted Wright's analysis and argumentation, and he therefore implicitly followed the exception barring approach. They both argued that a model should only be required to behave properly within its designated operating range - in the case of World 2 this is alleged to be 1900-2100. This however is arguably an unsatisfactory position because on the one hand the model cannot be run backwards for even 20 years and yet on the other its projections 130 years into the future were taken to be valid. Britting allowed that the structure of relationships could change with time and used this idea to support his contention that the model should not be expected to operate before 1900. It seems to have escaped his attention that his own argument undermines the very conclusions (drawn from the model) which he was trying to uphold.

As for Forrester himself, we have noted his shift in attitude towards the 1900-1904 population dip, but in no measure did he actually accord it the status of a real threat to his conclusions. In accordance with the routines of his modelling background - with (A) and (B) taken as rather self-evident - he did not investigate the problem and assumed that it was merely a question of initial values; he was also prepared to give the CIAF variable an unrealistic history in order to 'correct' it. This leaves (B) and (C) undisturbed. His strategy then was to slightly respecify his model simulation. However, in the case of this anomaly we cannot easily ascribe one of Lakatos's strategies to him because he did not treat it seriously. Though he did not perceive it as a monster, we have seen that he holds a strong conviction in his beliefs about systems and the overall adequacy of his model. This conviction prevented him from considering the possibility that something more serious was wrong with the model's formulation rather than a small initialisation error in the simulation.

This reminds us of monster adjustment - i.e. the potentially threatening anomaly is 'adjusted' and rendered harmless by the act of perceiving and designating it as an initialisation error. In other words, he adjusts the model's initial conditions only as a consequence of perceiving the anomaly precisely as an initialisation problem and thereby adjusting it to preserve (B) and (C). Thus, the model remains intact but the conditions given to it during the simulation change. We contend that such a change is of a different order than the parameter changes invoked by SPRU and Wright. The former only effects the proof whilst the latter
also effects the referent system (the model) implied by (B). We can illustrate this with another analogy. The choice of 'bad' initial conditions is comparable to finding that the rubber out of which one may fabricate a polyhedron is not isotropic and does not stretch flat properly. With uniform rubber it would; similarly, with 'correct' initial conditions (assuming that they exist) the model would not give a population dip between 1900-1904. It must be admitted that perhaps we are concept stretching Lakatos' idea of monster adjustment here but would argue that it is useful. For example, it enables us to understand how SPRU saw the anomaly as rooted in the DRMM parameter (i.e. the referent system) whilst Forrester - wishing to uphold (B) and (C) - perceives it another way. Moreover, Lakatos describes monster adjustment only in the face of global counterexamples whilst the ones in question here are both global and local. The common feature is that in each case the conjecture is upheld.

As regards the backcasting anomaly, he allows the possibility of backcasting but argues that it is "apt to be meaningless".

"Running a simulation model backward to see if it retraces past history is often suggested as a way to validate a model. Such was done with the World Dynamics model by the Sussex group...Yet, the procedure is apt to be meaningless unless a subtle combination of conditions falls within a narrow range in which the procedure is informative. Conditions that determine the relevance of backward integration include the purpose of the model, the complexity of its structure, the range of time constants in the structure, how far back in time reversal is attempted compared to the shortest time constants in the model, the presence and magnitude of noise introduced in the model, truncation error, roundoff error, the length of solution interval, the nature of the integration algorithm used. In addition, retracing with a model of real-life events is subject to the same limitations that apply to forward prediction...Practical, philosophical, and theoretical considerations overlap in a way that calls for clarification by new theoretical and interpretive work." Forrester(126)

In other words, it is a theoretical possibility but is most unlikely to have any relevance to (B) and (C). (One has to learn how to correctly interpret anomalous backcasts.) Again we are tentative about labelling him here but could once more suggest monster adjustment. We should note that his reference to backcasting comes in a paper in which he sets out to explain why people (particularly his critics) seem to misunderstand system dynamics. However, perhaps a better way of describing his response is not to say that he adjusts the backcast monster, so much that he monster bars the technique of backcasting. Indeed, this can also be seen as an undercurrent in the response of Meadows et al. Rather than
responding to a specific anomaly, Forrester is monster barring at the higher, methodological level of modelling techniques. His response must be set in context, which in this instance is that given by the earlier response of Meadows et al and the later ones of Wright and Britting. With Meadows the focus is mainly on the alleged anomalous behaviour of World 2, but with the advent of Wright's paper the "bug" in the model is acknowledged and backcasting becomes accepted as a possibility. Thus, by the time of Forrester's and Britting's responses emphasis has shifted towards method and away from the specific anomalies. The fact that backcasting can throw up anomalies is no longer in doubt and so the debate is re-cast in terms of how backcasts are to be interpreted. Indeed, this is why Forrester directs his response to the nature of backcasting as a modelling procedure rather than towards a specific defence of World 2. Whilst the idea of methodological monster barring is a higher level extension of Proofs and Refutations it does enable us to interpret Forrester's strategy alongside those of his colleagues. Moreover, other evidence of methodological monster barring can be found in mathematics itself. Pimm, for example, points to several instances including Gordans' objection to a non-constructivist proof by Hilbert ("Das ist nicht Mathematik - das ist theologie") and the controversy concerning the alleged computer proof of the four-colour problem.

Forrester also refers to Britting's work to support his assertions; thus, he 'raises and frames' the issue of backcasting in such a way as to protect (B) and (C). His reference to Britting implies that he accepts the existence of the anomaly uncovered by SPRU, but via his "subtle combination of conditions" it is rendered harmless and the whole relevance of backcasting is undermined.

Thus, the basic difference between SPRU and MIT is that SPRU are prepared to revise the model at the expense of the original trajectories and therefore (C), in order to allow (B). MIT, on the other hand, only revise the model on condition that (C) is not challenged. In other words, they attempt to uphold (B) and (C) by ad hoc modifications to the referent system or the simulation exercise (i.e. changed initial conditions).

At this point we should note that there is an interesting though minor difference between our backcasting example and Lakatos' study of the controversy surrounding polyhedra. In the latter case, it was sometimes clear where a local counterexample conflicted with a proof - i.e. the anomaly pointed to a specific lemma (in mathematics more generally, this is not always likely to be the case). In the case of the 1900-1904 population figures - which we ascribed the status of a global
counterexample - the difficulty is that we know that the counterexample may also be local but are unsure as to where it conflicts with the model. If it is located in the initial values then a minor respecification of the simulation may solve the problem; alternatively, if it is located in the DRMM multiplier - for example - then the counterexample is more severe because it affects the referent system.

Let us summarise at this point.

(1) In relation to the World 2 model, a set of conjectures and a proof have been defined in accordance with Lakatos' scheme.

(2) The form of possible counterexamples has been set out.

(3) Actual anomalies have been categorised in accordance with (2).

(4) The strategies of Meadows et al, Wright and Britting correspond with certain responses described by Lakatos - i.e. monster barring and exception barring.

(5) The strategy of monster adjustment has been used (stretched) to explain Forrester's responses to the 1900-1904 population dip, and methodological monster barring has been invoked to describe his reaction to backcasting.

(6) SPRU's responses, whilst not conforming to proofs and refutations comes closer to it than those emanating from MIT in the sense that they were prepared to bring (B) into accord with (D) without imposing such arbitrary conditions (compared to MIT's) so as to preserve (C).

### 4.4.5 Improved Models

The MIT modifications undoubtedly 'improved' the World 2 model but so too did the changes suggested by SPRU. How can we distinguish between them? We must try to address this question for doing so may indicate a path towards a better understanding of ways to improve errant models and it will also shed further light on the different styles of thought shared by SDG and SPRU. To answer this question we must return to the different views of the nature of models and we will also need to introduce Lakatos' important idea of concept stretching\(^\text{128}\).

By the term concept stretching Lakatos meant the process in which a concept is used in a manner which is not exactly consistent with the
implicit and explicit definitions pertaining to its original usage. For example, the definition of a polyhedron which was embedded in the Euler-Descartes conjecture became stretched to cover objects not originally envisaged by its adherents. Through the use of concept stretching one may generate or let in counterexamples to a conjecture; the responses to such anomalies focus attention more sharply on the domain of the conjecture and the definitions embedded in the proof for it. Often it is only by stretching a concept that we can force out the implicit assumptions upon which it is based.

When Wright asserted that the original model was only valid within its accepted operating range, was he contracting (or shrinking) the concept of a model in order to protect it from the SPRU counterexample? Forrester had not made the range of the model clear but it seems unlikely that he had envisaged the possibility of someone running it back before 1900. Alternatively, could we not equally say that the SPRU team were concept stretching? Consider what they had to say about models:

"As a model is a mimic of reality, it should reflect mechanisms and trends for the period of interest. If the same mechanisms were important in the past (before the period of interest), it is only reasonable to expect that a model should "backcast" or extrapolate into the past" (129)

Thus, it is perhaps better to conclude that SPRU stretched the system dynamicists' concept of a model to cover a range for which World 2 was never actually intended? This of course does not mean that SPRU did not subscribe to this principle before, indeed they noted its importance in other areas of science such as astronomy. Rather, it illustrates the different conceptions of a model with which the two groups operated. It also illuminates the fact that Wright's defence of the model was not necessarily a post-hoc redefinition of its purpose and scope. One may of course still disagree with his conception of a model, and certainly the fact that his reformulation was triggered in response to concept-stretching does not justify it - indeed, it merely shows his commitment to the original conjecture and model prediction.

SPRU had a pragmatic view of backcasting:

"In a non-linear dynamic model containing many parameters and many feedback loops, it is not practical to make all possible tests on the reasonableness of the model. "Backcasting" can be expected to drive some variable to unrealistic values and hence show up inadvertently incorrect assumptions underlying a model." (130)
Therefore, it was seen as a way of testing the model, of generating counterexamples with a view to improving its assumptions. Of course this means that the old prediction and the conclusions which follow from it may have to be surrendered, but that is not something which should be seen as problematical. It is here that the difference between SPRU's and Wright's modifications really lies. Wright wished to preserve the conjecture and the original prediction, and so modified the model with that aim in mind. Here is what Lakatos had to say about the exception-barring strategy:

"Most mathematicians, because of ingrained heuristic dogmas, are incapable of setting out simultaneously to prove and refute a conjecture. They would either prove it or refute it. Moreover, they are particularly incapable of improving conjectures by refuting them if the conjectures happen to be their own. They want to improve their conjectures without refutations; never by reducing falsehood but by the monotonous increase of truth; thus they purge the growth of knowledge from the horror of counterexamples." (131)

Wright's modifications lead to segmented knowledge whereas a deeper question would have been to ask what mechanism could account for both pre-1900 and post-1900 history? This form of exception barring and model modification ultimately lead to 'degeneration' in knowledge; as each exception is admitted into the domain of the conjecture through extra (arbitrary) 'lemmas' no substantial increase in depth or content is achieved. The model trajectories may suitably mimic more of history, but the model does not capture more of the "essence" of the global system.

SPRU, on the other hand, had no prior commitment to the conjecture or the original prediction and made a modification to the model so as to bring its behaviour into line with accepted history. In so doing a new prediction emerged - one which may be neither more nor less tenable than the old but which was at least based on a better 'model' - i.e. it did not impose such arbitrary conditions on the CIM and DRMM multipliers.

The type of approach which welcomes counterexamples (the method of proofs and refutations) is summed up by Lakatos as follows:

"If we want to learn anything really deep, we have to study it not in its 'normal', regular, usual form, but in its critical state, in fever, in passion. If you want to know the normal healthy body, study it when it is abnormal, when it is ill. If you want to know functions, study their singularities. If you want to know ordinary polyhedra, study their lunatic fringe." (132)
What of the MIT group's first response? Well, their position is even more problematical than that of Wright; by monster barring they remain closed to the inadequacies of the model and although they professed a deep commitment to improving our understanding of the global system it is clear that their strategy for dealing with anomalies would not further that end very well. They want improved models of social systems but appear to want to hold onto their conjecture and original predictions rather than give them up to better ones based on deeper and more adequate models.

These views of a model are of course related to the different modelling approaches adopted by each group and we will now discuss these in more detail.

4.4.6 SDG'S APPROACH TO MODELLING

The systems approach practiced by SDG centres on the formal modelling of social systems - they define a system as a set of elements which are united for some common purpose. They assume that the 'true' purpose or goal of any social system can be represented in a model and that policies to achieve it can thereby be tested. To them the general goal of modelling is to afford a better understanding of social systems in order to facilitate the objective of management and control. In the specific context of world modelling the goal is to aid the transition to a sustainable global equilibrium society sometime in the near future. This orientation carries with it an instrumental, pragmatic view of modelling: it is asserted that a model should only be judged in accordance with the purposes for which it is built. Further, this outlook permeates the view that Forrester takes of other research; for example, he argues that practical relevance should be accorded a higher place in judging research in the social sciences.

"Because the standards for judging publication and research originate in academia, criteria of excellence should be moved away from cleverness, mathematical skill, narrow precision, internal logical rigor, and data collection and analysis for their own sakes. Instead relevance to social policy should be expected along with a defense and explanation of the relevance."(134)

As regards their methodological orientation, two main features which we can readily discern are the use of a general systems theoretic framework and their position concerning the use of statistical - including time series - data. They contend that the properties of all systems - whether physical or social - are governed by feedback structures whose
definitive characteristics are more fundamental than the particularities of individual systems. In other words, a knowledge of a system's structure rather than a precise knowledge of the values of the variables which describe its components is sufficient to understand its behaviour - structure is therefore seen to more important than data. Forrester argues that models based on time-series data can only replicate behaviour modes that have been observed in the past. In contrast, he suggests that a system dynamics model can generate previously unseen modes and is therefore more pertinent for long-term modelling. For example, he notes the disparity between the assumption in World 2 that resource prices rise over time and the opposite view held by some of his critics who cite historical evidence for decreasing resource prices. He refers to two other system dynamics models in which prices hold steady over a fairly long period of time before a specific set of conditions precipitates a substantial increase. He then refers (implicitly) to the 1973 'oil crisis', in order to back-up his theoretical assertions.

"[T]he real world seems to be exhibiting the same new mode by breaking out of the past price stability. Education should place less emphasis on past data about behavior and more on the intrinsic structures that can render past trends irrelevant for the future management of society." (135)

System dynamics models are not used to make predictions about system states at specific points in time; rather, they are used to predict "behaviour characteristics" (stability, oscillation, growth etc). In order to test a model's validity, it is required to be able to reproduce or predict the behaviour of the real system to which it is supposed to correspond - the behaviour should be "plausible", the model should show the same "symptoms" and respond to extreme conditions and non-linearities in the same manner as the real system; any time phasing between variables or periodicities should also match those of the real system.136

Aggregation is an important aspect of any modelling exercise and in the case of system dynamics it is useful to consider the aggregation of 1) elements with similar behaviour, 2) parallel elements, and 3) aggregation in time. It is argued that if two elements have similar "underlying dynamic structures" then - given the purposes of the model - they can be aggregated together. For example, in World 2 capital and technology are aggregated together on the basis that the creation and depreciation of capital closely resembles that of technology.
Much of scientific and technical knowledge resides in the heads and skills of people and disappears from the system through death and decay in a manner dynamically similar to the obsolescence and discard of physical capital."(137)

Secondly, the models are aggregated at a global level because individual countries are regarded as parallel elements. In other words, world system behaviour is some additive sum of these separate elements - the feedback structure of the world system being regarded as identical to that which governs each individual nation. Thirdly, short-term responses such as price fluctuations are considered to be aggregated within long-term dynamics; the world models have a long-range time horizon and the behavioural dynamics of the long-term are considered to be more important than those of the short-term.

In Industrial Dynamics138 Forrester illustrates the essential principles of aggregation by considering an analogy between a water supply system and industrial systems. He points out that in a model of a water system all individual drops of water are aggregated; it is assumed that each drop flows through all the elements represented in the system description. In the case of an industrial system, he gives the example of the flow of an order item and the aggregation of all order items within a particular flow channel - all items pass through the same decision points. Now, whilst these examples are fairly straightforward the level of aggregation present in the world models is arguably of a qualitatively different kind.

"the models...were designed to examine the feasibility of continued growth in global population, capital and resource usage. These issues depend on the relationships between total world population, total food production, total resource consumption, and total capital, more than on the distribution of population or capital between nations." Forrester(139)

Meadows takes the same position as Forrester and for him too, global capital has "real-world meaning".

"Each assumption in the model should be consistent with direct measurements or observations of the real-world system; no assumption or parameter without real-world meaning should be added merely to improve mathematical convenience or historical fit." Meadows et al (140)

The problem here is that although it is easy to see the relationship between a real water system, each drop of water in it, and its model, the same does not necessarily hold with the world models. For example, other than its merely quantitative measure what, for example, is global
capital? (Even assuming that all types of capital can be valued on one basis.) Our point here is not to challenge their use of aggregation but to understand it. By asking this question we do not refute the concept of global capital but stress that its meaning depends on a given perspective. The principles of aggregation are therefore context dependent because what one group may take as empirical may be regarded as fiction by another. (This will become clearer when we consider SPRU's stance on aggregation.) SDG's treatment of aggregation - especially when we bear in mind the fact that causal relationships are posited between the global entities in question - lends further support to our conjecture that within the system dynamics framework, systems are considered rather as ontological entities.

The system dynamicists contend that formal mathematical models are more open to inspection and criticism than mental models; however, this seeming openness to criticism is tempered by the fact that they believe that critics must put forward alternative models - criticism must take the form of a better formal model.

"It is to be hoped that those who believe they already have some different model that is more valid will present it in the same explicit detail, so that its assumptions and consequences can be examined and compared. To reject this model because of its shortcomings without offering concrete and tangible alternatives would be equivalent to asking that time be stopped."

Thus, they imply that the way to improved models is through the construction of other formal models. Whilst they accept that no model can ever be perfect they argue that formal models are better than the intuitive models on which decisions about policy would otherwise be made. We can also note Forrester's argument that alternative formal models should be expected to be "ready for use" (i.e. in social policy) - this being in keeping with his instrumental view of modelling.

4.4.7 SPRU'S APPROACH TO MODELLING

SPRU also favour a systems approach to the task of understanding global problems; unlike the system dynamicists, however, they express more reservations about the practical difficulties of pursuing it. For them the concept of a system centres on the idea of interrelation between a group of elements but there is no assertion that a system necessarily has a goal or purpose. As for the aim of modelling, this they presume lies in indicating the way to "socially worthwhile futures."
Members of SPRU believe that suitable data is "essential" to any modelling activity. This, they argue, is because mathematical models require calibration and therefore "complete and coherent data" is needed. This necessity to ground the theory which is represented in a model in suitable quantitative data was a recurrent theme of their critique of the system dynamics world models. Their concern indicates that they are somewhat less pragmatic than SDG as far as model utility and purpose are concerned and it represents a strong empirical flavour within their methodological orientation.

In terms of testing the validity of a model, they believe - along with the system dynamicists - that a model should have predictive power, it should be able to forecast. However, in contrast to SGD they require more precise predictions than behaviour modes.

"We prefer to take a fairly pragmatic view of forecasting precision: that a forecast made for policy is accurate enough if making it more accurate would not demand a change in the inferences drawn from, or policies based on, the forecast." (145)

In their view the world models fall short of this standard.

"What, then, remains of Forrester's and Meadows' efforts? Nothing, it seems to us, that can be immediately used for policy formation by decision makers; a technique, one among several - system dynamics - of promise which needs improvement; but above all a challenge to all concerned with man's future to do better."(146)

They also advance other strands of model testing such as simplicity, linearization and sensitivity analysis. Let us consider the simplicity requirement first.

"we suggest that a primary requirement for the model to be of value is that it should be as simple as possible...In view of the problems of construction, testing and communication, Ockham's razor should be used ruthlessly, no material being included simply 'for the sake of it' as often seems to occur with simulation modelling."(147)

One way of simplifying a model is by linearization which is the technique of replacing non-linear model relationships by linear ones; this not only reduces complexity and therefore aids understanding, it also permits the use of other testing techniques which only have validity in the domain of linear systems. As an example of the usefulness of linearization they refer to the work of Rademaker et al in the Netherlands148 which showed that World 2 could be totally linearized and reduced to some five state variable equations (and some twenty
auxiliary equations for calculating the parameters which influence the state variables) without affecting the standard run of the model.

Another major facet of model testing which they propose is that of sensitivity analysis, the aim of which is to determine the relationship between a model's behaviour and the uncertainty in the knowledge of its parameter values. The system dynamicists also carry out a limited form of sensitivity analysis but - as we saw earlier - contend that complex systems are insensitive to parameter uncertainty. In contrast, SPRU argue that the analysis should not be carried out on one parameter at a time - as the SDG had done - but that one should seek to manipulate clusters of parameters.

"Both Forrester and Meadows, in their world models, employ one-parameter-at-a-time sensitivity testing, which is in general quite inappropriate to a highly interacting model involving considerable nonlinearities."(149)

In fact, throughout their critique of the world models SPRU endeavoured to test the effects of alternative assumptions and for them this constituted a form of sensitivity testing. They also suggest that sensitivity analysis should be used to locate redundant variables within a model - these are then to be excluded and the model thereby simplified.

Although they regard criticism as a necessary part of advancing the techniques of modelling, they do not equate criticism with refutation:

"One certainly should not reject a method because of intrinsic barriers, especially when they are not fatal. It seems to us not sensible, even dangerous, that only one method be prescribed or that any one method should be neglected."(150)

SPRU advocate the use of different models and modelling techniques when tackling a problem and indeed, much of their work on global modelling has taken the form of comparative analyses - in general they appear to favour an eclectic approach.

A final point we wish to make with regard to SPRU's approach to modelling concerns aggregation. They point out that although Worlds 2 and 3 were policy oriented, the high level of aggregation involved required a non-existent global decisionmaker - their policy utility was therefore seen to be questionable. Also, they objected to the global aggregation of pollution in the models because to them it did not have any empirical
meaning (of course SDG would contest this). For SPRU an entity such as "global pollution" simply does not exist. They support their scepticism on this matter by asserting that almost no empirical data concerning pollution is available for periods of greater than 10 or 20 years and yet SDG had extrapolated global trends on the basis of such data concerning specific pollutants.

"The difficulty is that many 'wholes', such as 'pollution', tend to be rather theoretical concepts with a poor empirical base; the statement that the pollution level has a certain value does not mean very much and a variable 'pollution' can only be quantified in an arbitrary way. Some disaggregation into types of pollutants seems essential for meaningful quantification." (151)

Thus, empirical validity to SPRU requires the criterion of quantifiability in contrast to the rather intuitive criterion of SDG. Lastly, they discuss a test of disaggregation which requires that if disaggregation at a specific point notably alters the behaviour of a model or the conclusions drawn from it then the model should indeed be disaggregated at that point. This test is connected to their suggestion that only independent parameters should be aggregated together.

"A set of parameters can be expected to merit aggregation if they have similar properties and are independent (in which case their properties are additive) or if they are numerous and interact in a random manner (when statistical laws may be used to give rather precise estimates of aggregate behaviour, as in the statistical mechanics of gases)."(152)

They carried out the test with the World 2 model by separating the world into two regions and it was found that the hybrid model gave different results to World 2\textsuperscript{153}. The argument that only independent parameters should be aggregated is also a factor in their criticism of the aggregation of capital and technology within the world models. Because the productivity of capital is seen to be intimately connected to the state of technological knowledge they are not considered to be independent. Indeed, SPRU found that the disaggregation of capital and technology - by the inclusion of incremental annual improvements in agricultural, resource and anti-pollution technologies - was capable of eliminating the collapse depicted by the models. In contrast, Forrester had only examined the effects of single discontinuous technical improvements - these only delayed the collapse for a few years.
THE SOCIAL CONSTRUCTION OF ERROR

It is clear that to a certain extent, whatever is perceived to be wrong with the model - World2 - is whatever the particular group in question takes it to be. That is, the source of the error is not fully determined by the model itself. Rather, there is an irreducible social factor - each group involved may perceive a different error and accord it a different status. This factor is social because it is located in the different styles of thought which are socially shared by the two groups.

It is important here to note that the development of the debate did not converge towards some ultimate single truth - rather the outcome (i.e. as far as each group saw it) was socially shaped or negotiated, by which we mean that it emerged through the processes of argument amongst the members of each group. During the course of the debate different positions emerged from the MIT group but the conclusions from the original model remained upheld. Further, though the SPRU backcast of World 2 came to be seen as legitimate the MIT group continued to resist the general use of backcasting as a way of model testing. Not all the contenders viewed the anomalies in the same way, logic or objectivity is not the final arbiter here as it wasn't with the controversy over the Euler-Descartes conjecture or indeed any clash of opposing systems of thought. Thus, to state the point again, the outcome of the debate - the development of each group's position - was a social product which the different groups involved construed in disparate ways. The anomaly was a different thing for SDG and SPRU and this difference depended on judgement. Moreover, SDG talked of their own model, they were defending their theory of the world. SPRU, in contrast, were not defending a theory of the world so much as criticising that of SDG. We might also note that Erickson and Pikul who upheld backcasting and extended the work of SPRU, nevertheless had a highly favourable view of system dynamics.

"These problems, of course, do not detract from the truly monumental achievement of Forrester and Meadows in introducing system dynamics into world policy considerations, and in fact, awakening the world to the possible predicament facing it in the twenty-first century." (154)

The differences between SDG and SPRU can be located in their different styles of thought - which in this particular debate we have seen in their conflicting attitudes towards models, anomalies and model improvements.

We have charted the formal positions of each group but these are the outcome of the broader arguments and counterarguments in which the MIT
and SPRU groups were locked. The debate did not reach a consensus but its social nature is unavoidable. Meadows saw a cognitive gulf between the two groups:

"A minimum level of training and experience in feedback systems and control theory is a prerequisite for the construction and analysis of system dynamics models. Without that training it is possible to make elementary mistakes and to expend unnecessary energy analysing irrelevant issues." (155)

To this we would like to add the difference in their respective group or professional boundaries.

In an article by Bloor, Lakatos' account of the Euler-Descartes controversy is analysed in terms of the grid-group theory. He associates each of Lakatos's strategies with a specific social structure and cosmology—see Figure (9). Bloor argues that the intellectual or cognitive boundaries of the mathematicians involved were negotiated into line with their social boundaries, and that these in turn conditioned their perception and response to anomaly. The social boundaries in question were those which defined them as distinct social groups—e.g. within their university departments. Bloor does not rule out certain individual differences within these groups but argues that they collectively developed and maintained socially accepted forms of knowledge (e.g. the classification of polyhedra and how to treat counterexamples).

Anomalies not only pose technical difficulties but also take on moral significance for they can be seen to disturb the 'proper' or 'natural' order of things (as we said earlier, they violate classificatory schemes). This is particularly so in the case of monster barring—in contrast to the strategy of proofs and refutations where anomalies have no social or moral significance at all. With strong boundaries (cognitive and social) anomalies represent potent threats but with weak boundaries they become rather a source of puzzlement.

Can we use these notions in a similar way in order to speculate about the development of the debate concerning backcasting? More specifically, can we say that the anomalies involved had any moral significance for the system dynamicists; did they threaten their sense of proper order? To answer this we should again consider the social differences between the groups at MIT and Sussex which we discussed earlier.
FIGURE (9) BLOOR'S MODIFIED GRID-GROUP DIAGRAM

GRID

SIMPLE COEXISTENCE OF THEOREM AND COUNTER EXAMPLE

MONSTER ADJUSTMENT EXCEPTION BARRING

DIALECTICAL METHOD OF PROOFS AND REPUTATIONS

GROUP

MONSTER BARRING
The MIT group harboured some internal differences about backcasting and the importance of the anomalies, but they shared a common identity as system dynamicists - which they defended in the face of SPRU's critique. Moreover, they were committed both to the potency of system dynamics as a modelling technique and to the conclusions inferred from the World 2 model. Those conclusions did not in fact stand solely on the results of one particular model but were underpinned by their belief in the properties of complex systems. The sense of proper or natural order for them was rooted in their general systems-theoretic perspective which - as we argued before - accords an ontological status to systems.

Further, their sense of identity was not only cemented by a shared philosophy and commitment but, more importantly, by a shared set of modelling practices. These were the accepted - or as modern sociologists such as Latour ¹⁵⁷ say - socially 'negotiated' procedures for building and testing models. (These practices stretch back over many applications to the 1950s.)

A reflection of the close-knit aspect of the group can be seen in the fact that a number of the system dynamics publications relied heavily upon each other with little substantial reference to, or analysis of, outside work. We might also mention that a model constructed without data does not lead its creators into discourse with those experts or bodies of knowledge in the fields from whence such information could be sought.

Therefore, in defending the conjecture about systems, the world model and its predictions, they were seeking to preserve both the cognitive boundaries which distinguish system dynamics from other techniques and the corresponding professional or group boundaries which underpin and reinforce their own identity. Particularly in the face of the criticism from SPRU - and indeed the scientific community more generally - these boundaries were all the more sharply perceived and maintained. In this type of social experience anomaly can take on the symbol of a 'monstrous' threat; it undermined their sense of proper order and to have assimilated it would have required giving up what they stood for. Moreover, the anomaly was a threat to their professional and group identity - and livelihood as modellers - as much as their cognitive boundaries.

On the other hand, SPRU were hired as critics, they were commissioned to test the world models and the system dynamics technique. As a rather more diverse team - who did not share a common faith in any given technique - they were less distinctly bounded as a group. A significant
range of perspectives - both academic and political - can be seen (and is acknowledged) in the SPRU critique; moreover, we have noted earlier that substantial reference to work in other fields is also much in evidence.

Corresponding to these more open social and cognitive boundaries we have discerned a relatively more open attitude to anomalies and a practice of generating them in order to test models and their conjectural assumptions. This of course is not to suggest that SPRU measure up to the method of 'proofs and refutations' in any absolute sense but, rather, that they were relatively closer to it in comparison to the system dynamicists.

Of course it could be said that they too shared a commitment; for example, that they had a common interest in criticising the World 2 model. However, the identification of social interests does not invalidate either a model or criticism of it. What is important here is the way in which two different styles of thought may both be underpinned by social interests and yet lead to contrasting styles and content of knowledge.

Social boundaries - rather than social interests - mediate and reinforce cognitive boundaries and we have asserted that the stronger group boundary of the system dynamicists is reflected in their defensive attitude towards anomalies. SPRU on the other hand - in this case at least - appear to be intrigued by anomaly. Their livelihood depended not on building and defending models but upon questioning them, upon asking why the different assumptions upon which they rested should be accepted.

We should also set SDG's responses in a developmental context because it is possible to show that their official attitude to the backcasting anomaly was at variance with Forrester's own methodological position as set out in *Industrial Dynamics*. There, in a section on model testing we find the following statement:

"Another effective test of a model is to attempt to precipitate additional obvious inadequacies by testing the model over an unusually wide environmental range (but still within the objectives of the investigation). This may well be a range wider than has ever been encountered by the actual system. Much of our knowledge of a system is in the form of knowing what would happen under various crisis conditions. A breakdown of the model policies under 'reasonable' crisis tests often reveals defects that affect model performance even in more normal circumstances." (158)
ow of course the locus of this position revolves around what is to be
considered as "reasonable" but it still stands as an evocation of the
use of crisis conditions to understand and thereby improve a model,
which is exactly what SPRU had tried to do with World 2.

The differences between the periods of industrial and world dynamics
were that SDG had been formed with its own laboratory, their work had
become more data independent as it was expanded to each new domain, and
they relied more heavily on internal cross-referencing. The industrial
dynamics technique developed into a shared worldview which was renamed
'system dynamics' for it was then perceived as a general systems theory.
Moreover, the models of corporations had been rather technical
descriptions of production systems etc., whereas the world models
represented the very basis of the system dynamics philosophy and
perspective, and they were meant to carry a message to the whole world.

Thus, system dynamics was embraced by a set of researchers who were
displaced further along the group axis of Douglas' diagram and in fact
this was reinforced as they closed ranks in the face of opposition from
critics such as SPRU.

Thus, as the nature of the social location within which the evolving
systems theory resided itself developed - from Forrester and a few
colleagues and students, to a research group in its own right - so too
did the nature of anomalies - from technical puzzles for improving
models to violators of their sense of proper order.

There are substantial technical differences - but also some
similarities - between the approach to modelling practised by each
group. SDG embrace a universal framework and build models which are
largely independent of formal empirical considerations. SPRU, on the
other hand, repeatedly emphasize the need to calibrate models, to ground
them in quantitative empirical data. This difference is partly explained
by SDG's greater pragmatism concerning the question of model purpose.
This pragmatism is essentially an instrumental attitude towards
modelling: model purpose (the end) dictates the selection of model
parameters and the degree of acceptable precision in the knowledge of
them (the means). In contrast, SPRU imply that the choice of purpose is
constrained by the empirical validity and quantitative knowledge of the
selected model parameters. On the point of model purpose, therefore, we
suggest that SDG appear lower grid than SPRU.

Both groups consider it important that a model has surplus content, that
it is able to predict. SDG provide theoretical justifications for their
predictions - based upon the properties of feedback systems - whilst SPRU require more formal empirical verification. The former only claim to predict behaviour modes whilst the latter prefer more precise predictions of system states. In terms of judging model predictions, then, SPRU's position (empirical) is lower grid than SDG's (formal).

As far as aggregation is concerned, both groups relate it to empirical considerations but differ as to what can actually be taken as empirical; SPRU, for instance, do not accept the global aggregation of pollution. SDG accept "real-world" intuitive observations whilst SPRU again require meaningful quantification. This disparity between intuitive and quantitative knowledge is one reflecting a difference between higher and lower grid.

SPRU discuss model testing to a greater extent; indeed, they propose a battery of empirical and formal test procedures, together with techniques for simplifying models. Moreover, whilst SDG's articulation of assumptions lies at the level of model structure - they enunciate concepts and justify them on formal grounds - SPRU aim to challenge the 'labels' that are used and supplement this with empirical arguments. Whether it is the degree of aggregation or implicit assumptions about technological change, SPRU manifest a curiosity in examining the underlying basis involved. This is complemented by their comparative approach to modelling.

Each group expounds a systems perspective but with a number of important disparities; for example, both stress the interdependence of system elements but SDG go further and assume that system elements share a common purpose or goal. This rests on the further assumption that the goal can be decided relatively unproblematically and it is a mark of higher grid for at root it implies that the goals are real and not mere interpretations.

We have now completed the second stage of our analysis and have elucidated the thought styles of SDG and SPRU; we have also interpreted these styles in terms of the grid-group diagram. In the following two Sections - 4.5 and 4.6 - we will discuss the content of their cosmologies, including their beliefs about knowledge, nature, man and society, and time.
The system dynamicists' view of knowledge implicitly stands upon what Mitroff and Turoff describe as "rationalist" or "Leibnitzian" ground; by this they mean that system dynamics models are largely justified independently of empirical considerations. The justification, of course, lies in the alleged universality of feedback structures which are posited as lying beneath different geographical, historical, social, cultural, economic or political contexts - the principles of feedback structures are considered to be applicable to all systems that change through time. Indeed, this is what underpins the relative importances assigned to structure and data in system dynamics.

It must be noted that the system dynamicists do actually display some diversity with regard to the use of data. With Forrester's later work - on urban and world dynamics - we find that he virtually eschewed the use of statistical and time-series data and strongly maintained his thesis that complex systems were insensitive to the uncertainties in data. In contrast, there was a concerted effort on the part of the World 3 project team - headed by Meadows - to try and calibrate many of that model's parameters. Even so, Meadows admitted that perhaps only 0.1% of the data required for the model was actually available.

The system dynamicists stress the use of informal empirical sources; they set great store in 'learning by doing' and believe that a knowledge of feedback systems comes from practical empirical experience with such systems. Moreover, the structure of a system dynamics model is constructed from descriptions based upon "intuition and insight". Speaking about the need to include the "least precise but most comprehensive" information in system dynamics models, Meadows states:

"Estimates of such unmeasured, intuitive variables are generally included...on the assumption that their inclusion, even with some inaccuracy, produces a more useful and accurate representation of the total system than does their omission." (161)

Similarly, Forrester urges that it is better to include a parameter whose magnitude is uncertain but which is known to influence the system, rather than to omit it.

The system dynamics framework seeks to explain real world behaviour and does so on the basis that all complex systems share similar properties.
Such explanations are not primarily causal; in fact, the actual concept of causality is seen to be problematic. This is because mutual-causal processes - that is, processes where 'A' causes 'B' and 'B' causes 'A' - are seen as an essential characteristic of feedback systems. They do discuss cause and effect to a certain extent, but it is only at a general level in terms of the properties (causes) of feedback structures and system behaviour (symptoms or effects).

Forrester has asserted that an aid to understanding a given set of observations lies in the fact that they "must fit into a limited number of categories". This means that anomalous observations are unlikely to remain recalcitrant; they will be fitted into the existing categories rather than serve as the basis for new ones. This is another consequence of 'Leibnitzianism' for if all complex systems share the same properties there is no need to look beyond the existing categories - all observations are explained according to expected system behaviour modes. In fact, the alleged generality of system dynamics is actually only one instance of the way Forrester posits universal forms of knowledge; for example, although he believes that Newton's laws, the laws of thermodynamics and Einsteinian relativistics are separate, he considers that they are but parts of some future "broader unifying concept" 162.

The reliance on the formal theory embodied in system dynamics is combined with laboratory experimentation and Forrester claims that "surprising discoveries" are the result.

We observe that relatively simple structures produce much of the complex behavior of real-life systems."(163)

The system dynamicists claim that their method has the advantage that - when compared to other modelling techniques - social and psychological factors can be built into their models. Such factors are implicitly represented in the parameters influencing the rate or policy equations. For example, the parameter which adjusts the death rate in World 2 in accordance with the level of crowding is formulated to reflect the effects of psychological and social stress. Their confidence in this approach to 'soft' variables leads to the statement that anything that can be described about a social system "can be represented in a laboratory model". This complements the idea that an ultimate simplicity lies beneath the complexities of observed behaviour. Further, we find repeated stress on the need to be explicit and the assertion that formal computer models make all assumptions open to criticism.
"Since ours is a formal, or mathematical model it also has two important advantages over mental models. First, every assumption we make is written in a precise form so that it is open to inspection and criticism by all. Second, after the assumptions have been scrutinized, discussed, and revised to agree with our best current knowledge, their implications for the future behavior of the world system can be traced without error by a computer, no matter how complicated they become. We feel that the advantages listed above make this model unique among all mathematical and mental world models available today." Meadows (164)

Similarly, Forrester asserts:

"The good modeller can discuss the issues surrounding his subject without contradicting himself. Such lack of internal contradiction is a goal that no public official can achieve based on a liberal arts education, and intuition. The modeller can know exactly the assumptions he has made. Without a shadow of a doubt, he can determine the dynamic consequences that follow from those assumptions." (165)

What is of interest here is the conviction about the certainty of the knowledge which they possess; it assumes that all premises can be made explicit and would imply that they perceive clear, well-defined categories in all things - whether in the realm of physical systems or social systems.

4.5.2 NATURE

As regards nature, we can discern a complex array of explicit and implicit assumptions which convey a distinctive view of the natural environment (some of these assumptions will only gain full import in the light of their views on man and society). The most explicit assumptions about nature are commonplace features of system dynamics literature: for instance, the titles of the books The Limits to Growth and The Dynamics of Growth in a Finite World are typical examples which carry the view of nature as limited. It is assumed that nature contains a given finite and exhaustable stock of resources; there are also limits to the amount of pollution that nature can absorb and to the ultimate level of food production. Similarly, there is a posited limit to the possible levels of crowding; as population density rises "psychological factors, fear, and the threat from world conditions" reduce the birth rate. Similarly, the death rate rises as a consequence of "psychological effects, social stresses that cause crime and international conflict, the pressures that can lead to atomic war, epidemics". Thus, we can consider the limit to crowding to be another natural limit - natural in the sense that it is somehow programmed into man as a biological species. Taken together
these limits underpin the notion that the planet has a fixed "carrying capacity" - i.e. it can only support a fixed level of population at a given standard of living.

Nature is seen to be under threat from man, his burgeoning numbers, industrial and agricultural activities. Whilst it is suggested that there is a danger in the exponential growth of pollution, it is the alleged exponential growth of population and resource consuming industries which are seen as the fundamental disturbing forces in the global ecosystem. However, despite the threat which man supposedly poses to the natural world he is seen to be fighting a losing battle - nature cannot be subjugated forever. Each technological advance is seen as merely a slight postponement of the time when the forces of nature will restore equilibrium.

"Fundamental forces of nature and the social system have been lying in wait until their time has come."(169)

World equilibrium, therefore, is considered to be the inevitable natural state - man must live in harmony with nature.

The members of SDG declare that they are followers of Malthus but whilst he only concerned himself with the limit imposed by food supplies, they point out that they have added the limits due to resource depletion, pollution and the effects of crowding. Malthus too spoke of natural checks on population growth but the system dynamicists give a much more formal explanation for them based upon systems-theoretic considerations. This explanation is rooted in the idea that a system's equilibrium seeking and requires a set of "pressures and stresses" in order to anchor it and prevent its drift out of equilibrium.

Many people have charged that Malthus' work - intentionally or not - provided legitimation for the inaction of the British Government during the infamous Irish Famine in the 1840s; at that time it was suggested that the natural checks should be allowed to take their course otherwise the future consequences would be even worse. Nature was therefore used for the purposes of moral justification and the character of the system dynamics message is very similar. Indeed, Forrester - in contrast to Meadows - goes so far as to suggest that world food production could be reduced, otherwise even more people will die in the coming collapse. Whilst differing with regard to this particular policy option, SDG appear to unequivocally support the call to stop population growth.
The necessity of balance between society and nature leads to the implication that perturbations of the 'natural order' are followed by a 'natural' response which restores equilibrium. Consider the following argument put forward by Forrester, it again resonates with Malthus' idea of natural checks on population growth.

"Consider an overpopulated country. Its standard of living is low, food is insufficient, health is poor, and misery abounds. Such a country is especially vulnerable to any natural adversity...Floods make many homeless; but is that because of the flood or because overpopulation forced people to live in the flood region? Droughts bring starvation; but is that due to the weather or to the overpopulation that made sufficient food stocks impossible? The country is operating in the overextended mode where all adversities are resolved by a rise in the death rate. The process is part of a natural mechanism for limiting further growth in population." (170) emphasis added

Within system dynamics we find that a number of analogies are drawn between natural processes and social processes. For example, the growth and depreciation of capital is seen to be "exactly analogous" to births and deaths in population - physical capital therefore mirrors social 'capital'171. In other words, natural processes are used as metaphors for describing social processes. This is not all, conflagration is also seen in terms of natural metaphors - war is viewed as a somehow 'natural' outcome of a social system pressing upon natural limits; it is the social manifestation of a system moving towards equilibrium.

**15.3 MAN AND SOCIETY**

Members of SDG appear to hold a rather pessimistic view of man and his social institutions - they regard their perspective as "humble". They assume that in general people tend to be only oriented towards their own short-term self-interests and do not bear due responsibility for the future. Further, political institutions are also seen as being fallible in this regard - politicians are regarded as being tied to the short span of political office rather than to a long-term perspective. Institutions are viewed as relatively inert, with a tendency to tackle complex problems with simplistic solutions172.

If we consider the view of man which they impute to SPRU - and which they take exception to - we can again see the moral view of nature which they expound.
"One possible concept of man, the one that is held by the Sussex group, is that Homo sapiens is a very special creature whose unique brain gives him the right to exploit for his own short-term purposes all other creatures and all the resources the world has to offer." (173)

This view of man is seen to be "firmly rooted in the Judeo-Christian tradition". In contrast, they regard the idea of man as 'ruler of creation' to be a short-sighted fallacy and put forward an opposite conception in which man is regarded as but one species along with all others; he is embedded in the "intricate web of natural processes that sustains and constrains all forms of life". In line with this view, man and his social systems are regarded as being largely unchanging in nature - this being another manifestation of the process-reduction which we discussed in Chapter Three.

"In fact, social systems are dominated by natural and psychological factors that change very little." (175)

Their view of technology matches their pessimistic view of man: "progress" is seen to have been obtained only at the cost of "natural beauty, human dignity, and social integrity." (176)

"Technical advances have not banished hunger or war. Instead, technical advances have only supported larger populations to be subjected to hunger and war." (177)

Of course not all men are considered to be shortsighted: the system dynamicists - amongst others - claim to take a long-term perspective which they regard as a moral responsibility.

"World modelling is so important that it should move in the most effective directions. The time has come to discuss the role of world modelling and the most promising approaches for fulfilling our obligation to civilization." emphasis added (178)

As they see it, part of their duty is to help educate governments and the general public in order to prepare them for the transition to world equilibrium and the consequent forfeit of freedoms that will be necessary to preserve it - we saw earlier that Forrester exhorted "restraint, self-discipline, and intentionally increased pressures". The system dynamicists argue that long-term values are needed - this implicitly emphasizes man's roles and duties to society rather than his material well-being - people are exhorted to give up current aspirations for the sake of generations in the distant future.
The reflection on the nature of society is complemented by the realisation that the individual may reject society's demands. Forrester recognises this and condemns it for he believes that the failure to meet the system's requirements - such as a commitment to long-term goals - may cause the whole system to falter.

The system dynamicists allow that men have a degree of autonomy; they have created the socio-economic system and are not the victims of forces from without. Rather, to some extent they are the victims of their own policies. It is suggested that the goals of subsystems, and therefore individuals, should be subordinated to the goals of the system as a whole. This alleged harmony between system and subsystem is a generalisation of the harmony between the self and society - each individual therefore has a role to play, a function to fulfill.

We have already discussed Forrester's beliefs concerning humanitarianism in the previous chapter but we can add to this by considering those concerning equality, moral responsibilities and one's links to the past.

"If all men are not to be equal at every point in time, then some boundary must be established around the concept that one is to be his brother's keeper...If one has a responsibility for the future, an inescapable symmetry commits him to a legacy from the past. There is no basis for world equilibrium unless the sins of the fathers are to be visited on the sons. One can have no right to equality in the present, but only to an accumulated equality that reflects the actions of his heritage and the long-term goals of his ancestors."(179)

Moreover, the "stresses" he observes in the present - "such social disorientations as drug addiction, rising crime rate, aircraft hijackings, genocide, and the increasing threat of a third world war" - are but the "price for advantages that mankind reaped in the past" and which allowed population growth.

These ideas sustain Forrester's belief that the transition to equilibrium may be most difficult for the developed nations - they are seen to be adopting technological means to put off the equilibrium state, but this only renders them more vulnerable and may cause the inevitable transition to be that much more painful.

Meadows' views are somewhat more moderate than Forrester's, he believes that only a non-growth society can effectively address the problem of maldistribution of resources. However, the possibility of egalitarianism in an equilibrium society is only a secondary matter, a 'spin-off', and
not the prime motivation for ceasing growth.

TIME

A common feature of system dynamics publications is the reference to the systems engineering field at MIT out of which Forrester's theory of systems developed. The following extract is a typical pointer:

"The field of System Dynamics has been developed at the Massachusetts Institute of Technology through more than thirty years of continuous effort directed toward the analysis and control of complex system behavior. From its birth in the study of relatively simple mechanical systems it has grown to provide a single framework for understanding the behavior of electronic, chemical, biological and social systems whose elements interact through time to produce system changes." Meadows

Thus, the system dynamicists cite their membership within a longstanding established tradition. The achievements of the past - largely in the domains of military and technological systems - therefore lend legitimacy to their claim to have the knowledge to tackle the problems of the future. They perceive the past as marked by distinct frontiers in knowledge; the frontiers of science and technology are seen to have been and gone whilst that of understanding the behaviour of social systems is only just dawning. The awareness of their roots in the past is matched by their long-term perspective and the symmetrical relationship which Forrester posits between past and future. These conceptions of time are also supported by their contention that the inherent delays of social and natural processes - up to 50 or 100 years - lead to the consequence that present policies determine the distant future or at least constrain it. Conversely, the present is the outcome of previous, delayed, policies.

The argument concerning delays also carries a coercive edge for it underscores their injunction to act now - otherwise, they argue, it may be too late to achieve an orderly transition to equilibrium and nature will impose one without men's wishes in mind. These delays - such as those inherent in population age structures or the dissipation of a pollutant - are seen to be "natural" and beyond technological control. Thus, time appears to be seen rather as a superposition of 'natural cycles' - future time is the unfolding of a myriad of delayed processes.

We noted earlier that the time scales often employed in system dynamics models tend to be very long - i.e. of the order of 200-250 years. We should further note that the urban dynamics model did not correspond to
any given period in history and despite the fact that the World 2 model was purported to replicate the period from 1900-1970, Meadows has argued that the role of time in a system dynamics model is only that of "an indicator of lapsed chronological interval". In other words, model time does not correspond to time in the abstract or physical sense, and it is not a causal factor in a model. This reinforces the notion that precise predictions of system states at specific points in time are eschewed - rather, as we stated earlier, it is the sequence of behaviour modes which is the focus of predictive effort. Indeed, it is argued that because of the noise inherent in system processes, two otherwise identical systems may manifest quite different system states at any given time - their structural behaviour will, however, be the same. In this respect, there is the implication that a certain temporal order inheres in the sequence of a system's behaviour modes and it seems reasonable to suggest that this is at the root of the SDG's arguments about the need for practical experience with feedback systems - such exposure yields insights into the dynamic properties (behaviour in time) of complex systems.

Although physical time does not play a causal role in system dynamics models the role allocated to "natural delays" in the real world implies that time indeed has a causal role in the determination of system behaviour.

"Everywhere in the web of interlocking feedback loops that constitutes the world system we have found it necessary to represent the real-world situation by introducing time delays between causes and their ultimate effects."(184)

It is these time delays between cause and effect that produces the "overshoot and collapse" of the world model rather than a more controlled asymptotic approach to the system's limits. We can therefore see that time has a 'natural' dimension in system dynamics and as such imposes further limits on growth and human actions.

4.6 THE COSMOLOGY OF THE SCIENCE POLICY RESEARCH UNIT

6.1 KNOWLEDGE

SPRU take neither a "Leibnitzian" approach to knowledge nor its opposite, "Lockean" empiricism 185, in which data is treated as prior to, and the justification of theory.
"In practice, it is not possible to realize 'pure' forms of either of these categories: a theory must depend ultimately on perceptions of the real world; data is inevitably conditioned to some extent by the way one chooses to look at the world."(186)

They argue that the selection of data is subjective and in fact theory-laden. Like SDG, they too accept that the interpretation of time-series data is problematical but further note that this also applies to "recent poorly quantified trends" which SDG extrapolate into long-term behaviour modes. Although the alternative data they put forward in criticising the models was "optimistic" - in contradistinction to the "selective pessimism" of MIT - it was allegedly based on equally plausible assumptions. In other words, the data advanced by SPRU did not refute the MIT models but rather was used to establish an alternative viewpoint whose validity was on an equal footing. On this basis then, they rejected the exhortation to stop growth. For example, consider their criticism of the agriculture subsystem of World 3:

"The assumptions about the physical limits of the critical variables in the agricultural sub-system of World 3 are pessimistic. By making more optimistic but, on the basis of available information, equally plausible assumptions about them, any physical limits to agricultural production recede beyond the time horizon of the model."(187)

Instead of empiricism or rationalism they avowedly choose a compromise "Kantian" approach.

"At least two theoretical representations are used, and data is collected, from which it is hoped that the 'best' representation of the problem can be selected."(188)

This stance reflects both their diversity in method - their 'eclecticism' and comparative orientation - and their concern to ground models in quantitative data. This of course does not guarantee objectivity which they believe lies "in the eyes of the beholder". Their approach is evident in the formal and empirical tests they brought to bear on the world models.

Members of SPRU argue that the basis of knowledge lies in causal explanation. Their advocacy of the systems approach is limited to a broad view of problems and they do not adopt the type of cybernetic approach taken by SDG - their use of the systems approach, then, has not displaced the analytical emphasis on causal explanation.

Of course a philosopher may well object to the simple use of the term.
"A precursor to rational forecasting and planning must be an 'explanation' of how the real world behaves. This entails the building up of descriptions about causal processes. 'Explanation' to us means the inference of causal links between phenomena..." (189)

In addition to causal explanation they urge the separation and rigorous study of issues before they are integrated within a systems model.

"Even for world problem areas, however, the separation of issues is often beneficial. It is useful to identify particular pollutants, particular technologies and particular social institutions. Both separation of issues and the resulting specialization within disciplines are essential parts of the creation of knowledge necessary for their study..." (190)

This provides a further qualification of their systemic approach: it requires the in-depth study of the important factors in a problem area together with a broad consideration of the set of factors which are taken to be relevant.

6.2 NATURE

SPRU accept that in purely logical terms the world's resources are finite, but they are at pains to add that this does not imply that they are necessarily exhaustible. Further, they regard the attempt to quantify resources in terms of some fixed stock to be entirely problematic. In place of natural limits to growth they perceive economic and technological constraints upon man's ability to exploit resources. Whilst pointing out that there have been many (incorrect) pessimistic forecasts of resource exhaustion in the past, they note the continued improvements in resource technology. Both in terms of exploration and recovery, technical improvements are seen to have made a mockery of such forecasts; they cite instances where advances have enabled the exploitation of progressively poorer ore grades - to the extent that previous 'waste' or scrap can become a future ore resource. In addition they maintain that much of the globe remains unexplored and argue that exploration - and therefore reserve estimates - have in the past been tied to effective demand. Strategic and economic interests are also considered to be important in this respect; for example, they refer to the growth in uranium exploration as a response to the tensions induced by the 'cold war'.

Their position on the question of energy reserves is similar and in reference to the oil 'crisis' of 1973 they point out that oil prices were..."
to some extent a reflection of OPEC bargaining power rather than of increased production or transportation costs. They do not see growth as being constrained by energy shortages.

"Contrary to the popular view, the real problem is not the prospect of physical shortage but the economic and social adjustments needed if rapid growth continues. The solution lies in the pursuit of policies to foster the developments needed to ensure that adequate energy supplies will be available before reserves of conventional fuels become excessively depleted and to discourage the profligate uses of energy."(193)

Much the same can be said of their view of food production - "the major problems of feeding the less developed world are seen to lie in political rather than physical limits"(194).

If nature is not seen as posing a barrier to continued growth, what of its capacity to withstand pollution? Their ideas on this matter have partly been touched on in relation to the question of aggregation and it is worthwhile returning to them. Speaking about the global aggregation of pollution in the world models they state:

"By aggregating all pollutants, and assuming that they behave in some composite way, attention is drawn away from what are urgent, and still soluble problems, and diverted into speculation upon an imaginary race against time between 'Life' and 'Global asphyxiation'."(195)

In other words, they do not support the idea of nature as some global entity which is under threat from another global entity in the form of pollution as represented in the world models. This is not to suggest that they are disinterested in pollution but, rather, they are sceptical about the terms with which it is discussed. Indeed, as the quotation shows, they are concerned about particular soluble pollution problems. Further, they state:

"We do agree with them, however, on the need to develop new technologies which do not damage the environment and which contribute to the conservation of finite resources."(196)

However, it is not the costs to nature but the costs to man which appears to concern them about pollution; moreover, they imply that other costs of economic growth such as work injuries may be equally important.
The Sussex team argue that social systems are qualitatively different to physical systems because they contain the "conscious actions of human beings" and because the underlying 'laws' which may appear to govern social processes may in fact change continuously. This helps to sustain an optimistic view of man and the possibilities of modifying social, economic and political arrangements. In the face of possible physical constraints to growth - and in opposition to the rigidity and determinism which they impute to the MIT models - they stress again, and again, the importance of adaptive social and economic feedback mechanisms.

"If the world were confronted with critical shortages of particular industrial and construction materials, then all kinds of substitution mechanisms would come into play."(198)

This perspective stems from a view of man as an actor who responds to his environment rather than merely conforming to it; he is also seen to act on the basis of hope as well as despair.

"Man is not pushed by a unified system mechanically into intolerable conditions but assesses the circumstances around him and responds actively by adapting his goals and values...Man's fate is shaped not only by what happens to him but also by what he does, and he acts not just when faced with catastrophe but daily and continuously."(199)

In his article The Luxury of Despair in which he criticises the views of Heilbroner - a Malthusian along with Forrester and Meadows - Freeman argues for what he believes to be the responsibilities of intellectuals. Not surprisingly, they vividly contrast with those we saw implied by Forrester.

"Whereas he [Heilbroner] speaks of the responsibility of intellectuals to prepare the population for the reduction of freedoms, I would maintain that the responsibility of intellectuals now more than ever is to uphold those freedoms, which we know from very hard-won experience are vital to prevent the arbitrary abuse of power."(200)

Although SPRU are optimistic about the potential for future technological developments they do not regard them as inevitable. SDC believe that if present trends continue then catastrophe is inevitable but SPRU point out that, on the contrary, if present trends do continue - with continuous technological improvement - then the opposite is likely to be the case. For them the form and use of technology is a question of social, political and economic choices and they therefore do not view...
technology as being either a priori 'bad' or merely an artificial means of temporarily staving off natural checks.

"To pose the problem of new technology simply in terms of individual choice of good and evil is a big oversimplification. As so often in human affairs it seems that frequently there are two 'rights' rather than a 'right' and a 'wrong'. If this is so, then a great deal depends on the way in which social choices are made - on the institutional mechanisms and filters by which values are reconciled and interpreted. The problem is one of social debate and experiment, as well as one of individual ethical choice." (202)

Indeed, they note that the internal logic of the world models implies that the creation of anti-pollution technologies would actually cause pollution to increase in absolute terms - either by stimulating more growth or by the pollutive load which is associated with each unit of capital! Rather than seeking policies to avert some future catastrophe, members of SPRU draw attention to the predicament - here and now - of the bulk of the earth's population; in place of equilibrium with nature they seek balanced growth.

"Since we believe that brute poverty is still a major problem for most people in the world, and since in general we do not believe that the physical constraints are quite so pressing as the MIT team suggest, we do not accept their enthusiastic endorsement of zero growth as the ideal for the world...Some types of growth are quite consistent not merely with conservation of the environment, but with its enhancement. The problem, in our view, is a socio-political one of stimulating this type of growth and of more equitable distribution, both between countries and within them."(203)

4.6.4 TIME

It is more difficult to develop an adequate picture of SPRU's perception of time than in the case of SDG; there are nonetheless certain implicit themes which we can discuss. To SPRU the future appears as undetermined; they make numerous references to previous forecasters - including economists such as Malthus, Ricardo, Marx and Keynes, as well as population forecasters - and argue that all can be found wanting. History is seen to have manifested continuous change; technological developments are seen to have wrought qualitative shifts in the nature - at least for some - of human existence. In so far as they perceive a common element linking the past with the future it is that of flux. This is not to imply that they deny that other factors do not remain static or change only very slowly; rather, it merely points out the importance
they attribute to change - it underlies their faith in the possibilities of purposive human action.

"If we have learned anything from history it is that men make it as much as they are made by it."(204)

We may note that like the MIT group, SPRU also recognize that there are certain important delays which have a bearing on global problems - for example, they cite the delays inherent in research and development. However, their position on this issue is far removed from the belief that delays are such that growth must be stopped now lest it may be too late.

In a series of tests on the world models SPRU contrasted their behaviour with that of accepted historical trends, arguing that the validity of a model is partly determined by its ability to reproduce such trends. They also advocate the use of time-series data for model calibration and testing. Such procedures implicitly assume that events (data points) can be fixed in relation to an abstract or physical conception of time. A choice between models can therefore be made on the basis of which is better able to reproduce the requisite values in accordance with their mappings within physical time. We do not mean to indicate that they would dismiss the system dynamicists' arguments about the temporal relationships that may exist between behaviour modes (including such things as phase shifts) but wish to suggest that SPRU require a model to pass a more stringent test than SDG. This can best be seen if we consider SPRU's advocacy of a test known as "2-sample" testing. In this test a time-series data base is split into two halves, one half is used to calibrate a model and the other is used for assessing the model's ability to generate that second half. Now the requirement that a model can generate data in accordance with their reference points within physical time is more difficult to fulfill than one which merely requires the reproduction of temporal sequences of behaviour (such as growth and collapse or oscillation). Indeed, the latter requirement can be seen as a subset of the first. We suggest that this difference should not only be considered as a technical or methodological matter - rather, we contend that there is a difference of perception involved here. Physical time is a reference line in one perspective whilst the temporal order inherent in feedback systems, which is - by implication - only apprehensible from experience of such systems or through the perspective afforded by system dynamics, is the benchmark of the other.
CONCLUSIONS

We have now completed our exposition of the different comparative elements taken for each group. Although we have already made some comparative remarks, this was to facilitate the exposition and we must now expand upon them and seek to interpret the differences in terms of the grid-group theory of cosmologies. In Section 4.3 we argued that in the case of social location, SPRU were lower in terms of grid and group than SDG; in Section 4.4 we showed that their thought style - as given by their methodological orientation and response to anomalies - was also lower grid than that of SDG. Now, our task is to see if this difference is systematically present in the other cosmological elements considered in Sections 4.5 and 4.6.

SDG adopt a Leibnizian approach to knowledge in contrast to the 'Kantian' position taken by SPRU. The former, based upon an all-embracing scheme, assumes that systems are real, as indeed it must do if its justification lies on formal rather than empirical ground.

Although SDG set great store by formal models we should not conclude that their modelling is abstract in the sense to which that term is applied to say theoretical physics. Rather, we have seen that system dynamics models are based upon intuitive observations of the behaviour of "real systems". Informal empirical observations are regarded as plain concrete facts, they are not theory-laden but do require to be set in an appropriate framework which in this case is given by system dynamics.

The Kantian position of SPRU sees all facts as theory-laden and they prefer a pluralistic, comparative approach to knowledge. Instead of unifying frameworks and global entities, SPRU are more interested in particular technologies, institutions or pollutants. The problems of formal data gathering notwithstanding, SPRU advocate the necessity of using quantitative data because it is seen to provide a more objective basis upon which to build and test models.

Whilst SPRU place a strong emphasis on causal explanation SDG give it less prominence and seek to classify social problems according to the properties of feedback systems.

Thus, on the grounds of their differences concerning formal empirical data, causal explanation versus categorization, and particular versus unifying frameworks, we would ascribe a lower grid rating to SPRU. We have seen that Forrester believes that criticisms of system dynamics are due to deficiencies in social science education. If however we recall the
distinction between object-oriented and person-oriented elaborated codes we can better understand the difference between SDG and some of their critics, including SPRU. For SDG, the important features of the world lie in the systemic feedback relationships between its general or universal components (e.g. capital, population, resources). For SPRU however, we have seen that the important features lie not in generalities, but rather in particularities - such as the variations between nations, institutions, or pollutants etc. We can suggest that this divergence may arise as a consequence of the two versions of the elaborated code. Each seeks to make their respective view of the world explicit, but one relates and subordinates the particular to the general, whilst for the other no general pattern exists and so it remains focused on particulars. These remarks are in line with Bernstein's ideas on the elaborated code.

"At the basis of the meanings of an elaborated code (object), is the notion of one integrated system which can generate order...At the basis of the meanings of an elaborated code (person) is a pluralism, a range of possibilities."(205)

Of course, the difference between the two versions of the code is relative and we are only asserting that SDG's is more object-oriented than SPRU's.

Turning to the conception of nature, we have found that SDG articulate an ecological view of a limited natural environment with which man must live in harmony. This position is complemented by the notion of natural checks on population growth, pollution, agricultural production and industrialisation. SPRU, on the other hand, view all constraints as being largely rooted in social, economic and political factors. They imply that society can improve upon nature through the appropriate use of technology - which once more denotes lower grid.

SDG's conception of nature is elaborated to a much greater extent and accords with a high-grid/high-group cosmology. The interdependence and necessary harmony between society and nature is one hallmark of that cosmology.

"So here one should expect an intellectual effort to elaborate a transcendental metaphysics which seeks to make an explicit match between civilization and the purposes of God and nature. Synedoche in metaphors of society and nature shows their isomorphic structure and expounds their reciprocal support."(206)

Douglas argues that the uses of nature for purposes of moral
justification are all-pervasive with this cosmology. We have seen that a similar thread permeates the system dynamics worldview: whether it is in the use of naturalistic metaphors for describing social processes, the translation of the Malthusian idea of natural checks into systems-theoretic notions of equilibrium or the necessity for pressures and stresses, we find a conception of the natural order underpinning a conception of society. Further, Douglas argues that high-grid/high-group people -

"use the incidence of misfortune to uphold the moral law. Disease and accident are either attributed to moral failures or invested with nobility in a general metaphysical scheme which embraces suffering as part of the order of being."(207)

Again, this parallels and illuminates Forrester's example concerning famine and the idea of pressures and stresses.

Their respective views on man and society can be readily categorised into one of pessimism in the case of SDG and optimism in the case of SPRU. One stresses man's shortsightedness and the fallibility of social institutions - man is but part of the web of life, as dependent on the global ecosystem as all other species. The other looks to the potential for improvement - man is a species which makes history.

With Forrester, all men cannot be equal, but in Meadows' case we find a discussion concerning the possibility of global redistribution once the equilibrium state has been achieved. However, this is only a bonus of equilibrium, not the reason for seeking to control the approach to it. In contrast, with SPRU we find a stated commitment to the goal of egalitarianism.

The system dynamicists stress the need for long-term values, man has to be held in check lest his self-interested orientation should lead to catastrophe. SPRU, in contrast, are concerned with the condition already faced by much of the world. Whilst Forrester asks questions about the means of coercion necessary to sustain zero growth SPRU argue for growth in order to remove the state of poverty endured by the underdeveloped countries.

The pessimists see technology as a transient evasion of the natural order, the optimists see it - when employed prudently - as a means of modifying the natural order.
On all these points we would place SPRU in a lower grid position than SDG. However, SPRU's acceptance of the need for balanced growth and for technologies which do not damage the natural environment, places them in a higher grid position than those who would countenance the most vigorous attempts to control nature. Thus, again we see that SPRU's views are not low-grid per se, but rather, are lower than SDG's.

Douglas argues that conceptions of time are employed in the role of justifying actions or coercing people to commit themselves to action. SDG justify their policy recommendations by appealing to the tradition within which they perceive themselves to stand (which in fact they do) and the long-term perspective they take of the future; the coercive edge of their views can be seen in the admonition to act now - for tomorrow may be too late. Historical tradition at MIT is well differentiated, and it is this which helps to support a long-term view of the future.

With SPRU we have seen that their view of time allows no policy formulations based upon forecasts into the distant future. For them the possibilities (but not the inevitabilities) of the future are matched by the changes wrought in the past - this serves to legitimate their scepticism and caution about the SDG's arguments. Further, their favoured model testing procedures implicitly seek recourse to a physical conception of time in order to assess model behaviour. SDG, on the other hand, consider the qualitative temporal order which is inherent in both natural and social system structures to be sufficient. All cosmologies employ time in order to justify or coerce, but the distinction between physical time and that embodied in system dynamics indicates a cosmologically based difference: SDG's conception of time is higher grid.

With each of the comparative cultural elements we have considered it has been found that SDG appear to hold a higher grid cosmology than SPRU. With the group dimension too, it has been found that SDG manifest the greater sense of group boundedness. Therefore, when considered together, this systematic cultural bias, in addition to the evidence we have concerning their social location and style of thought, would seem to support the hypothesis that the social experience of SDG is indeed that of a higher grid-group setting than SPRU.

Douglas' theory has not been tested here; rather, it has been used to show that on three different levels - social structure, style, and content of knowledge - we can reach the same conclusions about the relative grid-group positions of SPRU and SDG (see Fig(10)). On a note of caution, it must be admitted that the concreteness of the evidence for each level is not the same. That for thought style is the most
Figure 10: The grid-group positions of SDG and SPRU
densely documented followed by that for cosmological content. The evidence on social experience is the weakest. However, the findings for each level are mutually supportive and thereby render the overall conclusions that much stronger. Having established these connections, however, we can not answer the question as to why either group came to be where they are - i.e. we can not draw causal inferences and say that the social experience of SDG caused their cosmology or vice-versa. Indeed, we can only say that knowledge and social structure were mutually supportive in their co-development.

We have also suggested that SDG's grid-group position has changed, both during the processes of group consolidation and the closing of ranks which ensued when they came under criticism. The effect of that criticism would not only seem to have pushed them towards higher group, but also pressured them into a higher grid position by insulating them and reducing their transactions within the media of the scientific establishment.

SDG manifest a more object oriented elaborated code; starting from the perspective of a universal framework they seek to delimit the natural constraints which determine the potential form of future social arrangements and developments. In contrast, SPRU start from the question of social and political choices and seek to explore the avenues by which technological development and socio-political changes can be wrought to achieve them.

All of this does not imply that SDG are in any way perverse or unique; rather, it may be that all theories exhibit similar characteristics during the course of their development. However, whilst we cannot judge the ultimate validity of system dynamics we can perhaps suggest that it has some way to go before it reaches the stage of practical policy usefulness.

Douglas argues that no part of the grid-group diagram is without its own specific ills, all cosmologies have pros and cons and this is just as true for SPRU as for SDG. All groups draw upon a conception of the natural order to support their position vis-a-vis social institutions and here we have examined two different conceptions supported by two different social experiences.
CHAPTER FIVE

URBAN DYNAMICS AS A SOCIAL BINDING AGENT
The previous two chapters have been concerned with the influences of social structures upon knowledge. These have been examined in terms of the theoretical relationships between social development and worldviews, and between social structure and cosmology. Thus far, however, we have been mainly concerned with knowledge viewed as a product of social structures. Here we will begin to examine the other side of the relationship as outlined in our model in Chapter Two.

The aim in this and the following chapter is an investigation of some of the social effects of system dynamics - i.e. with the exoteric role of this knowledge system once outside the System Dynamics Laboratory. It must be stressed that we do not propose to investigate empirically questions concerning whether or not system dynamics has actually caused action 'a' or 'b'. As we shall see later, even if it has been the basis for deliberate policy decisions, the associated officials may be unlikely to admit to it. Rather, we are more interested in its potential societal role and seek to investigate its characteristics as a knowledge system in specific relation to that role. In other words, we seek to illuminate the social role implicit in system dynamics. We contend that this is a useful line of enquiry to pursue and is distinct from those critiques which have restricted themselves to questions concerning the likely efficacy of the recommended policies.

In Chapter Two we discussed the role of knowledge as a social binding agent cementing people together in various social groupings - i.e. knowledge is an essential part of the social bonds that people form with each other, whether in terms of shared cognitions or as a means of coercion or legitimation. The nature of the binding, the form and structure of the groupings, and their wider social and political consequences, are the social effects upon which we will focus our attention.

Our interest in the nature of the binding effect of knowledge will be concerned with the role of system dynamics as an explanatory resource - including a theory and set of exemplars - which serves to organise cognition. We will also consider the different elements of worldview and cosmology which cohere in such a way as to secure apprehension of a particular body of knowledge, and therefore to legitimate and ensure commitment to, the specific policies and social structures that are promoted by that knowledge.
The locus of our interest in social groupings centres upon some of the social, economic, and political features of the social systems prescribed by system dynamics; whilst with the wider social and political aspects our attention turns to the role of system dynamics experts vis-à-vis politicians and the electorate.

In discussing the role of knowledge as a binding agent we will focus upon the following five areas:

5.2 Characteristics of the urban structure
5.3 Knowledge as a conservative or radical force
5.4 Knowledge as an explanatory resource
5.5 Legitimation
5.6 The role of system dynamics experts

Rather than attempting to explore these issues in relation to system dynamics as a whole, we will concentrate on Forrester's efforts at modelling cities, particularly his work described in *Urban Dynamics*¹. This will provide us with a sufficiently tight framework within which to illustrate our arguments.

The first area of interest centres on the instrumental role of knowledge in social management and control. System dynamics models represent particular social structures and various policies are proposed for their control. The characteristics of the proposed urban structure, and the policies to achieve it, will be the focus of our concern. This will enable us to consider - in the following section - whether its potential role represents specific or general interests and goals of urban communities.

The second area, therefore, concerns the relationship between existing urban structures and the type advocated in urban dynamics. More specifically, it centres on whether or not the urban model aims to cement existing social arrangements, or whether it aims to change them, and the extent to which it may wish to do so. We have already argued that Forrester wished to maintain social order during the urban crisis, but this concern does not exhaust the nature of his policy recommendations. (In fact, we will argue that his model has a certain measure of autonomy vis-à-vis the interests of capitalists.)
The third area of interest is the use of knowledge as an explanatory resource for discussing the world about us and maintaining cognitive coherence. Here we will discuss the role of system dynamics as a device for explaining urban problems, together with the attendant theoretical and social ramifications to which this leads. For example, in representing a theory of a particular social system, a model can theoretically 'close off' other alternative theories. This can have social consequences because in seeking to define the essence of the system in question, the model closes off other conceptions of social reality and therefore alternative social structures.

The fourth area addresses those aspects of the model that serve to legitimate it and the arguments that are mustered in order to justify it.

Lastly, the fifth area of interest concerns the wider consequences of the spread of system dynamics and its use for the control and management of social systems. Earlier we argued that knowledge represents a power resource - that those who define, control, and implement knowledge have a certain measure of power. In terms of social policy, knowledge defines what is possible and what is not: it distinguishes the practical from the utopian. Therefore those who devise policy have a degree of control over social relations and hence power. We will refer to the particular laboratory basis of system dynamics and view its diffusion into policymaking as an extension of the laboratory. We will look at the role of system dynamicists in relation to politicians and the electorate; the effect of their proposed urban policies in ensuring social consensus through the integration of different classes into the urban structure - with the consequent acceptance of the cosmology which it supports; and the social and educational implications of the teaching of system dynamics as part of a wider attempt to ensure social consensus.

5.1 THE BACKGROUND TO URBAN DYNAMICS

In the 1950s the United States experienced a tremendous burgeoning of science and technology; scientific and technological rationality held out great hopes for many people as the generator of greater affluence and national pride. Science and technology took man to the moon, and technological applications of new knowledge increasingly penetrated many aspects of life for large numbers of the American population. Science and technology continued to restructure social relations in the workplace, developments which led many people - including politicians and administrators - to look to science and technology for solutions to
social problems. This was the era when the so-called 'end of ideology' was debated and some writers opined that the only problems left facing society were technical and administrative ones.

Amidst the affluence of certain social classes and the brittle technocratic optimism of the time, the problems of urban decay continued to worsen. Within this contemporary climate it was natural that people should have looked to science and technology to solve the problems of urban decay - social engineering held out the promise of solving the urban crisis.

"Such hopes are manifest in the commonly stated expectation...that the technical skills which put men on the moon ought to be able to solve the problems of our cities or nation." Greenberger et al (3)

In fact, Greenberger suggests that many engineers who were displaced as a result of cutbacks in the space program during the late 1960s actually moved into areas of social policymaking. The background of faith in technology and science provided the context within which certain groups began to use computer models in order to try and solve social problems. This gave the urban model a certain air of legitimacy, but we will see later that rather than offering a technocratic hope of solving the urban crisis, Forrester advocated a set of policies which appeared legitimate for quite different reasons too.

At the start of the urban project Forrester consulted top city officials before retiring to his laboratory to build the model. In other words, he constructed an esoteric variant of the background (exoteric) knowledge gained from his sources. It was from the laboratory that the urban policy recommendations emerged, shaped to play an exoteric role amongst the public and various administrative officials who were originally consulted.

5.2 CHARACTERISTICS OF THE URBAN STRUCTURE

In this section our aim is to piece together a picture of the policies and proposed urban structures contained in Urban Dynamics. Rather than discussing the model equations we will look beneath them for the pattern of assumptions which govern Forrester's theory of urban systems and which align it in accordance with specific interests and goals.

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*In this instance he performed much of the computational work from within his home study. However, the metaphor is still apt.
Perhaps the most important characteristic of his approach to urban modelling is that cities are viewed as systems. And not just any kind of system, but most specifically, systems whose behavioural characteristics are determined by the properties of feedback structures as described by system dynamics. Consequently, urban problems are explained in terms of the properties of complex non-linear feedback structures.

These properties of complex systems lead to urban mismanagement which is compounded by political expediency. Forrester seeks to explain urban crises by asserting that present administrations pursue policies which are oblivious to the behavioural characteristics of urban systems. Further, politicians are also charged with being too oriented towards the short horizon of their span of office, or towards the short-term political pressures of the underemployed.

"Humanitarian impulses coupled with short-term political pressures lead to programs whose benefits, if any, evaporate quickly, leaving behind a system that is unimproved or in worse condition." Forrester (4)

Thus, it is suggested that present policies which are designed to relieve urban problems are ineffectual, or even a means of exacerbating the very problems they are supposed to cure. It must be stressed that Forrester is not arguing that politicians are in any way inept; rather he believes that because our intuitions about dynamics are formed by experiences with simple systems, we are incapable of inferring the behaviour of complex ones.

In drawing attention to administrative failures Forrester locates them mostly at a local level and he asserts that the way towards urban revival lies in changed internal practices. The city is to be self-reviving, to be a "master of its own destiny". This belief in urban autonomy is tempered by two qualifications; firstly, urban goals should be subordinated to national goals; and secondly, Forrester envisages some situations in which the city would need assistance from outside.

"If the city needs outside help, it may be legislative action to force on the city those practices that will lead to long-term revival. Such outside pressure may be necessary if internal short-term considerations make the reversal of present trends politically impossible." Forrester (5)

What he means by this is that in cities where the electoral power of the lower classes precludes "long-term" policies, the government may

These were set out in Chapter One.
overrule the local political machinery and authoritatively impose alternative policies which it deems more correct.

Forrester does not just lay blame at the door of politicians who give sway to the welfare demands of the underemployed, he also charges the latter with irresponsibility because they vote for benefits which cities are allegedly incapable of providing. The political power of the urban poor is seen as too great, a consequence of their overwhelming numbers.

"The city, by shifting taxes off those who are already too numerous, encourages a still greater influx of the underemployed, who tip the balance downward in a spiral of urban decline." Forrester (6)

Forrester envisages an urban structure with a more "balanced" mixture of social classes. Since the political power of the lower classes is contended to be oriented towards short-term interests which strengthen the downward forces of urban decline, his proposed solutions would work to restrict this power by constraining the population of the lower social groups within the city. The most controversial example is his suggestion that city administrations should desist from building low-cost public housing. In fact, it is suggested that slums should be demolished at the rate of some 5% per annum and not replaced by new low-cost houses. Apart from the direct costs of construction, these projects also have an indirect cost-loading, caused by people who allegedly move to the city precisely because its housing is perceived to be attractive. Forrester believes that present laws and administrations encourage an "excessive" influx of the poor, whilst at the same time accelerating the exodus of the affluent.

"The increase of costs as the urban area ages is a reflection of the shifting balance that results from laws and administration that permit and encourage excessive immigration of the poor and speed the exit of the more affluent. As the poor begin to dominate, their political power is felt. Their short-term interests increasingly dominate their own long-term welfare and that of the city." Forrester (8)

This, he argues, is one factor in soaring municipal costs. Moreover, massive financial assistance to meet these costs is held to be ineffectual because the goals to which such aid is aimed are thought to be impossible. Not only does he state that much urban planning fails to distinguish the possible from the impossible, but he also suggests that the pursuit of unachievable goals can lead to a system state from which other achievable goals (that might have been possible) become foreclosed.
The main thrust of Forrester's alternative policies aims to restore "economic vitality" to stagnating and declining areas. The focus of this effort lies in the integrated employment of underemployed Blacks into mainstream economic activity. As we noted in Chapter Three, Forrester advocates a unified urban system which is socially, economically, and racially integrating; he sees the "extreme concentration" of social and economic groups as detrimental and believes that urban revival would be more easily achieved within one integrated system than in two separate and parallel systems. This belief provides us with a good example of how the proposed structure of social relations are thought to be underpinned by the 'a priori', or natural order, of feedback systems. (We will see the relevance of this when we discuss legitimation.)

Two key assumptions seem to govern the operation of Forrester's model; these are the concepts of "attractiveness" and the "unlimited environment". Forrester assumes that cities have a multiplicity of components of attractiveness such as housing and jobs etc. These determine the rate of immigration and migration to and from the surrounding environment. (It is assumed that people will move to the most attractive area, whether it is the city or the environment. Further, that environment is taken to be limitless - i.e. it can absorb as many people as possible who want to leave the city; and it can also supply an inexhaustible influx of people who may wish to enter.)

The total attractiveness of the city is fixed so that there will always be a trade-off in its different attractiveness components. Forrester asserts that urban revival will come from manipulating these components whilst keeping the total attractiveness the same. The only conceivable way for the total to increase is if the whole surrounding environment increases in quality. Any change within the city effects an interchange with the environment such that some new balance is obtained. For example, if the city appears attractive because it temporarily has a surplus of housing, it will attract an influx from outside; this population change lowers the city's housing attractiveness component and a new balance is achieved with the surroundings.

Forrester asserts that urban revival must be towards an equilibrium condition with a 'properly' balanced mixture of social classes and a 'correct' ratio of housing land to industrial land. He suggests that such a balanced city would serve all sections of the population more effectively. Also, it must be noted that although there would be a hierarchy of social classes, these would not be rigidly separated, but would be integrated together.
The proposed policies do not envisage more coercive legal structures, and he also expects less government encroachment. He suggests that the way forward lies in changing tax and zoning regulations so as to ensure that self-interested actions by certain sections of the city will lead to renewal. However, only certain parts of the population - the more affluent members of the community - are seen as the bearers of this revival. Amongst them we find owners of land and buildings. Present policies are said to lead to self-interested actions which produce degeneration, due to the migration of the affluent coupled with industrial and building practices that encourage stagnation and inhibit renewal.

"By shifting the tax burden onto those who generate the least municipal costs, who have the greatest mobility, who need not live in the aging structures, and who have the least reason to remain in the city, the city encourages the departure of the people and industries most necessary for its revival." Forrester (13)

Thus the tax structure is thought to penalize the people able to contribute most to the city, whilst at the same time favouring those who only generate costs. In contrast to this situation, it is argued that tax revenues should be closely correlated with the groups who vote for municipal expenditures.

"Only if the revenue is highly correlated with the people who require the expenditure will the city have a self-regulating system which generates a population able to sustain a healthy city and to pay for the urban services they require." Forrester (14)

Forrester also advocates a changed mix of industrial activities; he favours industries which are labour-intensive, profitable, and pay high wages.

"Such industries should be perceived as a great service to the community rather than as ones to be penalized and saddled with the burden of carrying the cost of the urban area they alone are able to revive." Forrester (15)

It is significant that the proposed urban policies would be more coercive towards the lower social groups whilst being largely favourable to the more affluent; Forrester advocates measures which would deter the influx of the underemployed but does not consider regulations which would prevent the movement of the higher social classes (or of capital). Rather, he seeks to persuade these groups to stay in the city through incentives. These features would appear to evince an elitist and hierarchical way of thinking - though of course he
believes that his proposals, despite their immediate effects, are for the long-term benefit of all.

"Policies that lead to urban revival will give the superficial appearance of favouring upper-income groups and industry at the expense of the under-employed." Forrester (16)

We can also discern elements of elitism in his attitude towards tax-exempt institutions. He argues that they should be judged on the basis of how they affect the city's cost and revenue balance, his point being that certain institutions put a cost load on the city by attracting a disadvantaged population from the outside. In such cases he argues that the institution in question could be considered "detrimental".

"If the institution attracts a population that creates a cost load on the city and does not pay its own way, the institution could be considered detrimental." Forrester (17)

In order to maintain its equilibrium Forrester argued that the urban system must have a set of pressures against which to press. People are exhorted to choose the behaviour mode they want for their cities and to accept the inevitable (even vital) pressures which will preserve that mode. Pressures, in other words, should be actively maintained.

"An urban plan that aspires to a different equilibrium than we now have must be firmly based on a public understanding and willingness to live with the corresponding pressures." Forrester (18)

This summary of the policies and urban structure envisaged in urban dynamics clearly shows that its exoteric role is not evenly directed to address the goals and interests of all sections of urban systems. This point will be further substantiated and developed in the following section.

5.3 KNOWLEDGE AS A CONSERVATIVE OR RADICAL FORCE

Having examined some of the major characteristics of the urban structure put forward in Urban Dynamics, we are in a position to discuss how that structure compares with existing urban structures, specifically in relation to the interests of the groups within it.

Although Forrester's rhetoric is aimed at all sections of society his policies would have the effect of benefitting the affluent whilst penalizing the less fortunate. The interests of private enterprise and
land owners are promoted with zoning, tax, and legal regulations being changed in their favour. At the same time, these changes would shift an increased burden onto the poorer sections of society. The urban model aims to change present urban structures in order to evolve new structures which would be organized in accordance with the dominant values and interests of the affluent classes.

To take but one example, let us consider the differential impact of the proposed revival policies on the upper and lower-income housing subsystems. During the first 55 years of the revival, the ratio of the managerial-professional class to their corresponding housing type (premium housing) increases by some 11%. In contrast, the ratio of the underemployed to their housing stock increases by some 58%. Or, in more precise terms, the number of the managerial-professional class increases from 71,100 to 108,700 whilst premium housing increases from 110,500 to 152,800 units. The number of unemployed actually falls - from 377,300 to 335,900 - but their housing stock falls - and much more sharply - from 310,100 to 175,300 units.

Society's master institutions such as private property remain intact and the measures to be adopted favour those institutions at the expense of the poorer groups. In three mutually supportive proposals Forrester seeks to curb the political power of the underemployed. Firstly, through education he endeavours to assure their consent for the type of economic revival which would "initially" disadvantage them; secondly, he wishes to restrict their numbers by directly limiting the provision of low-cost housing whilst simultaneously demolishing the slums; and thirdly (in the last resort) he reserves the right of the national government to ignore popular support for welfare policies and impose opposite policies of its own.

Yet Forrester does not unequivocally support all affluent sections of society; we cannot simply reduce his model to a mere emblem of 'bourgeois ideology' which singularly projects the interests of the rich. Indeed, he questions certain property rights of landowners, which in conjunction with present tax and zoning regulations, lead to urban deterioration. Also, it must be borne in mind that Forrester envisages an equilibrium condition for cities because he believes that growth is not indefinitely sustainable; this implies a change of imperative for private enterprise whose traditional ethos is growth oriented.

*The educational role of system dynamics will be dealt with in Section 5.6.
Urban dynamics can be considered to have a small measure of autonomy, in the sense that although he is committed to the long-term interests of capitalism, Forrester is not precluded from making policy recommendations which might be a disadvantage to some sections of private enterprise. For example, his arguments against large-scale transportation networks would undoubtedly run counter to the interests of some building contractors. Further, his model is more detached than those views which see urban problems solely as a natural outcome of city life; he insists that problems are due to bad internal practices (we will return to this point in the section on legitimation). This degree of autonomy is something which has been ignored by those critics who have sought to reduce system dynamics to a mere reflection of capitalist interests.

On balance, however, the urban model remains tied to the interests of the more affluent classes, for it does not challenge society's dominant institutions. Forrester is arguing for an urban structure organized in their interests and which would effectively penalize lower-income groups in order to secure those interests - though, of course, he maintains that his policies would benefit all sections of the community in the long run.

So far the discussion in this section has focused upon the role of the urban model in theoretical terms. However, if we consider the more practical political aspects of the urban model we can suggest several possible ways in which it could be used to promote sectional interests. For example, the model could be seen as a means of justifying specific policies that have already been decided; it may thus merely serve to provide a veneer of technological legitimacy for the vested interests that lie behind a particular set of policies.

Some actor, for example a politician, may use knowledge (in this case the urban model) in order to argue for a particular social policy. In such a case knowledge serves a purely instrumental function, in that it is employed by the actor for his or her own ends. There has in fact been some speculative discussion suggesting that Urban Dynamics can be considered in this way - though it must be noted that Forrester did warn his readers that his policy recommendations required further study and that they were an opening of the topic rather than a set of final conclusions. However, this did not prevent him appearing before the National Sub-Committee on Urban Growth - suggesting that its name be changed to the Sub-Committee on National Equilibrium and making 'authoritative' statements based upon the urban model. In regard to the instrumental use of the model Greenberger (et al) made the following.
"A model, masquerading as an oracle, may be nothing more than an advocate in technological guise. An urban model that assumes perfect equilibrium may be used by local officials to legitimize previously planned slum clearance programs despite the fact that its assumptions do not apply to their city." (23)

Overall though, Greenberger (et al) appear to underplay the possible impact of Forrester's work. In marked contrast, Averch and Levine - in a Rand Corporation Report - viewed the urban model as

"likely to be influential in Washington and elsewhere. The temptation to seize upon analysis that indicates not much can be done, and that what can be done is more wrong than right, is likely to be powerful at a time when public officials feel strongly that fiscal and organizational resources are in short supply." (24)

Whithed argues that the policy suggestions contained in Urban Dynamics may be utilized by people who wish to avoid public investment in urban programs, their positions being buttressed by the scientific aura surrounding the computer model. Also, he identifies a certain convergence between the aims of the model and various moves to limit the immigration of the poor into U.S. cities.

"For example, there has been considerable discussion in New York of limiting population inflows...An early approach suggested by Governor Nelson A. Rockefeller's office would mandate that big city immigrants who cannot find or afford adequate and safe housing would be denied welfare benefits and urged to return from whence they came...Although there has been little or no mention of Forrester's Urban Dynamics research in these policy discussions, there does seem to be a growing feeling amongst a number of urban scholars and public policy makers that the urban crisis requires a limitation on unemplyed's immigration to large cities." (25)

Another possible perspective for considering the role of Urban Dynamics is closely aligned to our argument that Forrester's work is a product of social structures. We cannot just assume that an actor such as a politician is someone entirely independent of the knowledge they use to authenticate their policies. A more complex situation arises when the actor actually sees the model as an authoritative source of social policy; this may be a case in which the politician calls upon technological expertise in order to try and solve their urban problems.

A politician resides in a social structure where some means of gaining knowledge are considered to be more efficacious than others. Thus they
are to some extent constrained by the systems of knowledge upon which they can legitimately draw. In this case we can cite some firmer evidence - though admittedly circumstantial - that the urban model has indeed been used in this way. The practical implementation of urban dynamics to real cities was attempted in a number of projects but apart from the city of Lowell, most of these efforts ended in failure.

"Most of these attempts did not get outside the classroom. Of those that did, some...could not make the model fit the city. In Lowell, where this was not a problem (partly because Forrester and his colleagues were directly involved), the Urban Dynamics model and the ideology that accompanied it got a good reception and fair hearing." Greenberger et al (26)

In the city of Lowell the model was employed as an educational tool in order to explore different policy alternatives. Although the policymakers there claim that the model was never used directly to formulate policy, Greenberger (et al) note that - amongst other measures - Sullivan (city manager and a friend of Collins - one of Forrester's colleagues) decided to stop sales of city land for low-income public housing projects. Greenberger (et al) claim that Sullivan feared that such housing would attract underemployed persons to the city - which of course is exactly what Forrester had argued for some time. Further, we should note that Forrester's imputation of a strong link between housing availability and migration is rather unorthodox; most studies would appear to have found that job availability is a much more important factor in migration*. Thus, Sullivan's policy would appear to be unorthodox too - lending further support to the implication of his decision with the results of Urban Dynamics.

We have now discussed two possible ways in which the urban model might be used in real policy situations: i.e. as a legitimating cloak, and as a source of authoritative knowledge. It is the second which concerns us more here because it presents the more interesting and complex role of knowledge in society. The urban model is a response to the urban crisis, a response which seeks to solve that crisis in the interests of the dominant institutions of society. The means employed are one of the dominant types of thinking - technological rationality aimed at social engineering - allied to the highly fashionable use of computers.

* Full details of the Lowell Project are contained in a two-volume set (27).
** This topic has been the subject of much controversy between the urban dynamics modellers and other researchers (28).
Forrester's theory of urban systems is directed towards the control and management of cities; however, this is only one dimension of its character as a social binding agent. Another is its role as an explanatory resource, a means of talking about cities and urban problems, and thereby negotiating social consensus on these issues. Urban dynamics provides a framework within which urban problems may be discussed; in doing so, it offers a language which may well appear to be objective and value-free.

In explaining the present condition of cities, urban dynamics takes a particular theoretical position which closes off other non-system-theoretic explanations. Theories of contradictions and class conflicts, for example, are excluded from the discussion. In addition, it defines only certain goals as possible; other goals are said to be impossible or utopian. This theoretical closure has indirect social and political consequences in terms of the range of urban structures that are deemed to be attainable. In particular, it parallels Crenson's concept of the 'framing and raising' of political issues.

"Political issues can create political consciousness. They also tend to shape or restrict that consciousness. Political agenda items like the economic development issue do not produce a general expansion in the scope of political discussion, but expansion only in certain directions." Crenson (29)

Thus, urban dynamics frames the urban question in a particular way, defining problems in a manner that relates to its proposed solutions. It provides a 'new' way of looking at the urban question, but whilst claiming to be objective it restricts the consideration of other perspectives and therefore other possible solutions. Embodying a theory of both urban interactions and the causes of failure of previous urban programs, it also advances a set of exemplars concerning the feedback properties of all systems. These constitute the boundaries within which any discussion of urban problems is to be articulated.

In addition to the claim that the urban model can explain the existence and persistence of urban problems, it is also claimed that it explains the failure of previous urban programs. Again the explanation is rooted in the properties of complex feedback systems, particularly the principle of counterintuitivity, and no attention is given to the alternative explanations which abound in the rather large urban literature. A consideration of some of these different explanations
reveals other features of urban systems which Forrester's theory closes off. A brief reference to some of these can help to reinforce our picture of his urban theory and the urban structures which he wishes to consolidate.

Considering the concepts which Forrester eschews rather than the ones he implicitly or explicitly adopts may seem unfair. However, we are merely following Mannheim's idea that the absence of concepts may indicate a wish to avoid coming to terms with certain phenomena. In the case of Forrester, we are told that he explicitly ignored documentary information when formulating his urban model and instead relied partly on the information of "practical men".

"Several reviewers of the manuscript criticised the absence of ties to the literature on the assumption that such ties must exist but had not been revealed. Actually the book comes from a different body of knowledge, from the insights of those who know the urban scene first hand..." (32)

The point here is not to criticise Forrester because he deliberately avoided the literature but rather to emphasize that he avoided certain concepts, of which the idea of conflicts of interest is one of the most notable. Let us now proceed by briefly considering some alternative views of the failure of urban programs.

Gans has been a major critic of urban programs, particularly the urban renewal program which was devised to clear slums, relocate their inhabitants in decent housing, stimulate rebuilding, and revitalize downtown areas of cities. In contrast to the aims of the program, Gans maintains that clearance of slums made way for many luxury housing developments and some middle-income projects. As a result, the people who were dispossessed were unable to afford the cost or rents of the new properties and many simply moved into other slum areas. This led to further decline in those areas and increased overcrowding together with the concentration of racial minorities into ghettos. He cites startling figures to support his case.

"[A] 1961 study of renewal projects in 41 cities showed that 60 per cent of the dispossessed tenants were merely relocated in other slums..." (34)

He also contends that certain areas were cleared not because they contained the worst slums, but because they offered prime sites for luxury developments. Because public funds were used to undertake the clearance work and to make the land available to private developers at a reduced cost, he concludes that the low-income population was in effect
subsidising its own removal purely for the benefit of those in a better financial situation. Finally, he argues that another failure of the renewal program was that some cities scheduled clearance projects just to clear away non-white poor people who were seen as standing in the path of the progress of private enterprise.

Other programs ran into quite different problems; in particular, the housing subsidy programs have been subject to criminal abuse by the illegal tactics of several groups including bankers and speculators. Mercer and Hultquist contend that the subsidy programs failed the very people that they were designed to serve whilst benefitting others who were not in need.

"[I]nvestigations have revealed scandalous and often criminal actions to which these investment schemes contributed...as the extent of the abuses became clearer, the Nixon administration suspended much of the federal housing apparatus." Mercer and Hultquist (36)

None of these difficulties is mentioned by Forrester, nor are any of the other factors - such as discrimination against Blacks - which could be cited. Yet, such problems are a pointer towards the failure of urban programs and also direct attention towards causes of urban problems that lie outside the narrow framework adopted by Forrester. He is concerned with the technical management and control of urban systems and therefore needs a technical explanation for the causes of urban problems and the failure of previous programs. His denial of contrarieties is of course grounded in his cosmology, its style of thinking prevents him from seeing the possibility that society may be rent with contrarieties, conflicts of interest, or paradoxes. Also, his belief in the oneness and unity of the world leads him to ignore the basis of class conflicts; although he admits that goal conflicts exist, he sees them as due to shortsighted interests which should be subordinated to the 'true' common interests of the urban system.

Because his level of explanation is pitched at the level of the city, it fails to consider the nature of the links between the city and the rest of society. Consistent with its theoretical closure, we might also usefully note that the theory precludes even a consideration of the possibility that urban problems may be generated in the wider societal

*We have also mentioned that Forrester has a moral conception of certain problems; this shifts responsibility for social problems onto individuals, but in so far as these failings are seen as a result of the breakdown of the social system's moral training schemes, his conception is still compatible with a systems-theoretic framework.
system; for example, by contradictions within the capitalist system itself.

This argument has been developed by Castells who has sought to examine urban crises within the context of the wider crises of capitalist societies. Central to this line of argument is the contradiction between the privatization of profits and the socialisation of costs. Forrester sees economic activity as an almost independent sphere of social reality and does not consider the argument that the state, or local government, pay part of the cost of reproducing labour power.

"Enterprise of the right kind costs the city very little by its presence. It polices its own internal land area. It buys water and other utilities...it demands little of fire departments. Industry of itself does not require schools..." Forrester (38)

The socialisation of costs is reflected in schooling, housing, medical provision and transport systems etc. In effect it subsidises the costs of production and yet the profits of that production are privatized.

These issues defy a crude reduction to the structure of system dynamics models for they cannot produce serious patterned conflicts or contrarieties of this sort. As well as denying the possible importance of conflicts and contradictions in the explanation of urban crises they are also denied any relevance in social life in general. As an explanatory device the urban model therefore upholds the legitimacy of the present social order and institutions. Urban dynamics reflects the unity of the city, an imaginary unity which it constitutes within the sphere of abstract knowledge.

In the next section we will discuss the legitimizing nature of the urban dynamics model in greater detail and argue that technological rationality is by no means an exhaustive description of its perceived legitimacy.

**LEGITIMATION**

It is contended that a model may serve to project and legitimate specific social structures, and to do so in characteristic way determined by the worldview and cosmology implicit within it. The worldview of the person who creates the model governs the form in which it takes shape; the form may be, for example, verbal or mathematical. If someone builds a computer model is is because in their worldview such a
task is deemed to be a valid way of exploring social policy. At the same
time, the very utilisation of technological resources can serve to
provide justification for the model in the eyes of other observers. Thus
the form of a model may express one layer of legitimation; other layers
will be governed by different aspects of the modeller's worldview.

The fact that some people associated Forrester and his urban model with
science and technology served as a form of legitimation for his work,
and therefore for the policies which he advocated. However, the
legitimating resources of the scientific aura which surrounded the
urban project are not the only sources of justification that we may
discern; they are perhaps only the most explicit aspects of legitimation
that shrouded Forrester's work. To expose others we will again have to
consider the cosmology of system dynamics.

In Chapter Four, we argued that cosmologies carried some baggage of
implicit assumptions concerning the nature of man and the cosmos; these
assumptions provide the ultimate justification, the fundamental
legitimation, for the cosmology. In any discussion about social reality
such assumptions will govern the form in which the arguments are
couched. This may be so even in the case of formal modelling.

Each cosmological type is characterised by a set of assumptions which
remain implicit because they are self-evident. 'Common sense' dictates
that things could not be any other way; the assumptions encapsulate the
logical order of things. In actuality this logical order is really a
product of social relations, of the experiences that confront each
person in his or her interactions within a particular social
environment.

It is Douglas' contention that people use concepts of nature in order to
legitimate their social institutions; nature is seen as a resource for
talking about society. In grounding their justifications for the
dominant social relationships within the context of the grand meaning of
nature and the cosmos, people legitimate the prevailing social order.
Nature is the final arbiter of what is right and what is wrong, what is
deviant and what is natural.

In using nature as a source of legitimation, people actually make
statements about the characteristics or 'a priori' of the natural order.
The structure of assumptions underpinning these statements is of course
predicated upon the structure of social experiences that characterise
the given social context. We have previously argued that the patterns of
classification employed to the describe the natural world may be based
upon those of the social world; we can now add to that assertion by contending that the logical or causal order of the natural world is a reflection of that implicit in the self-evident assumptions in which cosmologies are grounded.

"I feel we should try to insert between the psychology of the individual and the public use of language, a dimension of social behaviour. In this dimension logical relations also apply. This is the nub of my contribution to how intuitions of self-evidence are formed. Persons are included in or excluded from a given class, classes are ranked, parts are related to wholes. It is argued here that the intuition of the logic of these social experiences is the basis for finding the a priori in nature...Apprehending a general pattern of what is right and necessary in social relations is the basis of society; this apprehension generates whatever a priori or set of necessary causes is going to be found in nature." Douglas (39)

In describing their social environment people generate a set of hypotheses, seemingly validated because they are seen to be 'natural laws', which serve to legitimate it, to endow it with meaning and make it reasonable in their eyes. The set of hypotheses will be commensurate with the dominant cosmology and interests within society; they will preclude (theoretically close off) other hypotheses which are rooted in alternative cosmologies and which would be considered as a threat. Alternative hypotheses would appear as anomalies which could conceivably threaten material interests, but would also threaten to undermine cognitive security. They would be denounced as utopian, impossible, or - most efficaciously - 'unnatural'. Thus, the roots of legitimation go deeper than the question of what is natural and what is not, for the hypotheses which describe the cosmos share a pattern of assumptions that actually reflect the very self-evidence of the social environment. In other words, the 'coding' of the hypotheses matches the 'coding' implicit in the prevailing order of social relations. Therefore, people do not see them as legitimate just because they say what is natural, but because they also match their own intuition. Given this theoretical basis, let us now apply it to Forrester's urban theory.

A close examination of Forrester's work on urban systems reveals several layers of legitimation. At one level, we have the use of esoteric computer simulation techniques, the 'mysterious' complexities of counterintuitive feedback systems, and the technocratic promise of social engineering - not of the piecemeal variety, but large scale control of social systems. At another level we have revelations about the order or a priori of the social and natural worlds; these are assertions about what is possible and what is utopian in society, and are grounded in terms of what is natural.
Forrester's thought displays a tension between these levels; he eschews the extreme optimism of those technological rationalists who have contended that the only problems in advanced capitalist societies are technical ones; at the same time he does not reduce the causes of urban problems to purely natural ones. The latter position would view urban problems as the inevitable outcome of natural laws; instead, he maintains a position between these extremes.

We are told that urban areas have a characteristic life-cycle and evolution, with ageing and deterioration as natural features; stagnation and decay are seen as episodes in the cycle of the occupation of land. Further:

"The natural condition of the aging city tends toward too much housing and too few jobs for the underemployed population." Forrester (40)

"Urban difficulties are not a matter of location so much as a phase in the normal life cycle of occupied land." Forrester (41)

Forrester's argument is that these "natural" conditions are encouraged by present tax and zoning practices; conversely, opposite practices can reverse decline and lead to a new and better equilibrium condition. He sees the cycle of growth-equilibrium-stagnation as a highly stable mode of behaviour.

"It does not within itself contain natural or psychological processes that will shift the mode to one of revival." Forrester (42)

Forrester regards the city as an "organic living complex", its "evolution" is not seen as the intentional plan of designers, but as the outcome of a "self-directing system" which people have set in motion. Although he does not believe that urban problems are eternal or naturally fixed properties of urban systems, he does seem to view cities as though they were natural products in the occupation of geographical space. Such a view resonates with what Castells has described as the urban ideology.

"The urban ideology is that specific ideology that sees the modes and forms of social organization as characteristic of a phase of the evolution of society, closely linked to the technico-natural conditions of human existence and, ultimately to its environment." Castells (43)

In seeing urban systems as something natural, people do not see the conflicts of interest which are incipient to their development. Given such a view, problems come to be seen as either natural inevitabilities,
or as aberrations, rather than as indigenous properties of certain types of social organization. This is also the case with Forrester: he argues that cities age, but that the problems associated with ageing are due to internal practices - in other words, they are aberrations which may be remedied by administrative changes.

"By accepting old structures and their consequences as a condition of nature rather than as reflections of the legal and tax structure people fail to see the true causes of urban decline." Forrester (44)

The path from decline to revival is thought to lie in social management and control. But, there are limits as to what can be done - as revealed in the notion of natural and unnatural goals. Discussing outside help for the city, Forrester argues that it cannot be sustained indefinitely if the effort is aimed at an "unnatural" goal that the city cannot maintain itself. Further, the idea that all sustainable system modes require pressures recurs throughout his discussion of urban systems.

"We must contemplate realistic urban goals that include negative forces powerful enough to limit population and population density. These might be ensembles of policies that can maintain high prices of land and rents, or a housing shortage, or a job shortage (that is the unfortunate control in present ghetto areas), or limited transportation, or limited land area that does not communicate with other areas, or zoning to control density, or a bad array of 'quality-of-life' conditions." Forrester (45)

This is the point where we see that negative aspects of the world become integrated (and thereby justified) into the system dynamicists' cosmological scheme, thus becoming pressures which have to be accepted and even maintained.

We can also discern some other layers of legitimation. For example, Forrester talks about "misfits" - by which he presumably means those who do not match up to the acceptable norms or grid of rules inherent in his cosmology. Such people are to be prevented from entering the city whose 'natural' boundary is to be preserved. This boundary requires a balanced mixture of social classes (hierarchy) and an equilibrium with the surrounding environment; further, the boundary is to be protected against the "excessive" influx of the unemployed, with a shortage of housing and high rents as possible deterrents.

If we reflect upon Forrester's thoughts on welfare provision we can further see the influence of boundary maintenance.
"In the welfare substructure we may find that the welfare system is creating the welfare classes and may discover that the welfare system is an active part of the social trap that keeps people from becoming self-supporting." Forrester (47)

Forrester is asserting that welfare cases are products of the welfare substructure and he wishes to redraw the boundary of the social system so as to exclude the welfare subsystem. In seeking to alter the system boundary, Forrester is upholding the legitimacy of a social structure whose problems are alleged to be partly rooted in the welfare substructure. (As we noted earlier, opposition to welfare and to 'New Deal' ideas generally have a strong tradition amongst certain sections of American society.) Further, if welfare cases are created in the manner in which he suggests, it means that other causes may not exist; it implies that there is a poverty trap but not a social structure that creates poverty amidst affluence.

We can also find statements directed towards the nation. We are told, for example, that a healthy city is not a "drag" on the country and can even benefit the nation as a whole. The city must also be in equilibrium in terms of costs and revenues; again this may appear as a statement of the obvious to many people, but in fact it resonates with cosmological assumptions concerning the need for a balance within the cosmos at large.

5.6 ROLE OF SYSTEM DYNAMICS EXPERTS

In this section of the chapter our task is to examine the possible wider role that system dynamics might play in society. Given the structure and characteristics of system dynamics we can consider the potential social and political implications of the role of the experts who would understand, practise, and implement that knowledge. It is contended that in accordance with our model which posits knowledge as a social binding agent, system dynamics contains policy implications - which amongst other things - prescribes roles for system dynamicists in their interaction with politicians and laypeople. The need to examine their potential place in society is not due merely to the claims which Forrester in particular has made, but, more importantly, to the nature of the belief system that system dynamics represents. What we are looking for is a congruence between the structure of system dynamics and the structure of relationships through which it would be practised or taught. Such a congruence would mean that the constraints of this
knowledge system could well be translated into social ramifications. More specifically, we are interested in how the laboratory - in this case the System Dynamics Laboratory - can become extended, out into the world where particular problems are to be solved, and can thereby modify social relationships in doing so.

It is contended that as a system of knowledge, system dynamics entails features which somewhat distance it from techniques such as statistical or other types of computer modeling. Generally, such techniques cannot make value choices within the theoretical terms of the methods themselves; in contrast, system dynamics actually seeks to make objective statements about values. Forrester claims that system dynamics reveals constraints upon our choice of value structures if social systems are not to collapse; it is more akin to a social theory than a technique. (Of course we do not suggest that techniques are value free, or that they are not used to enforce value choices.)

In addition to this difference, system dynamics has at times been promoted by assertions that seek a privileged epistemological position for it. These claims are rooted in the ontological primacy which feedback systems are accorded, together with the contention that only the expert use of computers can reveal the complex behaviour of our social systems. The system dynamicists are not just claiming that system dynamics is useful, they see it as vitally essential for the future of our social systems. System dynamics is being disseminated in two essential ways; firstly, at an educational level in schools, colleges and universities; secondly, it is being adopted by various groups to solve particular problems.

In the introduction we raised the idea that those who 'own' knowledge have the ability to exercise power; the claims of the system dynamicists are in that sense indirect claims for power. In discussing the control and management of social systems they seek to carve out a special role for themselves and for system dynamics. This role would insert them into a distinct network of relationships with politicians and the electorate; it is only they who can carry out the simulation modelling and reveal the possibilities of social systems, the sustainable behaviour modes and the attendant pressures and stresses. Thus, system dynamics is a knowledge resource by which the system dynamicists can create a new pattern of social relations - between themselves, politicians and the electorate. It is also a symbolic system which can then serve to mediate and reinforce that pattern.
In such a situation the traditional role of the politician changes; choices are to be made concerning the possible ensemble of pressures under which people may live, but the task of ascertaining what is possible is for the system dynamics expert and his computer. Meadows, suggests a central role for such experts; in discussing a potential move towards urban prosperity he maintains:

"To do so requires a concentration of will, both on the part of the city residents in adopting trade-off policies and negative counterbalances, and on the part of our national and state administrations and politicians in adopting policies which will further this process. At the centre of such a process is the use of dynamic modelling techniques to evaluate new programs and suggest ways for improving old ones." (48) emphasis added

Implicitly, the role of the politician becomes one of delivering policy options (drawn from system dynamics models) to urban residents. He or she becomes more like a public relations officer, informing the electorate of what our social systems will and will not allow. The political machinery would be structured towards the choice of behaviour modes, but the criteria by which possible modes would be decided, would remain in the hands of the expert and effectively beyond open political discussion. Thus, the problems of any particular city are to be taken over from urban administrations and brought into the System Dynamics Laboratory where solutions can be found. The solution set is then to be handed back to the politicians for implementation.

"People would never attempt to send a space ship to the moon without first testing the equipment by constructing prototype models and by computer simulation of the anticipated space trajectories...Why, then, do we not use the same approach of making models of social systems and conducting laboratory experiments on those models before we try new laws and government programs in real life." Forrester (49)

The important mystique of the laboratory translation of 'outside' problems has also been discussed by Latour in his Give Me a Laboratory and I Will Raise the World and we can identify a number of parallels between his observations concerning the work of Pasteur and the role of the System Dynamics Laboratory.

For example, Latour argues that Pasteur reformulated the interests of farmers in relation to the problem they had with anthrax.

"[I]f you wish to solve your anthrax problem you have to pass through my laboratory first. Like all translations there is a real displacement through the various versions. To go straight at anthrax, you should make a detour through Pasteur's lab. The anthrax disease is now at the Ecole
Similarly with system dynamics: urban problems have been translated into a computer model in a laboratory where they can be solved. Moreover, just as Pasteur's laboratory facilitated the control of the anthrax organism and its elimination - this being impossible in the outside general environment due to innumerable contingencies - so too the System Dynamics Laboratory allows experiments upon the social systems models. However, an important distinction here is that whilst the anthrax organism actually did come to reside in Pasteur's laboratory, system dynamics translations are purely symbolic. So too, therefore, are the solutions, the policy recommendations.

The message which Forrester is expounding is not a simple technocratic one on the line of "Tell me what you want, and I will design the system so as to provide it"; rather, he is stating what possibilities exist and what our interests are. He is informing us about what we can have in terms of quality of life and the range of values which may be legitimately held. Further, these constraints are not due to any inherent weaknesses in system dynamics, but rather are seen as the real constraints of systems themselves.

In Chapter Four we discussed the self-image that the system dynamicists have of those who understand feedback systems: distinctly bounded groups reinforce their own social identity by promoting their philosophy, they may see themselves as special.

"The approach is easy to understand but difficult to practice. Few people have the required level of skill." Forrester (52)

Further, because system dynamics is thought to have a universal validity, there is an implication that someone trained in the nature of feedback systems could enter any subject area or field without prior experience of the subject concerned.

"The same dynamic structures recur within different fields and in the connections between fields. When a structure is understood in one setting, it is understood wherever else it may be found...By creating an educational system on a common dynamic foundation, we can hope to develop a modern 'Renaissance Man' with a command of universal concepts that allows him to move between fields in a unified framework." Forrester (53)

The restructuring of education that this envisages is only one of the implications of system dynamics. Another is its potential for organizing
the perceptions of its practitioners. The theory of urban systems provides a specific role for system dynamicists such that the 'logic' of their social experiences would match the essential 'a priori' of the cosmology implicit in the theory. In other words, urban dynamics defines the role of system dynamicists in urban systems, their job description and, further, actually organizes the perceptions of those who adhere to it; they see themselves in a particular way and they see the world around them in a special way too. Thus, within different social environments - whether the school or the political machinery of cities - system dynamics has the potential for re-organizing those structures in accordance with its implicit cosmology.

In Kuhnian terms, the system dynamics paradigm brings with it a general theory of feedback systems, together with a set of exemplars, which serve to order the cognitions of its adherents. Here again we can point to parallels with Latour's study of Pasteur: the success of Pasteur's program depended on the extension of the laboratory to the farm in order that the farmer's vaccination procedures could be matched to those in the laboratory. In relation to this point, we can note the dissemination of system dynamics as a 'packaged technique'. For example, Dynamo - the computer language in which system dynamics models are encrypted - is written for those people who have little or no mathematical/programming expertise. Also, programs are available for checking the dimensional consistency of model equations etc., and a number of system dynamics textbooks and workbooks are now available. These, coupled with the non-data dependent character of system dynamics, similarly represents the extension of the laboratory out into the 'real world' where problems are to be solved. They serve to secure a correspondence between the use of system dynamics inside the laboratory and outside in policy and other contexts.

One of the roles of system dynamicists is to aid policy formation in urban systems, and - as we argued earlier - their policies would seek to maintain the operation of those systems by organizing them in a specific way. To a large extent we have seen that this organization is but a copy, or projection of dominant interests within present urban structures. Forrester's urban policies would consolidate an urban structure which would preserve the social relations and the experiential 'a priori' of the social environment which gave rise to system dynamics at the outset. Within such a social structure the expert's perceptions would be consistent with the theory of urban systems, and the perception of the urban residents would be such as to make the policies appear self-

*This of course was discussed in Chapter Four.
The practical implementation of urban dynamics would change urban structures in such a way as to exclude those sub-structures which do not conform with the ones advocated by the theory; these exclusions would centre upon the welfare subsystem and highly concentrated social and economic areas. This indicates a further intricate strand in the relationship between knowledge and social structure; for when Forrester advocates the integration of underemployed Blacks into mainstream economic activity, we can understand this as a policy which would submit them to the dominant public grid. Moreover, the elimination of the ghettos would also help to eliminate the cosmologies which they support. These people would be incorporated into a new urban structure in which the cosmology represented by system dynamics would be the dominant cosmology of the whole city; each person would be subordinated to the public grid, with a social hierarchy and balanced population etc.

Urban dynamics promotes a theoretically closed view of cities; it also aims to concretize an urban structure which would support the cosmology implicit in the theory; this structure would therefore reinforce the proposed policies. Thus, another effect of urban dynamics may lie in its promotion of a social restructuring which could close off alternative perceptions and dissent.

In Chapter Four we asserted that the range of linguistic codes which is available to a person is a quality of his or her social environment. During the socialisation processes of education people may gain access to different forms of the elaborated code and therefore we may raise the question of the connection between the dissemination of system dynamics within the education system and the control of access to codes. Not only do the system dynamicists seek to consolidate an urban structure whose ramifications may be those that we have just discussed, but because of their desire to extend system dynamics into all levels of education they are also indirectly making a bid for power over the access to elaborated codes.

The teaching of system dynamics is equivalent to the teaching of the object-oriented code and the social cosmology which are implicit within it. Speaking about how pieces of knowledge are classified within the classroom Douglas states:

"As they are connected in the curriculum so they enter the minds of the pupils, and, though the details of the content will fade, the connections are likely to guide their judgements and perpetuate the system of power
It is not necessary for us to be drawn into the debate concerning the wider pedagogical implications of this idea, but we can use it to throw some further light on the teaching of system dynamics. The relationship between teacher and the pupil is part of a control system in which the curriculum is an example of a symbolic system which mediates and reinforces hidden power relations. In the context of the school, these relations are represented by the groups who decide upon the content of the curriculum. In seeking to extend the teaching of system dynamics throughout the educational system, Forrester and his associates are indirectly seeking to exert some measure of control within the system of power that determines the curriculum.

5.7 SUMMARY

Seeking to take a holistic view, comprised of multiple perspectives, this chapter has advanced several arguments about the potential role of system dynamics as a social binding agent which mediates and reinforces social relations, and the picture that we have developed has revealed several interconnecting dimensions by which this could be effected.

In no part of the discussion have we meant to imply that these social effects are within the conscious control of Forrester or other system dynamicists; rather, they express the possibilities of a system of knowledge which has evolved from the social context within which these system analysts reside. They are constrained by that knowledge, just as the urban residents would be if the policies were implemented to their full extent.

With the system dynamicists we would find a self-reinforcing social position which would insert them into a special relationship with politicians and the electorate. With regard to the latter, we have pieced together a picture of an urban structure which, given our argument concerning cosmologies and social structures, would perhaps constrain them towards an uncritical acceptance of the role of the system dynamicists and the policies which they recommend.

Referring to the work of Latour, we have shown that the extension of the laboratory is not solely a feature of natural science, but may pertain to social science too – in this case we have discussed the extension of the System Dynamics Laboratory into policymaking.
We have also argued that the urban theory has a degree of autonomy with regard to capitalism - though Forrester does not seek to change the fundamentals of the established order, he does advocate some policies which would be to the disadvantage of certain capitalist enterprises.

Several interwoven threads of legitimation pervade the theory, each displaying a distinct facet which functions so as to make the theory appear rational or self-evident in people's eyes. Taking a position between technocratic optimism, and one which might construe all urban problems as a natural outcome of city life, Forrester puts forward a mixture of ideas whose justification arises from different sources. From the moral indictment of the 'irresponsibilities' of the poorer classes, to the promotion of capitalist enterprise and technocratic ideas of the need for changed urban administration, the theory spans almost the whole gamut of conceivable notions which could lend it legitimacy. (This again supports our conviction that system dynamics cannot be reduced merely to capitalist or technocratic interests.)

Urban dynamics is a claim for power: it seeks to stake out a position for system dynamics and carries an assertion of authority to speak about the nature of our social systems. This claim bears a hallmark of our times - the ceding of authority to those who command the use of esoteric techniques in technology and the physical sciences. Beneath the technical glare we find a strong moral position: system dynamics offers to fulfill the promise of social engineering while remaining rooted to a traditional conservative view of people's societal duties.

We have explored several interconnected strands within the exoteric role of system dynamics: these further illuminate the development of this particular branch of the systems movement which of course is one of the objectives of the dissertation. The question of system dynamics' actual role is perhaps better left for the future, and in any case is more concerned with much broader social issues than can be dealt with here. What we have tried to show is that its potential role is complex and multifaceted; bringing together models of thinking from anthropology, sociology, and political economy, we have sought to map out the important questions pertaining to its role, and these stand as possible directions for further research. Our contribution to the understanding of system dynamics, therefore, resides in the originality of the perspective we have erected, rather than in solving the very questions we have achieved in formulating.
CHAPTER SIX

THE SOCIAL AND PSYCHOLOGICAL EFFECTS OF SYSTEM DYNAMICS

THE CASE OF THE WORLD MODELS
In this chapter our attention turns to the system dynamics world models and the controversy which surrounded them. These models are the most widely known and extensively publicised of the various system dynamics projects, and have generated both widespread support and criticism, particularly in North America and Western Europe. Here, we are specifically interested in the spectrum of beliefs and disbeliefs which the models stimulated and we will employ some sociological and psychological ideas in order to examine the differential reactions of different audiences.

The world models did not enter a social vacuum, but emerged at a time of considerable social change - including economic upheavals and the decline of traditional values and institutions - which some people saw as a portent of a threatening future. Our contention is that it is in relation to the prevailing social context that the public appeal of the models is best understood.

The world models must also be seen in relation to the environmental movement of the 1960s and early 1970s which was itself part of the wider social context. We cannot hope here to provide an explanation of this movement: the reasons for the rise of environmentalism are obviously beyond the scope of this thesis. However we must acknowledge that the world models contributed to the development of the movement.

Basically our approach is to contend that the models represented a complex message which was interpreted in divergent ways by various groups with different cosmologies. These groups ranged from those who saw the message as confirming their belief in the imminent collapse of Western civilization, and who subsequently sought survival in small alternative communities, to those who viewed the message as a justification for increased international regulation and the formation of a 'world government' or some other supranational institution.

The message encapsulated many intuitive feelings about the state of the modern world. In fact, it embodied age-old ideas about the relationship of man to man, man to society, and man to nature - though casting these ideas in a somewhat modern form. These "natural symbols" - to use Douglas' term - vary from cosmology to cosmology; this variation offers some prospects for understanding the different reactions to the models.

It is contended that the message was also a focus for psychological concerns - that it played upon certain psychological needs. These
include the need for cognitive security - i.e. the need to be able to explain one's life and endow it with meaning and a sense of purpose. We will argue that these needs are discernible amongst a number of different responses to the models even where those responses are superficially disparate.

The principal psychological reactions on which we concentrate are the mechanisms of projection and displacement. Because the world models became a lever of protest for various groups, they provided a resource by which those groups could project their dissatisfaction and lay blame at the door of the establishment, scientists, technology, industrialists, or whoever. In doing so, these protest groups were protecting themselves against their own complicity in the global problems (complicity which would be painful to admit). This type of reaction is an example of what psychologists call displacement - i.e. the substitution of an acceptable explanation for one which would be painful to admit or sustain.

To take another example of these reactions, we may note that Elias has drawn attention to the way in which some people make a fetish of nuclear weapons. The nuclear bomb is a symbol onto which people project their fears; they blame scientists for its presence - thus displacing a more objective explanation for the existence of nuclear weapons and substituting a more welcome one. Our conjecture is that these reactions are closely bound up with preserving cognitive security.

The plan of the chapter is as follows. Firstly, we discuss the actual details of the message contained in the models. Secondly, we use Douglas' ideas as a background for analysing the social roots of beliefs concerning pollution. Then we discuss the types of response to the message which could be expected in the light of her theory of cosmologies. In the following section we will describe some actual responses with reference to these expectations. Finally, we examine the responses at a somewhat deeper level and try to explain some of the similarities which underlie them.

Our main theme will be the social and psychological needs which the world models fulfilled. We will argue that they afforded a form of belief system which sought to explain the contrarieties of the world and endow it with meaning and coherence.
Some of the similarities in the responses to the models centre on the idea of radically changing the social order whilst others tend towards a more passive acceptance of the message. To understand the radical responses requires that we deal with the question of millenarianism—the belief that some total and sudden transformation of the world is at hand. This is important for two reasons; firstly, some scholars have drawn attention to the millenarian overtones of the environment movement; and secondly, Douglas's theory of cosmologies identifies certain millenarian tendencies with specific types of social environment. These two factors match neatly into our theoretical framework.

Finally, in order to illuminate the nature of the passive response, we will undertake a comparison of the belief system represented by the models with that pertaining to astrology. We will argue that like astrology, the world models may countenance passivity and individual adjustment to social conditions. This final section will constitute the most speculative part of the thesis but is justified because it covers particular ideas about the impact of the models which have not been discussed elsewhere. We do not wish to argue that system dynamics is reducible to astrology or vice versa, but rather, seek to illuminate beliefs in the message of catastrophe by pointing out interesting parallels between the two. These thereby highlight novel aspects of system dynamics and the widespread popularity of its message.
6.1 THE MESSAGE OF THE WORLD MODELS

We propose to treat the message of the world models - World 2 and World 3 - as being basically the same. There are of course some differences, The Limits to Growth being somewhat less pessimistic than World Dynamics, but for our purposes it is reasonable to refer to the message of the two models collectively as "the limits to growth" (LTG).

Our use of the term "message" is based on the idea that the world models carried a number of different themes - each containing condensed symbols - which render any simple treatment inappropriate. Thus, we cannot spell out the message in the form of a clear-cut unambiguous interpretation for this would undermine its complexity. Instead, we will endeavour to point out the range of symbolic elements within the message without forcing it into a singular rigid mould.

The LTG message contained the ominous prediction that the world was facing a total catastrophe. This prophecy appeared to be different in kind from earlier predicted disasters because it was apparently based upon the behaviour of computer simulation models - a feature which set the message apart from religious and other apocalyptic prophecies. It had overtones of scientific objectivity because it came from a group who were amongst the world's leading scientific and technological elites.

The potential collapse may be caused by one of several factors, acting singly or in concert. Amongst other possible scenarios we find pollution crises, starvation, and industrial collapse through the exhaustion of natural resources. The global collapse would give way to an equilibrium condition with a much lower level of population, and the "shift from growth to equilibrium may be initiated by catastrophes such as wars, or epidemics" 3.

The concept of system viability is used to focus doubts about the future, and the modellers question whether man is about to fall into an abyss of his own creation - a social and technical system which he can no longer control and which is driving the whole race towards disaster 4.

In addition to arguing that the viability of the world system is threatened, the system dynamicists advocate measures which will supposedly bring the global system into an equilibrium state and thus guarantee its viability. Indeed, the conception of viability is directly linked to the means of sustaining it - i.e. equilibrium. These measures are directed towards curbing the present growth in population, industrialisation, and pollution. This would require a shift in values.
from those oriented towards short-term interests and material growth, to those compatible with long-term equilibrium.

Forrester advocates an enhanced role for religion in the proposed equilibrium society and suggests that churches are guardians of the future. His assumption is presumably that a stronger religious orientation would seek to provide the stricter moral codes required to secure the forfeit of expectations in a world of no material growth. The system dynamicists argue that because of the alleged slow response time of complex systems, people must take action soon for it will take some time before their efforts come to fruition. They suggest that if people postpone action then it may well be too late to avert the catastrophe.

The concepts of system viability and equilibrium are further linked to the ideas of order, conservation, the purposive nature of systems, harmony, and balance with nature. A world in equilibrium would be a world of order and harmony between man and nature, and between the different subsystems.

Equilibrium occurs when growth in the positive loops has been arrested by the negative loops, thus yielding a balance of forces and harmony, i.e. "a condition of constant population, constant use of resources, and constant generation of pollution, all limited so that the equilibrium condition can be sustained indefinitely into the future." So, the equilibrium society will have no conceivable end - its social order will be perpetual.

The system dynamicists believe that systems have a purposive nature which is oriented towards the attainment of an equilibrium state. A future world equilibrium is therefore seen to be inevitable. However, they also stress that men should act to influence the particular state into which the world will move; for if the choice is left to the system alone it will of course not bear human considerations in mind. We are told that man must not seek to conquer nature but try to live in harmony with it.

In the early part of the 1970s, ecology became a widely-used term in Western societies and served as a focus for a series of related concerns. The LTG message was seen by many people as a vital part of the argument for environmental protection, for it purported to show that...

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This idea reflected the rising concern with ecology and is consistent with Commoner's so-called 'laws of ecology' - one of which states that "nature knows best" (7).
Figure (1) ELEMENTS IN THE LIMITS TO GROWTH MESSAGE
environmental abuse not only threatened the extinction of obscure species of animals, but the existence of man himself.

Although appearing to many as scientists, Forrester and his associates distanced themselves from the scientific and technological rationality which they saw as being tied to short-term interests - designed to treat the symptoms of the world's problems rather than the 'true' causes. They were therefore much opposed to technological 'fixes'. In fact, the method with which their models had been formulated was claimed to embody a new and distinctive way of thinking about the world - i.e. a dynamic systems approach which its proponents believed was the only way of comprehending the behaviour of a complex system. The method used in constructing the models was holistic, the World 3 project team was multidisciplinary, and a long-term view was taken of the future of the global system.

Forrester and Meadows both acknowledge that the models do not consider the political changes that would be necessary to achieve global equilibrium, restricting themselves only to a consideration of the viability of the physical infrastructure which underlies the social world. Yet, this admission is not just a statement regarding the limitations of the models; it also serves to set their work above the sphere of politics, to make them appear more objective. Further, we should note that in painting their system analyst's view of the world, conflict is seen largely as a symptom of exponential growth or competition for limited resources. It is seen as being rooted in short-term considerations. The message of the world models was therefore projected above short-term political squabblings, class conflicts and other similar conflicts of interest - it purported to address the long-term future of the whole globe. The main elements of the message are depicted in Figure (1).

THE SOCIAL ROOTS OF BELIEF

Modern man is not alone in fearing for the safety of his environment, Douglas tells us that most tribal environments are also held to be in danger. Though the nature of the perceived dangers are not the same, she argues that we allocate responsibility for pollution in the same way as do people in primitive societies. Pollution, in her view, is a social construct which is loaded with moral persuasiveness and used as a means of coercion.

In certain tribal societies, accusations of witchcraft, unnatural sex and pollution are amongst many similar charges which may be made against
specific sections of the community. Douglas argues that these accusations are a means of enforcing power or exerting political control. In the last chapter we discussed the thesis that knowledge may be considered as a resource for the exercise of power. An accusation of witchcraft or pollution is rooted in a system of knowledge which defines what is 'natural' and 'unnatural', which distinguishes the honest man from the man-eating witch, the pure from the impure. Thus, those who exert control in this system and its classifications also influence the social system for which the system of knowledge is a necessary support.

Within primitive cultures, charges concerning pollution often take one of two distinct forms. Firstly, an accusation of witchcraft (of being a source of pollution, a danger to the rest of society) may be issued by the leaders in order to exert control over some individual or group within the tribe. Secondly, the converse of this is that members of the tribe may suspect their leaders of corruption and accuse them of witchcraft. The typical targets of the charges depends upon the relative power of the leaders and their followers.

"Pollution ideas, however they arise, are the necessary support for a social system. How else can people induce each other to co-operate and behave if they cannot threaten with time, money, God, and nature? These moral imperatives arise from social intercourse. They draw on a view of the environment to support a social order." Douglas (8)

Transferring this line of thought to modern society, Douglas suggests that this age-old formula may well underlie the present debate concerning the environment. If this is indeed the case, then we must consider the environmental debate in political terms.

Douglas argues that the "centre" (the leaders) and the "border" (peripheral groups) of modern societies translate their political objectives into views about pollution and the environment. For example, if a border group considers the 'system', or industrialisation (which is often identified with it) to be a bad thing, then pollution may be seen to emanate from institutions. According to this type of view, man is seen as naturally good whereas institutions are seen as a cause of corruption in men and pollution in nature.

Despite the view that ecology is above or beyond politics the debate over the environment is therefore essentially a political one. Each party to the debate has its own conception of man, nature, and pollution; there is no objective or scientific theory about pollution and the environment; in Douglas' terms they mean different things to different
"The scientists find out true, objective things about physical nature. The human society invests these findings with social meaning and constructs a systematic time-tabled view of the way human behaviour and physical nature interact. But I fear that it is an illusion if scientists hope one day to set out a true, systematic, objective view of that interaction. And so it is also illusory to hope for a society whose fears of pollution rest entirely on the scientists' teachings and carry no load of social or moral persuasion." Douglas (9) emphasis added.

Figure (2) shows how the message of the world models may be interpreted in two distinct ways. One is a centre interpretation and the other represents a border view where certain elements of the message are assimilated into an anti-centre position. For example, a group which is opposed to the establishment, and the industry and technologies identified with it, can latch onto the system dynamicists' concern about growth and technological 'fixes' in order to reinforce its own position. The important point about this from our point of view is that each group receives the same message but draws different conclusions from it. (In other words, there are different exoteric interpretations of the esoteric message: different sets of message components become built into the commonsense, 'self-evident' outlooks of various groups.)

In addition to this social dimension of pollution beliefs there is also the psychological dimension we discussed earlier. To charge someone else or some other group with pollution is to externalise its causes and project guilt onto parties other than oneself. Thus, in addition to masking the social and political interests of border groups, pollution charges may also mask their complicity in the production of the pollution which they despise.

The concept of the environment as a potential weapon of social control is not the only one which has a bearing upon the message of the world models and their reception. Douglas also draws our attention to the social bases of credibility and to the problem of pollution fears in "unstructured" societies. Each concept of the environment masks a certain form of social structure and is rooted in a moral consensus that both protects that structure and is in turn reinforced by it. Further, each environment has dangers which are organised into a system of knowledge which allows people to cope with them.

"In essence, pollution ideas are adaptive and protective. They protect a social system from unpalatable knowledge. They protect a system of ideas from challenge. The ideas rest on classification. Ultimately any forms of knowledge depend on principles of classification. But these
Figure (2) TWO INTERPRETATIONS OF THE MESSAGE
principles arise out of social experience, sustain a given pattern and themselves are sustained by it. If this guideline and base is grossly disturbed, knowledge itself is at risk." Douglas (10)

The basis of belief in any particular danger (the credibility of the threat), is maintained by a moral consensus within the society. Conversely, the absence of a moral consensus leaves us open to the multiplicity of dangers that may usually confront us without our being aware of them.

"In a sense the obvious risk to the environment is a distraction. The ecologists are indeed looking into an abyss. But on the other side another abyss yawns as frighteningly. This is the terror of intellectual chaos and blind panic." Douglas (11)

Douglas conjectures that the lack of structure within modern societies actually increases our pollution fears and leaves us "prey to every dread". A society with a strong moral consensus embraces a view of the environment which provides discriminating criteria which control danger and allow people to live with many risks which actually surround them. In modern societies however, the social structure is weakened, scientists are in conflict about what is dangerous and what is not, and we are confronted by an intractable array of reports about possible dangers - from our diet and the air we breathe, to the medicines we consume and the technologies which sustain our material comfort.

These arguments are of considerable relevance to the set of responses which greeted the world models. We have already hinted that the responses to the models reflected the diversity of beliefs in Western society and our discussion of pollution fears is an example of why this is so. In the following section we will discuss the ways in which different cosmologies may be expected to influence the reactions of various groups to the message of the models.

6.3 EXPECTED RESPONSES TO THE MODELS

If we examine the various general conceptions of the universe which the grid-group diagram contains, we can begin to discern the possible variations in belief and interpretation which greeted the world models. With high-classification there is a close matching between the purposes of society and nature, which are seen to be in reciprocal interdependence. This of course is similar to the position of the world modellers themselves, and so the response of people with high-classification cosmologies is easy to see because the style of thought
underlying the message of the models would be similar to their own. We would thus expect a strong concern with maintaining social order, and equilibrium with nature, and also an emphasis on the idea of natural laws.

With small-group cosmologies the distinction between inside and outside is transferred to thoughts about nature. Just as society is split between 'them' and 'us', so too nature is divided into purity and danger. The LTG message may appear to symbolise that part of nature which is 'good' - especially as it is seen to be similarly exploited by the larger society from which the people in the group have withdrawn. Also, we should note that this cosmology is open to millenarianism - the withdrawal from mainstream society and its rewards means that these groups are lured by the threats and promises of millenarian movements.

At high-grid/low-group, people are insulated from each other. This social insulation produces a corresponding insulation between cognitive categories and therefore a low degree of reflexiveness. Hence, these people patch together a cosmology which is often eclectic and contradictory and in which no dominant theoretically elaborated concept of nature or the environment is to be found. These people could respond favourably to the LTG message, or part of it, without any particularly coherent reason.

This obviously makes it difficult to suggest what responses might be expected. However, two possible tendencies - which are noticeably disparate - are passivity and millenarianism. In other words, some of these people may just accept the message as true without seeking to question it, whilst others may see it as an omen of some sudden and total transformation which they expected. In fact, we will have to return to this cosmology when we deal, in the final section, with deeper questions concerning the socio-psychological roots of belief.

In contrast, at the other extreme - low grid - there is a characteristic high degree of reflexiveness; there is a tendency for boundaries to be made and broken almost at will and scepticism is a dominant trait. Here, the competition between individuals is strong and exacting in its toll. Nature, however, is identified with all that is innocent and pure, and stands in stark opposition to society. Because of its refined critical apparatus, this cosmology is not prone to millenarian tendencies and people who predict the end of the world are subject to much scrutiny and have to compete like the rest to make their voices heard. Here we should expect to find critical scientific reactions to the models.
Within the individualist environment at low grid we can in fact distinguish two other variations on its cosmology. The first represents that of autocrats who exert much control over other people; an example of this type of cosmology is referred to by Douglas as "Big Man". The Big Man is a remote and powerful leader who is often geographically separated from the bulk of his followers.

"...the successful leaders, having spiralled free of personal constraints, emerge into a rarified atmosphere which has something in common with the world view of the people most heavily subject to controlling pressures in the same society. Their ephemeral social contacts and imperviousness to personal pressures enable them to see the cosmos as a rational order not dominated by people but by manipulable objects. These objects are the impersonal rules which govern their transactions. Their world is not controlled by independent ghosts and witches, or evil men. There is no sin: only stupidity. Human nature is divided between the foolish and the wise, between 'those who know' and the others...For them it is a rational world whose laws are perfectly intelligible and unmysterious." Douglas (12)

So, to these leaders, the world is rational and is to be exploited for their own purposes. Douglas suggests that this cosmology has much in common with certain powerful figures in modern societies who view the world as a morally neutral technical system which is accessible to their own resources. If the message of the world models appealed to these people, we can expect to find that they would respond with suggestions for increased regulation and control. Further, those with a particularly technocratic point of view would be biased towards the emphasis of technological solutions to the problems raised by the system dynamicists.

However, we might also expect to find negative responses in so far as the proposed global equilibrium is construed as a threat to capitalist interests. The low grid cosmology demands freedom for individual transactions and so talk of regulating production - and thus contracts or transactions - would tend to be resisted.

The followers of the Big Man have quite a different view of the cosmos. Though they too see it as demarcated by impersonal rules, they are oppressed by them. These people would be located further up grid than their leaders and Douglas refers to their cosmology as "strong grid".

The leaders are perceived as remote and powerful figures.

"Recruited and harnessed to a competition which seems to hold glittering rewards for all, they find themselves trying to work a complex system of rules...Whether it be rules of monetary exchange, debt and credit, or
rules of etiquette and hospitality, the system constitutes an oppressive grid." Douglas (14)

Douglas points out that certain sections of modern industrial societies have similar perceptions of the world.

"Some more than others feel their lives controlled, not by persons, but by things. They wander through a forest of regulations, imponderable forces are represented by forms in triplicate, parking meters, inexorable laws. Their cosmos is dominated by objects of which they and fellow humans are victims." Douglas (15)

Further, she argues that people with strong grid cosmologies are prone to recurrent outbursts of millenarian fervour, periods of belief that some total transformation of the world is at hand. These people also tend to identify with nature. For our purposes here this has two interesting features. Firstly, some form of union with nature offers a tantalizing escape from the oppressive grid of society; secondly, the topical themes which centre upon the technological exploitation of nature can be seen as a symbol of the exploitation experienced by these people themselves.

In contrast to earlier conceptions of nature, some groups in modern society (notably those of low group) embrace a unique vision of the natural world. What seems important about these modern conceptions is that nature is no longer viewed as a source of danger. As Douglas points out, nature has come to be seen as an innocent party rather than as an instrument of God's revenge. (People sometimes, for example, viewed adverse weather as a reaction of the gods.) The innocence of nature is a reflection of the alleged innocence of the individual: both are seen to be murderously assaulted by society. Hence, we can suggest that the message would appeal to these people because its stress on harmony with nature would resonate with their own feelings vis-a-vis society.

In line with our discussion of comparative method in Chapter Four, it is worthwhile restating the point that the level of 'griddedness' or the strength of 'group' pertaining to any given cosmology is only intelligible within a comparative framework. Thus, rather than seeking to identify responses purely on the basis of cosmologies viewed in isolation, we must look for differences in response in relation to gradual shifts in cosmology. To this end it is useful to consider some general trends within the grid-group diagram and thereby use these as a basis for identifying different responses.
For example, we can envisage a continuum of responses running from a plea for un-fettered growth at low grid/low group to a no-growth position at high grid/high group. In between these two extremes we would expect to find advocates of balanced or directed growth.

(pro-growth) directed growth (no-growth)

(low grid/low group) (high grid/high group)

Further, running from top (high grid) to bottom (low grid), we would expect a shifting emphasis between order and liberation. This differentiates another low-growth cosmology, only this time the stress would be on an alternative society based on individual liberation or alternative communities rather than some form of world government as at high-grid.

We have now indicated why and how, on the basis of different cosmologies, various groups might be expected to respond to the world models. In the following section we will discuss some actual responses in connection with the expectations set out here. We will discuss these responses in relation to the cosmology which appears to be held by the group or individual involved; however, it must be stated that we are not offering a definitive identification of these cosmologies because to do so would require a detailed study of the people concerned. Nevertheless, we can discern important cosmological characteristics amongst these groups and we contend that these form a sufficient basis for understanding their particular interpretations of the message. Also, it must be noted that we are not seeking to offer a precise description of the social environment from which different responses ensue. This is in line with what we said about making individual predictions with the grid-group diagram in Chapter Four, but it does not affect the differentiation of responses according to cosmological beliefs; it merely requires us to observe the possibility that an individual's beliefs are not necessarily always correlated with the social environment in which he or she resides.

Indeed, it is perfectly possible for a person in a given social location to articulate a cosmology which actually corresponds to a different social environment. In other words, we may well be dealing with that person's wished-for pattern of social relations. However, we would still expect Douglas' theory to hold in as much as specific configurations of beliefs will still be found together. For example, one is unlikely to find advocates of zero-growth who think that nature should be dominated and controlled by technology. Thus, we seek to explain various responses to the message on the basis of different interpretations which are
refracted through the cosmology held by the particular groups involved - whether that cosmology legitimates their actual social location or is used as a resource to justify their wish for a different social location.

**DIFFERENT INTERPRETATIONS OF THE MESSAGE**

In this section we will consider some different responses to the message; most of the examples we have taken were generally favourable to the message, or part of it. However, we will endeavour to highlight the similarities and differences between them.

We may begin by considering several responses which are rooted in various ideas of 'authoritarian' utopias - i.e. alternative societies based upon centralised authoritarian control - where in our terms grid and group would be strong. Firstly, we can consider the case of Ophuls who said of the LTG message:

"Admittedly only crude first efforts, these computer simulations of the global ecosystem nevertheless provide a graphic picture of the way in which exponential growth is rapidly thrusting up against natural limits; they seem to show that only quite radical changes in policy will allow us to avoid catastrophic situations in the inevitable transition from growth to equilibrium." (17)

Ophuls' proposed solution, which he sees as unpalatable but nonetheless necessary, is to establish Leviathan - in other words, to build up grid and group.

"Only a Hobbesian sovereign can deal with this situation effectively, and we are left with the problem of determining the concrete shape of Leviathan." Ophuls (18)

Another utopian vision is provided by the Blueprint for Survival which was published in 1972 and resonated with many of the issues raised by the system dynamicists. In fact, the Blueprint borrowed the results from the world modelling project in order to bolster its own case. Goldsmith, a co-author of Blueprint and editor of The Ecologist, thus responded favourably to the message.

"The only sensible reaction to the Blueprint for Survival and the Limits to Growth is that their conclusions are obvious - painfully obvious." Goldsmith (20)

*For a broader discussion of such utopian recipes see O'Riordan (16).*
The picture of the utopia which emerges from Blueprint is again a rather authoritarian one. Though Goldsmith is favourable towards small-scale communities he sees them as being integrated into an overall social system which is marked by hierarchy and order, and in which individuals are differentiated into different niches.

"Undifferentiated individuals competing for the same ecological niche cannot co-operate in any way ... It is only when as a result of competition, they have been found to specialise in such a way that each one learns to exploit a different sub-niche, that co-operation is possible... Competition is the means whereby a hierarchy is set up. In the right conditions... the competing individuals eventually arrange themselves so as to constitute a hierarchy and learn to accept their respective positions within this hierarchy." Goldsmith (21)

In fact, Cotgrove has observed that Goldsmith's views represent a traditional view of community which is characterised by explicit forms of authority and hierarchy, and a belief in natural differences and inequalities; further, in this view the purposes of society and nature are closely matched and so the optimal social organisation allows people's 'true' nature to exert itself. These beliefs of course echo with our earlier description of high grid/high group cosmologies in Chapter Four.

Another writer with similar views is Hardin who also responded positively to the models.

"The book is receiving wide notice and thoughtful discussion. Perhaps this time the message will be remembered. Perhaps, this time Cassandra will be believed. Let us hope so." Hardin (24)

In his The Tragedy of the Commons Hardin calls for mutual coercion to enforce population control. Cotgrove views this paper as a forceful expression of the "emphasis on order and traditional authority emerging from the will of the community".

"The most important aspect of necessity that we must now recognize, is the necessity of abandoning the commons in breeding. No technical solution can rescue us from the misery of overpopulation. Freedom to breed will bring ruin to all. At the moment, to avoid hard decisions many of us are tempted to propagandize for conscience and responsible parenthood. The temptation must be resisted, because an appeal to independently acting consciences selects for the disappearance of all conscience in the long run, and an increase in anxiety in the short." Hardin (27)

Again, in similar vein to Ophuls, Hardin argues that it is necessary to
cede power to a hierarchy of "custodians".

"[But how do we legislate temperance? Experience indicates that it can be accomplished best through the mediation of administrative law. We limit possibilities unnecessarily if we suppose that the sentiment of Quis custodiet denies us the use of administrative law. We should rather retain the phrase as a perpetual reminder of fearful dangers we cannot avoid. The great challenge facing us now is to invent the corrective feedbacks that are needed to keep custodians honest. We must find ways to legitimate the needed authority of both the custodians and the corrective feedbacks." Hardin (28)

In Chapter Four our comparative analysis between SPRU and SDG illustrated a cosmology which was at lower grid and group than that of the system dynamicists. SPRU are committed to directed growth and a similar view is shared by Bray, a Labour MP and a member of the Club of Rome, who also rejected the message of the world models. Reviewing The Limits to growth he stated:

"There may well be a role for simple global material flow models, even of the simplicity of that in this book, but to have any practical implications for policy they will have to be more firmly based in reality, and better linked with the more complex systems behaviour models which man has found necessary throughout history." Bray (29)

Rejecting the call for zero growth, he advocated growth to meet human needs.

"[T]he continued growth of GNP...is needed to meet the many human needs in all nations, including provision for a rapidly expanding population for the next 50 to 100 years. In practical human and political terms it is much easier to redress serious inequalities, and to provide for new needs within nations and between nations if men feel their own conditions of life are improving..." Bray (30)

Another expression of the need for controlled growth can be found in Catastrophe or New Society, a report on a counter-modelling project conducted by a group in Latin America. In this project - which was a reaction to the pessimism of LTG - the aim was to explore the transition from the present world economy towards one in which resources would be allocated to meeting basic needs for all people. In opposition to the views characterised by LTG we find the statement:

"The stance of the present authors is radically different: it is argued that the major problems facing society are not physical but sociopolitical. These problems are based on the uneven distribution of power, both between and within nations. The result is oppression and alienation, largely founded on exploitation. The deterioration of the
physical environment is not an inevitable consequence of human progress, but the result of social organizations based on destructive values." (32)

What of the cosmology of the "Big Man": this is to be found amongst other objectors to the message who called for unfettered growth; these were technocrats and leaders of large corporations - advocates of unrestrained economic forces and the market economy. Such a position which called for growth per se was represented by Gaines, senior vice-president and economist for Manufacturers Hanover Trust. In The Doomsday Debate he wrote:

"It is growth, after all that will provide the products and services needed to eliminate want worldwide and to reduce pollution without reducing the real scale of living of people. Also, growth provides the incentive for technological breakthroughs that will restrain our consumption of limited resources by developing economically usable substitutes." (33)

Greenberger (et al) point to an advertisement headed "Can technology solve the problems caused by technology?" - carried by Scientific American on behalf of a Japanese company - in which it is claimed that:

"[I]t is through better technology that man will solve the problems caused by industrial progress...We don't claim Chiyoda has all the answers. But we do feel our 1,800 engineers and scientists and those at other technology-minded companies around the world provide hope. With community support, we can make technology solve the problems caused by technology." (34)

This company was said to be the largest engineering concern in Asia, and its message stands as an unambiguous statement of technological optimism.

Another example of the "Big Man" cosmology is perhaps to be found in Peccei, the head of the Club of Rome. He implies that the world has a rational foundation but that man's evolution has lagged behind his powers of destruction.

"[Man] is presumably the only planetary species aware of his own predicament and with the potentiality of self-development, yet the very forces of his nature which have raised him above the animals weigh against deliberate self-evolution...Our destiny is in our own hands; how can we learn to achieve it." Peccei (35)

He did not give unqualified support to the message of the world models, which had after all been commissioned by the Club, but rather saw it as a
way of grabbing the world's attention.

"[The Club's] immediate purpose was thus temporarily shifted from the search for answers to basic questions to the search for a device capable of opening a breach in the hearts and minds of people, of arousing their awareness to the complexity and seriousness of the world problematic. After long consideration, a commando operation was decided upon, in the hope that its rapid tactical success might have strategic consequences." (36)

Pececi was not an advocate of zero growth and he eschewed the type of moral stance and view of natural laws typified by Forrester. Thus, he does not so much believe in human sin so much as human stupidity.

"The struggle to survive has cultivated aggressive characteristics, vanity, greed, desire for power, etc. which are not the elements on which to build the wisdom he now requires." Pececi (37)

Cotgrove draws attention to the fact that some of the environmentalist groups displayed tinges of what Mannheim described as 'orgiastic chiliasm'. This refers to feelings of ecstatic immediacy which centre on the idea that a sudden and total transformation of the world is at hand. This is a characteristic which is found amongst some millenarian groups and it can be discerned to a varying degree amongst certain supporters of the LTG message. For example, it can be seen in a mild form in the publication *Towards Survival* which gave qualified support to some aspects of the world modelling effort. Notably, it sought to draw membership from those who "are already convinced, from their own thinking, reading and observing the world around them, that we are entering the most crucial period in the history of mankind". To take a more telling example, we can turn to Allaby who was one of the co-authors of the *Blueprint for Survival*. He also therefore looked upon the LTG favourably and he was convinced that American society could be reformed in a short period of time, with far reaching ramifications for the Western world. He viewed the environmental movement as a kind of revolution; interestingly, it was to be like a "religious conversion" rather than a violent political upheaval.

"Their revolution may involve a certain amount of violence, but this will be accidental and incidental; there will be no barricades, blood will not flow in the streets. The environmental revolution will be gentler and more violent than that, for its target is the very fabric of society itself. It can succeed only if it changes the hearts of the majority of men...The revolution in this sense is much more akin to a religious conversion, a 'turning about at the seat of consciousness'." Allaby (40)
These examples provide evidence for the millenarian interpretations which may emerge with insulated, strong grid, or small group cosmologies. The LTG message appeared to confirm the millenarian outlook to which these groups were prone. Further, we might add that the temporal uncertainty pertaining to the date of the predicted catastrophe would resonate with the millenarian's sense of immediacy - the exact timing of the total transformation is unknown, but its signs are already at hand, it is immanent.

The LTG found a ready audience amongst many other groups who were often associated with the counter-culture of the time. These sections of the environmental movement have been the subject of a large investigative literature and though we cannot refer to specific named groups we can draw upon this material in order to paint a general picture of their reactions.

Some groups expounded views which were almost the complete antithesis of the aims of the traditional environmentalists. Cotgrove labels these people as liberal environmentalists (this dichotomy corresponds to the order/liberation distinction we made in reference to the grid/group diagram).

"By contrast, the 'eco-activists', 'eco-freaks', and other environmentally oriented expressions of the counter-culture are opposed to almost everything that the traditional community stands for. Indeed many of its activities - the challenge to traditional sexual ethics, the use of drugs, the rejection of hierarchy and institutionalised rule-governed behaviour in the pursuit of liberation - are amongst the indicators of social pathology which traditional environmentalists' reassertion of community seeks to cure." Cotgrove (42)

However, despite these important differences, like the traditional environmentalists these groups too were opposed to reductionist modes of thought. They believed that the apprehension of the world required an ecologically oriented holistic way of thinking. It is therefore not surprising that the world modellers' concern for nature, coupled with their systems approach, should have proved appealing.

Finding society (the centre) oppressive, some liberal environmentalists opted for a survival strategy which often took one of two forms. Firstly, some formed border groups or even withdrew into self-sufficient communes and adopted alternative philosophies and lifestyles - sometimes with a strong religious orientation, typically culled from
Eastern thought. These people became, or wanted to become, a small group or sect. Enzensberger refers to them as "eco-freaks".

"They live in rural communes, grow their own food, and seek a 'natural way of life'. Their class background corresponds to that of the hippies of the 1960s - of reduced middle-class origin, enriched by elements of peripheral groups." Enzensberger (43)

Such people would typically have come from social environments which were individualist (including strong grid) or insulated. The move to form groups would appear to show the lack of personal bonds and the experience of control by impersonal rules. If members from individualist environments, their action corresponds to a rejection of the competition it involves - a renunciation of its rewards and a longing to escape its pressures.

Once formed into sects, the sectarian would have perceived a strong boundary between themselves and the outside (the centre). The catastrophe predicted by the models would have been a powerful reinforcement of this boundary. Indeed, Douglas suggests that the stronger the boundary is, the greater is the degree of hate and vengeance with which prophetic threats are loaded. Hence the world models would have been appealing not only because they could be seen to justify the withdrawal from society, but also because they resonated with this potent element of small group cosmologies. In Risk and Culture Douglas herself discusses the sectarian nature of some environmentalist groups - such as Friends of the Earth. They are considered to adopt typical border strategies - "attacking centre programs on behalf of nature, God, or the world is a border strategy". Further, she asserts that

"Foe maintains an almost utopian vision of future society in which all forms of life will exist harmoniously without political, economic, and technological restraints. We hear the sectarian overtones of love, cosmic unity, and resistance to centre machinations." Douglas and Wildavsky (45)

A second survival strategy was to 'drop-out' on an individual basis, often with the proposed aim of self-discovery. This was sometimes allied to the use of 'mind-expanding' drugs which would allegedly enable the user to peer beneath the mask of society and discover his or her true unity with nature and the cosmos. To these people the LTG message could have reinforced their unease and encouraged personal survival as the

*As we saw in Chapter Four, Meadows too spoke of Eastern philosophy and its view of nature.
most immediate task. But its holistic approach to the relationship between man and nature may also have been alluring because it would seem to be divorced from the oppressive rationality which such people attributed to the centre.

In most cases these responses bear out, and in no instance refute, the general styles of the expectations set out in the previous section. Although we have only looked at a few cosmological characteristics it would of course be possible - as we did in the case of SPRU - to carry out a more detailed analysis.

Though we have primarily focused on the differences between responses to the models, the selected examples mostly share the conviction that the present world situation is problematic. Further, they all have their own particular prescriptions for a better future - prescriptions which may take the form of a new utopia or a revival of the utopia perceived in past traditional societies. The different views - from technocratic optimism and the promotion of unrestrained growth, through the idea of directed growth and the meeting of basic needs, to the call for an end to growth - are complemented by different beliefs about nature and society. In concert, these beliefs led to various interpretations of the world modellers' message from which disparate inferences were drawn. For example, we have seen that the idea of ending growth was a feature of the authoritarian utopias advocated by Goldsmith, Hardin, and Opnuls, in which man would yield to natural laws. Thus, the most positive responses to the message coincided with posited utopias which, being implicitly marked by strong grid and group, had something in common with the equilibrium state adumbrated by the system dynamicists. In contrast, those who advocated more libertarian forms of utopia - in which grid and group would presumably be weaker - placed an emphasis upon directing growth for human purposes.

We might also mention that the focus on society as a systemic whole appears amongst many of the responses. As we implied earlier, the systems view of society may tend to negate the idea of class conflicts and as such its apolitical - if not suprapolitical - stance appeals to certain people.

At a deeper psychological level, it may be that they seize upon the LTG message because it absolves them of complicity in the global problems with which they are concerned. By ignoring the role of conflict amongst the causes of contemporary problems, people can ignore their own complicity in them - or at least their own individual helplessness in the face of such problems and conflicts. Of course this does not mean...
that such groups absolve themselves of blame entirely. Quite the contrary, the stress upon system interdependence - often allied to the rhetoric of 'we are all in the same boat' - admits of blame, but because it is equally apportioned it therefore becomes its own negation.

Thus the surface features of different reactions conceal certain similarities. In the following section we will consider deeper social and psychological needs which underpin them. We will begin by discussing the millenarian overtones of environmentalism. We have seen that for different reasons, different cosmologies may be open to prophecies of the total transformation of the world. This begs the question of whether the message 'caused' a millenarian reaction amongst environmentalists and others?, or whether it merely reverberated amongst groups whose marginality had already confirmed their beliefs that a new world order was at hand?

Our final task is to return to the passive response to the message which we discussed in connection with insulated cosmologies. We are primarily interested in the unquestioning acceptance of the message and a willingness to adjust to its policy recommendations. As with millenarianism however, this type of response may not be confined to the insulated cosmology. We contend that the millenarian and passive responses share some interesting characteristics, even though one may lead to radical actions and the other does not. This is because they both indicate the search for a belief system which will endow the world with meaning and coherence. In other words, they are based upon similar social and psychological needs. This is the theme we explore in the last section.

6.5 DEEPER SOCIAL AND PSYCHOLOGICAL QUESTIONS

In his discussion of the LTG debate, Sandbach refers to Barkum's thesis that the environmental movement was a millenarian one. Though a detailed examination of this idea would go beyond the scope of this dissertation, nevertheless Barkum's conjecture does have some relevance for anyone seeking an understanding of the social effects of the world models.

Barkum links millenarianism to disasters and has suggested that real or imaginary disasters reduce people's threshold to susceptibility by exploiting their fears and anxieties. Further, he argues that people are then more readily moved to "abandon the values of the past and place their faith in prophecies of immanent and total transformation."
Disasters may take many forms; amongst others, Barkum refers to natural catastrophes, demographic shifts, economic depressions, and industrialisation. But also, he suggests that in some societies people experience a prolonged sense of unease and uncertainty (a non-specific "sense of dread") which similarly increases the plausibility of impending disaster.

In reference to America's recent history he describes the cultivation of a "disaster imagination", elements of which include nuclear holocaust, over-population, race war, and ecological imbalance. Thus we can see that the global collapse associated with the message of the world models fits in with this picture very well; the credibility and appeal of the message being dependent upon its efficacy in touching existing fears and anxieties. Are we then to conclude that the world models helped to cause a millenarian outburst? In fact, this is too simple a picture - to understand why, we must refer to Barkum's theoretical assumptions.

One major problem with Barkum's thesis is that it stems from functionalist premises and implies that the normal condition of society is some kind of steady state. Disasters, of whatever form, are seen to disturb this equilibrium and precipitate millenarian outbursts. Secondly, whilst there may indeed be a historical correlation between disasters and millenarian movements there is not necessarily a causal relationship.

Another view of millenarian movements has been developed by Cohn, who offers a socio-psychological account in which he seems to suggest that such movements are a collective delusional action, a form of paranoid fantasy which seeks to alleviate the anxiety attendant upon the various contrary experiences, deprivations and disasters in the societies in which they occur. In other words, they are a means of meeting certain psychological needs.

"This phantasy performed a real function for them, both as an escape from their isolated and atomized condition and as an emotional compensation for their abject status..." Cohn (49)

Douglas refers to Cohn and argues for a more sociological interpretation of his material - drawn largely from millenarian movements in the middle-ages. She pinpoints weakness of social structure as a common element in the movements he has documented. Douglas' account of millenarianism, however, stands in sharp contrast to Barkum's functionalist thesis. For her, the contextual sources of millenarianism are located in the social structure itself. Indeed, certain societies
are conjectured to be actually prone to millenarianism. This still allows a role for elements such as disasters, real or imagined, and deprivations; but in her analysis the role is that of a triggering agent rather than an external perturbing force in an otherwise well-balanced system. This brings us back to our discussion in Section 6.2 where we referred to Douglas' idea that the "chasm" perceived by the ecologists is complemented by a chasm in knowledge itself; thus, the millenarian aspects of environmentalism are located in the lack of structure in modern societies.

"[F] or lack of a discriminating principle, we easily become overwhelmed by our pollution fears...An unstructured society leaves us prey to every dread. As all the veils are successively ripped away, there is no right or wrong. Relativism is the order of the day." Douglas (50)

Douglas' position offers a better way of considering the relationship between the world models and the millenarian features of environmentalism. She contends that the lack of strong social articulation leads people at the fringes of society to express their marginality in millenarian movements. In becoming converted to such movements, people express the need for a more meaningful belief system, one which offers redemption and an alternative to the lack of coherence in their lives. In this respect, therefore, the world models carried a message which mapped onto the contemporary millenarian tendencies of the period. The message should not be considered as a solitary, independent triggering agent - an imaginary disaster as it were - but as a social product of the times, and a knowledge resource for symbolising those times, which both explained them and provided a vision for the future.

Ironically, despite the fact that the message was taken up by various millenarian groups, it was not the intention of the system dynamicists to promote mass collective radical action. Rather, to a certain extent they sought to solicit individual actions which would secure a future equilibrium states. To be sure, some did draw radical conclusions from their message, but with Forrester in particular we find a primary emphasis upon individual values, self-restraint, and the forlorn of aspirations. This focus upon individual adjustment and subordination to the requirements of the proposed equilibrium society has direct parallels with the hypothesis that systems analysis and popular ecology have authoritarian implications. This idea has been echoed by a number of writers; or example, Lowe and Worboys assert that popular ecology represents a deeply conservative response to a perceived crisis of authority in Western societies51. Also, we might add that the
development of systems analysis and its extension into many different areas of social management has been seen by some as a reflection of increasing authoritarianism.\textsuperscript{52}

Whilst the authoritarian implications of systems analysis and popular ecology are relevant to the social effects of the world models, we cannot hope to cover so much ground here. However, one important effect which we can consider is the unquestioning individual adjustment (though perhaps on a mass scale) to the message of the world models. This is particularly relevant when we bear in mind the authoritarian overtones of some of the policy recommendations explored by Forrester.\textsuperscript{53} Whilst this type of response is different to that of millenarianism in terms of the social actions which ensue, we contend that it may reflect some similar social and psychological needs. Further, like millenarianism this type of response may be deemed to be non-rational. For example, it might be argued that the LTG message has both a rational and non-rational aspect; it is rational to be concerned about the environment but arguably non-rational to think that the question of ecology or the environment is above or beyond politics.

"If the ecologists are right about the crisis facing spaceship Earth, this is not the time to move beyond politics or to end politics. If they are right, we are challenged to excruciatingly political decisions about the distribution of power on this planet." Neuhaus (54)

Our notion of rationality and non-rationality should not be taken in any absolute sense, for it would be incorrect to dismiss certain strands of environmentalism, including the world models, as non-rational and just leave the matter there. Rather, we should try to understand all beliefs as a 'rational' way of coping with certain situations. We have already suggested that the mechanisms of projection and displacement have a bearing upon the apolitical overtones of the LTG message and it is to these and similar phenomena that we must look to gain an understanding of the passive response.

6.6 SYSTEM DYNAMICS AND ASTROLOGY

How are we to understand the mixture of rationality and non-rationality in the responses to the LTG message? And, why should people respond positively to its authoritarian implications? In fact, this type of

\textsuperscript{*}In Chapter One we discussed Forrester's policy options for securing world equilibrium; he suggested, for example, a reduction in food production.
reaction has been discussed before by the critical theorist, Adorno, who studied various mass movements in the 1950s with the aim of investigating "the nature and motivations of some large-scale social phenomena involving irrational elements in a peculiar way - fused with what may be dubbed pseudo-rationality."55.

One aspect of Adorno's work focused upon the content of newspaper astrology columns and various astrological magazines. He was interested in the social and psychological needs which they exploited and saw astrology as a key to understanding certain mass movements. Astrological beliefs were seen as a symptom of something that was of greater importance within the wider culture of contemporary North American society.

"We want to analyze astrology in order to find out what it indicates as a 'symptom' of some tendencies of our society as well as of typical psychological trends amongst those this society embraces." Adorno (55)

Adorno viewed the non-rationality of the source of astrological knowledge as merely a minor part of its non-rational content; he held that the greater part was due to the fact that it represented a self-defeating over-extension of self-interest.

"Overly shrewd concentration on self-interest results in a crippling of the capacity to look beyond the limits of self-interest and this finally works against itself. Irrationality is not necessarily a force operating outside the range of rationality; it may result from the process of rational self-preservation 'run amuck'." Adorno (57)

Adorno contended that the aid and comfort offered by astrology requires adjustment to the absurd and contradictory nature of society as seen by many people. The astrological adept behaves rationally to the extent that they are concerned with themselves and controlling their life, but this is done by conforming to existing conditions rather than by seeking to change or question them. Again, this is perhaps the more interesting aspect of astrology and one which is present in the message of the world models as well. It is this feature which differentiates its implied social effect from millenarianism - where mass collective radical actions may ensue.

Adorno's study of astrology was in the 'critical' tradition of the Frankfurt School of which he was a former director. One important consequence of this was that he maintained that astrological beliefs could only be understood in relation to social reality as perceived by their adherents. The ultimate explanation for such beliefs was thus held
to lie in society itself rather than in the psychology of the individual believers. This sociological orientation is in keeping with our own theoretical position.

In connection with his methodological stance, Adorno discussed the idea of the "opacity" of the social world; he contended that society appeared inexplicable to many people, by which he meant that they could not understand its workings, it appeared opaque. Further, he argued that astrology "mirrored" the opacity of the empirical world and was therefore accepted by sceptical, disillusioned people.

"It may also be mentioned that the modern science, which has replaced more and more categories which once interpreted events as though they were meaningful, tends to promote a kind of opacity which at least for the uninitiated is hard to distinguish from an equally opaque and non-transparent thesis such as the dependence of the individual human fate from stellar constellations." Adorno (58)

His point is that although a critical person may perceive the deficiencies of astrology, some people see no difference between its postulates and those of modern science. Thus, ordinary people may accept systems of delusion because it is too difficult to distinguish such systems from the opaque system in which they actually live out their lives. Just as the paranoid interprets his or her world in an extremely egocentric manner, the astrological adept displays a similar tendency. Yet, ironically, each belief system is a way of coping with life.

Our conjecture is that Adorno's study affords some illuminating insights into the nature of system dynamics and the public response to the message of the world models. He was interested in the psychological susceptibilities and social needs that are exploited by cultural phenomena such as astrology, and we are interested in examining the similarities between astrology and system dynamics to see if the latter fulfills or exploits similar social and psychological needs.

One way of structuring the task is to consider the comparison along the following lines. Firstly, we will examine two specific features of the style of their respective messages - namely, the way in which each seems to be derived from an abstract source of authority, and the sense of impending doom which pervades their respective predictions. Secondly, we will refer to their structures as belief systems; in particular we will discuss the way in which they offer a coherent picture of the world.

The notion of opacity may be particularly relevant in the case of people with insulated cosmologies.
which is based upon a holistic fusion of physical and social reality. We will also refer to the mechanisms of projection and displacement. Thirdly, we will turn our attention to their social effects: this will include the solicitation of individual adjustment to social conditions (rather than radical change), together with the expression and reinforcement of people's sense of dependence or helplessness.

6.1 **MESSAGE STYLE**

(a) a source of abstract authority

Adorno's study was restricted to those people who take astrology for granted, just like other aspects of culture such as economic forecasts, the cinema or music. Astrological advice mediated through newspaper columns, is seen as emanating from a depersonalised source - the stars - and is interpreted by an expert. Adorno considered astrology columns to be an abstract source of authority:

"[which] attempts to satisfy the longings of people who are thoroughly convinced than others (or some unknown agency) ought to know more about themselves and what they should do that they can decide for themselves."

(59)

Our argument is that scientists and computers are similarly surrounded by myths which also serve to portray them as abstract authorities. Just as there is no way of arguing with the advice of astrology columns, there is (for most people) no way of challenging the authority of a computer: indeed, for some it stands as a symbol of legitimacy. On the one hand, computers have become increasingly employed in all sectors of society, and yet on the other hand a remarkable degree of mystique and ignorance surrounds them. Popular names and images such as 'robots' (an obvious human projection) and 'brain', only serve to perpetuate the myths. Also, the media abound in reports containing statements such as "computers show that...", or "computers predict that...". The devices themselves are often made the subject of the sentence whilst the people who program them remain hidden or appear as mere interpreters. Because the LTG message was based on computer simulations it is suggested that the aura surrounding the world modelling project exploited the same susceptibility to 'authoritative sources' as that exploited by astrology columns.

*The tradename of one contemporary microcomputer is 'Newbrain', another is known as 'Superbrain'.
Another obvious similarity between these two belief systems is the element of doom which guides their respective predictions. Discussing the nature of the imagery employed by the astrologers, Adorno suggests:

"[That] the heavy employment of the 'impending doom' device is hardly accidental. It encourages the addressee's destructive urges and feeds on their discomfort in civilization, while at the same time stirring up a bellicose mood." (60)

Here Adorno is referring to Freud's theory of the death instinct. Without being drawn into the controversy about the existence or otherwise of such an instinct, we can at least draw a parallel between "destructive urges" and the contemporary interest in disasters. In fact a similar element has been observed by Enzensberger who has conjectured that scenarios of eco-catastrophe played upon the "delight in the collapse of things" which many people appear to harbour.61

Returning to Douglas' ideas, we can interpret this reaction as part of a backlash against strong grid social environments, or the expression of the hatred and loathing accompanying the boundary which closes off small group social environments. Whatever the fundamental explanation of people's interest in disaster, it is suggested that the images of catastrophe carried by the LTC message exploits that interest in the same way as does astrology.

In addition to articulating threats, both astrology and system dynamics present a remedy as well: each claims to have knowledge that can be used to exert a measure of control over our lives.

STRUCTURES AS BELIEF SYSTEMS

(a) the offer of coherence

The appeal of astrology lies in the fact that it transforms "free-floating" anxieties into a definite symbolism; it offers coherence in a world where none may seem to exist and it attracts those who are searching for a meaning to existence.

"[I]t also gives some vague and diffused comfort by making the senseless appear as though it had some hidden and grandiose sense while at the same time corroborating that this sense can neither be sought in the realm of the human nor can properly be grasped by humans." Adorno (62)
System dynamics also offers the promise of coherence by purporting to explain the cause of many disparate social problems and in locating this explanation at the level of the global system, mankind, and nature, it furnishes it with ultimate legitimacy. Moreover, we should not forget the system dynamicists claim that the human brain is incapable of following the behaviour of a complex feedback system and that computers must be employed to perform this function instead.

(b) crude holism

Both astrology and system dynamics force together separate fields of enquiry. Astrology attempts to conflate psychology with astronomy, whilst system dynamics forces together the properties of physical and social reality - e.g. of electronic and social systems - under the mantle of a general systems theory.

Astrology occupies a gap in knowledge left by the division of labour in science, a gap which is located between astronomy and psychology. The conflation of these two sciences is 'non-rational' and another source of the mystery which surrounds astrology, in that it interrelates fields which, at the present state of knowledge, cannot meaningfully be integrated.

System dynamics too, occupies a gap - that between all the disciplines which it attempts to interrelate. It also has mystical overtones derived from its appeal to notions of nature and its offer of insight into the workings of the world, an offer which is based upon an allegedly new way of thinking.

Although appearing to be a source of mysterious knowledge, astrology sometimes attempts to portray itself as a science. From one point of view it represents a logical outcome of a mechanical deterministic approach to science: human fate is seen to be ruled by the stars which are themselves ruled by mechanical laws. Similarly with system dynamics: though it rejects a linear monocausal approach, it reduces social phenomena to the determined behaviour modes of feedback systems. Whilst appearing to be based upon a different way of thinking (a holistic systems approach) it reduces the intricacies of social reality to the simpler properties of physical reality. This echoes Adorno's description of astrology as being something which reduces "the complex to 'simple and mechanical' inferences, doing away with anything that is strange and unknown and at the same time fail(s) to explain anything".63
Astrology claims to have an insight into the fate of mankind; yet we can see that it in fact projects the social world onto the heavens and therefore displaces a more objective explanation of the events in people's lives.

"Superstition is insight, because it sees together the ciphers of destruction scattered on the social surface...from the transfigured society, whose forms it has projected into the skies, it promises itself the answer that could only come from real society." Adorno (64)

If people wish to understand their own lives, or the world around them, they cannot find the answer in the stars, for the real explanations are more likely to lie in society itself. The projection of social phenomena onto the movements of the stars is paralleled in system dynamics by the projection of social problems and human characteristics onto the properties of feedback structures and nature.

"The battle between the forces of growth and the restraints of nature may be resolved in a number of ways." Forrester (65)

"But the complex system is far more devious and diabolical than merely being different from the simple systems with which we have experience." Forrester (66)

"To make matters still worse, the complex system is even more deceptive than merely hiding causes." Forrester (67)

Moreover, it also purports to explain the "ciphers of destruction"; bringing together all the disjointed and contrary events and experiences within modern societies, it offers an 'insight' into the workings of the global system which generates them. It neatly summarises all the feelings of malaise and the attendant premonitions that something cataclysmic is about to happen. Forrester believes that system dynamics offers a way of explaining a vast array of different things—from revolutions and economic crises, to global interactions and social evolution. It offers a panacea which promises to render all social problems intelligible.

6.3 SOCIAL EFFECTS

We have already suggested that astrology and system dynamics encourage individual adjustment to existing social conditions rather than radical change. This is a crucial similarity in their social impact and is
complemented by the way in which they may function as ideologies which make conditions bearable. With astrology, this particular aspect of Adorno's thesis rests upon the concept of dependence. He discussed the dependent state of modern man, "caught by a world of administration" where people feel as if they were powerless pawns. (Here we have a similarity to strong grid and insulated cosmologies.)

Although men have always been dependent upon each other, this fact was once masked by the market which intervened in the interaction between people. Though modern man may in fact be no more dependent than his ancestors, Adorno argued that he experiences his dependence in a more personal and conscious way. In giving credence to astrology, people express their sense of dependence by seeking to attribute it to a higher and more justifiable source.

"If the latter would fully admit their own dependence on man-made conditions, they would somehow have to blame themselves, would have to recognize not only their impotence but also that they are the cause of this impotence and would have to take responsibilities which today are extremely hard to take." Adorno (69)

This brings us back to the concept of displacement which we discussed earlier. In attributing dependence to the stars or to nature and feedback systems, people can justify it whilst avoiding the admission that they are themselves partly causes of it. Further, these beliefs function in such a way that they reinforce the dependence.

"What drives people into the arms of the various 'profets of deceit' is not only their sense of dependence and their wish to attribute this dependence to some 'higher' and ultimately more justifiable sources, but it is also their wish to reinforce their own dependence..." Adorno (70)

Adorno asserted that astrology could not just be interpreted as an expression of dependence, but also as an ideology for dependence: "an attempt to strengthen and somehow justify painful conditions which seem more tolerable if an affirmative attitude is taken towards them".71

System dynamics can also function as an ideology for dependence, and therefore encourages acceptance of the status quo rather than the collective radicalism found in millenarian movements. Forrester claims that in choosing the system mode we wish for our social systems we also choose the pressures under which we must live. If people accept this they are forced to take an affirmative attitude to pressures and stresses.
System dynamics offers to bring structure and coherence into the uncertainty of a crisis-ridden world. By forcing the realisation that pressures and stresses are inevitable they become less debilitating. Instead of leaving people prey to the chaos of seemingly disjunct fears and anxieties, it introduces an element of certainty which is rooted in the 'grand' concepts of nature, the global system, and mankind; this brings comfort and strengthens the conviction to face up to an existence under pressures, self-restraint, and the forfeit of aspirations.

In projecting their dependence onto the global system and nature, the powerlessness which people feel becomes more dignified. Curiously though, whilst the LTG message resonates with their intuitive feelings of dependence, it also seems to make them appear important. This is because the viability of the proposed equilibrium society requires individual acts of adjustment. Thus, while the message reflects the social world as it appears to some people, it also counteracts their credibility by appealing to their sense of (or wish for) personal importance. Making the powerless feel important is of course another aspect of astrology, for while human fate is thought to be governed by the heavens, each horoscope is ultimately individual.

6.7 SUMMARY

The main points to emerge from this chapter are that the social effects of the message of the world models were neither simple nor isotropic within its target audience. (Further, to the extent that the debate still persists, these effects may be detected as long as discussion continues.) The message resonated within a social context in which certain groups were looking for a coherent view of global problems, and system dynamics offered a suitable mapping of the world which was appealing for a variety of social, political, and psychological reasons. The environmental debate - to which the world models were a stimulus - was a forum for different political interests where various groups employed different conceptions of the environment, including different interpretations of the message, in order to argue for their own particular goals. Further, we have seen that these conceptions can be distinguished by considering the cosmology employed by the groups involved, and that this also informs their specific interpretations. (In other words, the message did not simply diffuse amongst different groups, but was subject to various esoteric interpretations.)

The world models played upon certain social and psychological needs which are particularly pertinent to the millenarian and passive
responses. System dynamics offers a belief system which shares important similarities to that of astrology, both in terms of style, structure and social effect. Moreover, the analogy with astrology not only illuminates the social and psychological function of system dynamics within the passive response, for it also increases our understanding of the other responses too. A belief in immanent catastrophe has a social dimension, but we have seen that it also has a psychological basis in a fascination with destruction. This is also the case with the need to maintain cognitive security.

We have tried to open up an area for discussion and further research on a topic where we feel that the conventional explanations for the appeal of the world models have not done justice to the variety of social and psychological factors which are implicated in the various responses of different groups. On the negative side however, it must be said that our discussion remains somewhat speculative, especially with regard to the millenarian and passive responses. Also, our approach to the question of social and psychological needs has begged deeper questions about the relationship between the domains of sociology and psychology. In fact, the arguments presented here address the area of overlap between the two - namely, the relationship between individuals and their 'ego' oriented needs and susceptibilities, and their socially constructed views of the world. Douglas has hinted at this overlap and suggests that one could map the "classic psychoses" onto the different social environments of the grid-group diagram\(^2\). Whilst we have not gone this far we have implied that certain social environments may accentuate specific psychological needs.

Whilst the discussion in this chapter has provided new perspectives on the impact of the message of the world models, it also implies questions concerning the problems of credibility faced by those members of the systems community who deal with research into global problems. More specifically, the example of the reception of the world models illustrates the fact that those who construct esoteric models of the world can not control how they will be interpreted. We have seen that not only did the social and political interests of the various groups amongst the target audience act to influence how the message was interpreted, but so too did their more general social and psychological needs - which must themselves be considered in relation to the specificities of the social fabric of the time. We have not, of course, answered the problem of credibility, but we have illustrated some of the important features which pertain to it.
CHAPTER SEVEN

CONCLUSIONS
Before proceeding to a general discussion, we will recap on the main parts of the argument developed in the preceding chapters.

Our investigation has shown that system dynamics cannot be narrowly defined as a mere technique and is best viewed as a body of knowledge with several dimensions - each of which makes sense only in relation to a specific nexus of questions. In other words, system dynamics is not a 'thing in itself'; rather, its perception depends upon one's perspective. For example, technical questions about the computer simulation stages of system dynamics modelling fall within the appropriate domains of mathematics and computer science. This, however, is not an area which interests us here; we have sought to address quite different questions. Thus we have shown that system dynamics may be considered as a social theory - a social cosmology which mediates and reinforces specific patterns of social relations, or as an ideology which functions so as to enable people to adjust to and accept existing social conditions in respect of society's dominant institutions.

We began the analysis by drawing an analogy between the worldviews of Forrester and Parsons. This showed that they share a number of important theoretical beliefs and value orientations, and this gave us the idea of seeing whether - like Parsons - Forrester too could be considered to be located within a middle-class conservative tradition which is primarily concerned with the problem of maintaining social order. Looking at the development of system dynamics, we saw that this idea could enable us to explain its inherent theoretical shifts and domain expansions.

The development of system dynamics has been marked by its extension to new domains - from the corporation, to the city, the world and national economies - with consequent expansions of its theoretical core. Each new application has been addressed to a specific social crisis, which it has sought to ameliorate without challenging the controlling institutions of society. In each case Forrester's basic concern has been the restoration of social order. With the emergence of the world model he raised the idea of arresting economic growth. The environmental crisis was perceived as a portent of severe social breakdown and the preservation of social order was again of the imperative - even if it meant halting growth, which would challenge both the short-term interests of capitalism and its traditional growth-oriented ethos.

Of course halting growth could conceivably undermine the whole logic of capitalist production, as Habermas as pointed out:
"Capitalist societies cannot follow imperatives of growth limitation without abandoning their principles of organization; a shift from unplanned, nature-like capitalist growth to qualitative growth would require that production be planned in terms of use values. The development of productive forces, cannot, however, be uncoupled from the production of exchange values without violating the logic of the system." (1)

Whether Forrester himself perceives this implication is another matter; his views on halting economic growth are a reflection of his deep commitment to social order rather than a challenge to capitalism per se. It does show, however, that his thought has a certain detachment in relation to capitalist interests.

Our next task was to obtain a more detailed description of the system dynamicist's style of thought and the social structure which they occupy. To do this we employed Douglas' theory of cosmologies and compared the System Dynamics Group with the Science Policy Research Unit. We showed that on three different levels - thought styles (including questions of modelling methodology and response to theoretical anomalies), the content of cosmologies, and social experience - we could reach the same conclusions about the relative grid/group position of each group. On each level we found that SDG were in a relatively higher grid/group position than SPRU. The evidence marshalled in Chapter Four represents the most detailed and substantive empirical basis in the dissertation, and therefore bears the main load of its claim to originality.

We used the idea of the dichotomy between object and person-oriented elaborated codes to throw some light on the divisions between the system dynamicists and some of their critics. We argued that their style of thought is concerned with relationships between objects which are perceived within an underlying universal scheme which endows overall cognitive coherence. This scheme includes the properties of feedback systems and it underpins their conviction that the world has a rational foundation. Some of their critics, on the other hand, perceive no such universal scheme and draw attention to the non-uniformities and particularities of the world.

Forrester has no doubts about the efficacy of system dynamics. For him and his fellow system dynamicists it describes the properties of a world that is actually systemic. Our explorations of their social cosmology indicates a social component in their unshakeable faith - it is correlated with their social environment; the greater fixity of their cognitive categories vis-a-vis our control group (SPRU) correlate with
In Chapters Five and Six we investigated the social effects of system dynamics. Some of these have been potential rather than actual and our discussion has therefore encompassed speculative areas. For example, on the question of the use of system dynamics for policy formation, we sought to develop a picture of the social implications indicated by our adopted framework. Given the lack of empirical evidence (itself a consequence of the very nature of the politics of expertise) we have tried to focus upon some of its interesting features in so far as our theoretical position is relevant to them. Thus, we have argued that a system dynamics model may not only be aimed at policies for social cohesion - through economic, social, and political measures - but may also be used to negotiate consensus through education. This brings us back to the difference between system dynamics and those 'techniques' which remain solely esoteric or narrowly technical; system dynamics aims to map out the policies for the control and management of social systems, but also seeks incorporation in curricula at all levels of education. The teaching of system dynamics - and therefore socialisation into the cosmology and linguistic code that carry it - would aim to secure a broad social consensus.

Further, at different levels within the education system we would expect to find different roles implied by the knowledge being disseminated. At the lower levels we would expect to find the knowledge geared towards its passive acceptance along with the rest of the curricula. Forrester believes that only a few people have the special skills which are required for practising system dynamics; thus at the higher levels we would find the elite - the prospective system managers or controllers.

If we refer once more to Bernstein's work for a moment, we can pin-point another interesting facet of the teaching of system dynamics. Bernstein has argued that most subjects are hierarchically ordered so that as one ascends the educational ladder the "ultimate mystery" of the subject is only revealed at a late stage. This mystery is not however revealed as order or coherence, but rather as disorder - i.e. sophistication involves an appreciation of the very provisional and contingent nature of our knowledge. For example, a young budding physicist may believe that he or she will ultimately discover the truth of the universe when the top of the educational ladder is reached; however, he or she eventually finds that truth is not quite all that they had been led to believe. For the majority however, the picture is different because they never reach this insight.
"For the many, socialization into knowledge is socialization into order, the existing order, into the experience that the world's educational knowledge is impermeable." Bernstein (3)

Returning to system dynamics we can suggest that its social and educational implications are somewhat at variance with those outlined by Bernstein. Rather than revealing disorder and the provisional nature of knowledge, system dynamics seeks to consolidate order - the general or universal order which underpins all systems. Even for those at the higher stages - such as Forrester and others in the System Dynamics Laboratory - this is the quintessential feature of system dynamics, and so we can suggest that its educational dissemination carries no potential for ultimate critical reflection. Hence, as with those at the lower stages, those who are trained to be practising system dynamicists would share the same socialisation into the notion of the coherence and permanence of their knowledge.

In our discussion of Forrester's urban modelling we set out reasons (e.g. because he argues that urban policies should be in line with natural goals) why his policy recommendations could be perceived as legitimate by politicians and the electorate. We further argued that these reasons are pertinent to system dynamics in general. Douglas contends that men use their cosmologies in order to coerce each other, that they make appeals which usually contain some reference to either time, money, God, or nature. Our analysis of system dynamics shows that we can find all four elements. Taking time first; the system dynamicists argue that time is not on man's side, that the outcome of his action can take many years to produce their full effect. Thus, although their prophecy of world catastrophe located it sometime within the coming century, they argued the necessity for taking action now. The monetary dimension can be discerned in the stance against massive financial programs for alleviating the problems of cities and the belief that successful schemes must be intrinsically low-cost. Thirdly, though the concept of God is not employed in any direct way, we have noted Forrester's discussion of the prominent role of religious institutions in any future equilibrium society. Lastly, we come to nature: system dynamics is imbued with unambiguous views concerning the natural ordering of the universe; whether it is the necessity of urban pressures, urban goals, or a world equilibrium, all are perceived as being a reflection of the natural state of affairs.

The arguments presented and developed in Chapter Six have been the most speculative. The scope of the problem of understanding the effects of the world models was both challenging and somewhat daunting in its
prospect. Despite this, we sought to explain some of the more manifest features of the episode, such as the differential interpretation of the message. Moving on from this we raised the question of millenarianism and therefore issues about the general social context of the time. While avoiding the inference that the prophecy of catastrophe has caused a millenarian outburst amongst the young and disaffected, we nevertheless contended that it did provide a convenient focal point, as well as a resource for those groups with millenarian tendencies.

Just as millenarians are usually vague about the precise timing of the total transformation which they await, the world models also avoided exact predictions about the date of world collapse. At a deeper level this temporal uncertainty reflected and strengthened a social and psychological uncertainty due in part to the unstructuredness of the social environment within which these millenarian groups resided.

Following on from this discussion, we drew an analogy between system dynamics and astrology which showed that the former had a potential for touching or exploiting other social and psychological needs and susceptibilities. The analogy therefore revealed some aspects of system dynamics - for example, the fascination with disasters - that have not emerged in previous studies.

The most problematic implication to emerge from the comparison between system dynamics and astrology concerns its potential for eliciting the unquestioning acceptance of the proposed policies, and we briefly expanded on this issue in terms of its social ramifications. We drew attention, for example, to the fact that a number of writers had argued that systems analysis had authoritarian implications. Although we did not pursue those arguments, our comparison showed their relevance to system dynamics. Whilst some of those arguments, such as those of the Frankfurt School, are primarily pitched at a philosophical level, they nevertheless overlap with some of the social implications of systems theories which we have uncovered here.

Our avowedly non-philosophical study, based upon social anthropology, has shown that system dynamics has authoritarian tendencies which can be discerned at several levels. Firstly, there is the nature of some of the policy recommendations - from reducing food production to constraining the low-cost housing market. Secondly, there is the abstract form of system dynamics modelling and the air of objective authority which emanates from the use of computers and esoteric techniques. Thirdly, there are the pedagogical and wider consequences inherent in the teaching of system dynamics. Fourthly, there is the role of system
dynamics experts in policy formation. And while we have discussed only the case of system dynamics, it is worth noting that we have also implicitly raised questions about the wider uses of systems theories generally.

We contend that our analysis has fulfilled the three objectives set out in the preface: namely, we have examined the cultural tradition from which system dynamics emerged, and which shaped its development; secondly, we have investigated the relationship between the system dynamicists' social environment and the intellectual style and content of their work and beliefs; and thirdly, we have illuminated the role of system dynamics in mediating and reinforcing different patterns of social relations.

The pursuit of these goals has been effected with the expectations of two academic communities in mind: sociologists of knowledge and systems theorists. In terms of the former, the most elaborate and empirically substantiated argument is that presented in Chapter Four. As for the systems community, we have sought to marshal unconventional tools - drawn largely for sociology and anthropology - in order to explain the development of one specific strand of the systems movement. The construction of this explanation has been informed by the need to provide different perspectives and to adopt a broad holistic view of the problem. Whilst we have not advanced systems theory in itself, we have provided an interpretation of the development of system dynamics which can inform decisions about future goals of the systems movement. Both at the knowledge level of how our social constructions arise, and at the policy level of how social change might be effected, our case study of system dynamics may stimulate some debate concerning key issues central to those goals. Of course this is not to suggest that our account is in any way final. Rather, it is partly in relation to existing accounts that our own is to be judged; this is the theme of the next section.

7.1 RELATIONSHIP WITH OTHER LINES OF ENQUIRY

We have examined system dynamics in relation to various theoretical ideas concerning the relationship between knowledge and social structures. Implicit in what has been said is the awareness that 'knowledge' and 'social structure' are themselves theoretical constructs - abstractions, or fast-frozen glimpses of the much wider and deeper phenomenon which we refer to as culture. In Chapter Two we argued that approaches such as those based upon the internal/external dichotomy, idealism or economic reductionism, could not afford us the understanding
of system dynamics which we sought. We therefore adopted a more holistic, dialectical position, which gave a significant role to knowledge but affirmed that the symbolic life - working through media of expression - is constrained by the limitations of those media which in turn are set by the prevailing pattern of social relations.

The different features of system dynamics which we have uncovered would thus have been closed to us if we had taken any of the other positions discussed in Chapter Two. For example, we have noted Forrester's commitment to capitalism; but we have also seen that this does not exhaustively explain the social underpinnings of his work, which in fact has a certain autonomy from the social context which nurtured it. Other critics have viewed system dynamics purely in relation to capitalist interests; the rigidity of the base/superstructure model which they have explicitly or implicitly adopted has prevented them from seeing that this model cannot account for a number of important features of system dynamics. For instance, they could not explain the moralistic imperatives within system dynamics, nor could they account for the moral compulsion and legitimacy of some of the policy recommendations with which we have dealt, or the variation in beliefs which greeted the world models. Neither could these other approaches explain Forrester's ideas about halting economic growth.

The same applies to those critics whose analysis is grounded in some version of idealism. Their intellectual framework blinds them to the social constraints upon Forrester's thought. To take just one example, idealism cannot explain the system dynamicists' responses to anomaly - particularly in respect of their changing positions as their group came under threat. Moreover, neither economic reductionism nor idealism could account for the domain expansions and theoretical shifts which have marked the development of system dynamics. The same can be said of analyses based on the internal/external dichotomy. Indeed, following Fleck, and in contradistinction to the empirical philosopher's view of scientific development, we might say that both the active and the passive connections within system dynamics have increased during its evolution.

We have also sought to circumvent the problems which arise if the analysis proceeds by trying to establish whether or not system dynamics is science or ideology. For science too is a cultural product, and we have seen that it is not possible to elude the social mediation of ideas concerning pollution, nature, or the relationship of the self to society. Thus, we could not have understood the social effects of the world models if we had viewed them as mere ideology, for our understanding
would only have been tenable in relation to the assumption that there could be a scientific concept of the natural order which was devoid of social implications and meanings. Further, our anthropological approach has revealed the factors which have lent credibility to the message of the world models. The science/ideology dichotomy assumes that scientific knowledge is accepted as being true because of the force of reason. It does not, however, have any substantive hypotheses to explain why so many different groups - including scientists - gave credence to the idea that the world faced a catastrophe. Going beyond the fact that some people perceived the system dynamicists as scientists, and therefore regarded the message as objective, we have seen that the models symbolized the cosmological characteristics of different social environments and were consequently seen to be self-evident by various groups. If system dynamics had been viewed as either science or ideology, then we could not have explained this variation, nor the differential inferences which different groups drew from the message.

Moreover, if we had adopted the received view of the transmission of scientific ideas - typically based on a production-diffusion model - again we would have failed to grasp these specificities. In Fleckian terms, we have shown that the exoteric role of scientific ideas is not one of mere diffusion but a process of multiple interpretation within the self-evidential knowledge system of different exoteric circles.

7.2 RESERVATIONS

Though this amounts to a justification for the approach which we have taken, it is not intended to suggest that we have explained everything, or indeed that other problems have not arisen as a very consequence of our approach. Certainly there are other questions about system dynamics which cannot be accommodated within the scope of our framework. Some of these are due to lack of information concerning the System Dynamics Group but others are methodological in origin. In the first case we have already mentioned (in Chapter Five) that we do not have sufficient data to draw inferences about the consequences of the nature of system dynamics teaching - i.e. in terms of the pedagogical relationship between teacher and taught. This is important because this relationship is one of power; it is a control system which is mediated by the curriculum. As such it is - as Bernstein as shown - another example of the interaction between social relations and symbolic systems. In

*A critique of this model from a Fleckian position is provided by de Vries and Harbers (4).*
principle however, we could discuss this further if the requisite information were available.

On the methodological front, we may note that we cannot adequately deal with the individual variations amongst system dynamicists. Whilst we do not disallow the possibility of dissent amongst the people who embrace system dynamics - indeed, we have noted the differences in opinion concerning backcasting - our theoretical nets cannot capture the specificities of these differences. Rather, it has been public knowledge which has been our concern here.

Another and more complex methodological question centres on the fact that we have relied upon textual extracts for our empirical evidence. Others would demand direct empirical observation or a consideration of more informal sources. Some others would also require us to start not with beliefs as evidenced in texts, but with discourse. Indeed, the development of the formal record of system dynamics which we have sought to explain here is but one type of discourse and so we are not in a position to address other levels.

It may be objected that throughout this dissertation we have been treading a thin line between a socio-anthropological explanation of the development of system dynamics and an evaluation of its content. Whilst we do not deny that a certain evaluative element has tended to follow our arguments - rather like a shadow, now hidden, now exposed - we feel that it has been restricted to the purpose of bringing the system dynamicists' perspective into sharper focus. Thus, if we have said that system dynamics eschews the idea of class-conflicts, we have - to use Mannheim's term - shown its particularity. In other words, we have not been trying to show that system dynamics is either true or false, but rather, that its perspective is particular to a specific style of thought - itself related to a particular social context.

"The different perspectives are not merely particular in that they presuppose different ranges of vision and different sectors of the total reality, but also in that the interests and powers of perception of the different perspectives are conditioned by the social situations in which they arose and to which they are relevant." Mannheim (5)

There is also another sense in which this dissertation has been evaluative; this has surfaced in connection with our discussion of the social effects of system dynamics where we pointed to its theoretical closure and potential authoritarian characteristics. We feel that these were a legitimate subject of investigation, but in the very act of
unmasking them we have inevitably made evaluations. To balance this we may assert that other theoretical beliefs have their own particular closures too. Further, we have focused upon the disadvantages of a cosmology marked by higher grid and group than our selected control, but in fact Douglas' work shows that all cosmologies have their own characteristic problems and woes.

Other critical remarks may be made with regard to the overall theoretical basis of our work. Where this has seemed pertinent – especially in Chapter Four – we have drawn attention to the problematical and less rigorous aspects of our arguments; but there is also the question of the eclecticism manifested in the number of disparate intellectual strands from which we have borrowed in order to expand the scope of the investigation. These strands are variously similar and dissimilar and on certain points we have perhaps given insufficient attention to their critical evaluation. Instead, we have chosen to use them as theoretical tools – if somewhat brutally – in order to develop our case. Given the nature of our subject matter we may perhaps crave leniency and ask to be judged finally on whether we have succeeded in shedding some light on areas where hitherto there has been darkness, confusion or controversy.

7.3 IDEAS FOR FURTHER WORK

Finally, it is also worth briefly mentioning some of the questions which have been suggested by the nature of our enquiry. For example, given that we have identified an implicit social cosmology within system dynamics, we can ask whether it is to be expected that other system dynamics groups may be found in social locations similar to the one attributed to Forrester and his colleagues? Or, in what spectrum of social structures would we expect the system dynamics framework to become consolidated? And this in turn raises the question as to the ways in which system dynamics may become modified because of the different cognitive constraints imposed by alternative social structures. Another obvious line of enquiry to pursue would be to directly investigate the social environment of the System Dynamics Group.

In terms of the sociological study of science, our analysis of the response to theoretical anomalies has shown that the work of Douglas and Bloor may also yield useful results outside the domain of the natural sciences and mathematics. Indeed, our study of system dynamics has shown the applicability of their conceptual tools to a subject breaching the gap between the natural and social sciences. It therefore stimulates
questions as to their potential usage in studying other areas of social science. These questions are for the future, but they show at least that our approach has the ability to set puzzles in addition to offering solutions to them.
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5) R. M. Williams, 'American Society' (New York: Knoff, 1960), 401
CHAPTER ONE

1) These details are taken chiefly from Forrester's curriculum vitae and his book 'Collected Papers of Jay W. Forrester' (Wright-Allen Press, Inc. 1975)

2) This has been discussed by F. Noble in 'America by Design' (Oxford University Press, 1977). In particular, he describes the role of engineering in the development of American corporate capitalism. Although he allows that some engineers were indeed social reformers, he argues that their predominant role was to countenance acceptance of capitalist social relations.

"For them, technology was exclusively a means of strengthening capitalism, rather than something which pointed beyond it. And since they pretty much defined what form technological advances would take, technology tended to evolve in close conformity with capitalist requirements. This is not to say, of course, that they were altogether successful in this regard, that technological progress no longer held out the promise of a new society. Indeed, it was partially for this reason, because it did, that the engineers steadily extended the range of their professional activities to include the deliberate fostering and strengthening of the social relations of corporate capitalism, to encourage working people to work within the system rather than struggling against it, for a better life." Noble (xxiii)

3) J.W. Forrester, 'Industrial Dynamics' (MIT Press, 1961)

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J.W. Forrester, 'Innovation and Economic Change', Futures, August 1981, 323-331
AWARDS

Inventor of the Year Award from George Washington University (1968)

Valdemar Poulsen Gold Medal from the Danish Academy of Technical Sciences (1969)

Medal of Honor from the Institute of Electrical and Electronic Engineers (1972)

Systems, Man and Cybernetics Award for Outstanding Accomplishment from the Institute of Electrical and Electronic Engineers (1972)

Howard N. Potts Award from The Franklin Institute (1974)

Honorary Membership in the Society of Manufacturing Engineers (1976)

Harry Goode Memorial Award of the American Federation of Information Processing Societies (1977)

Induction to the National Hall of Fame (1979)

Common Wealth Award of Distinguished Service (1979)

MEMBERSHIP OF PROFESSIONAL ASSOCIATIONS

National Academy of Engineering

Fellow of the Institute of Electrical and Electronic Engineers

Academy of Management

American Academy of Arts and Sciences

American Association for the Advancement of Science

Benjamin Franklin Fellow of the Royal Society of Arts (London)

American Institute of Physics

American Economic Association
The Institute of Management Science

DEGREES

B.Sc., University of Nebraska, 1939

S.M., MIT, 1945

D.Eng., University of Nebraska, 1954 (honorary)

D.Sc., Boston University, 1969 (honorary)

D.Eng., Newark College of Engineering, 1971 (honorary)

D.Eng., Union College, 1973 (honorary)

D.Eng., University of Notre Dame, 1974 (honorary)

D.Pol.Sci., University of Mannheim, 1979 (honorary)

4) J.W. Forrester, 'Industrial Dynamics' (MIT Press, 1961), vii

5) Ibid., 17


7) Ibid., 136

8) Forrester's reference to K. Lewin actually occurred sometime after "Industrial Dynamics". In his Collected papers, for example, he quotes (p.144-145) from the foreword by Cartwright to a book of papers by Lewin - 'Field Theory in Social Science', edited by D. Cartwright (New York: Harper and Row, 1951)

"The most fundamental construct for Lewin is, of course, that of 'field'. All behavior (including action, thinking, wishing, striving, valuing, achieving, etc.) is conceived of as a change of some state of a field in a given unit of time...in treating individual psychology, the field with which the scientist must deal is the 'life space' of the individual...it is the task of the scientist to develop constructs and techniques of observation and measurement adequate to characterise the properties of any given life space at any given time and to state the laws governing changes of these properties...Lewin's assertion that the only determinants of behavior at a given time are the properties of the field at the same time has caused more controversy than any of his other
systematic principles. This principle asserts that the life space endures through time, is modified by events, and is a product of history, but only the contemporaneous system can have affects at any given time."

9) Forrester, op. cit. note 6, 135


11) Ibid., 107-114

12) Ibid., 9

13) Ibid., 110

14) Ibid.

15) Ibid., 111

16) Ibid., 112

17) Ibid., 3

18) J.W. Forrester, 'World Dynamics' (Wright-Allen Press, Inc. 1971)

19) A. Peccei is an Italian industrialist who is a former director of Fiat and Olivetti. The Club Of Rome describes itself as:

"Not a political organization, either of the right or of the left, but a free assembly of individuals seeking to find a more objective and comprehensive basis for policymaking." King

This is taken from A. King, 'The Club of Rome Today', Simulation in the Service of Society, 1974, 4(8)

See also:


A. Peccei, 'Global Modelling for Humanity', Futures, April 1982

A. Peccei, 'The Chasm Ahead' (The Macmillan Co. 1969)


20) Forrester, op. cit. note 18, viii
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J.M.Richardson, Jr., 'Global Modelling I', Futures, Oct 1978


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26) Greenburger, op. cit. note 23

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T.S.Kuhn, 'Theory Change as Structure-change: comments on the Sneed formalism', Erkenntnis, 1975, 10, 179-199
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M.Douglas, 'Implicit Meanings' (Routledge & Kegan Paul Ltd. 1975)

2) K.Popper, 'The Logic of Scientific Discovery' (London: Hutchinson, 1959)

Popper's demarcation criterion centres on the idea of falsifiability, whereby a hypothesis is judged to be scientific if it is intrinsically open to falsification through empirical testing. Kuhn offers a very different picture of science in which he differentiates between 'normal' and 'revolutionary' science. Kuhn argues that normal science is distinguished by the activity of 'puzzle-solving' in which scientists solve puzzles that have been defined by the tools of the paradigm within which they work. Unlike Popper, however, Kuhn does not see any one criterion as being decisive.

T.S.Kuhn, 'The Structure of Scientific Revolutions' (The University of Chicago Press, 1962)
T.S.Kuhn, 'Logic of Discovery or Psychology of Research', in 'The Essential Tension' (University of Chicago Press, 1977)

3) This idea is derived from Douglas and other work in the sociology of knowledge. For example, Bloor argues - according to his 'strong programme in the sociology of knowledge' - that the same types of causal explanation must be sought in explaining both true and false beliefs.

D.Bloor, 'Knowledge and Social Imagery' (Routledge & Kegan Paul Ltd. 1975)

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7) K.Marx, 'Preface To a Contribution to the Critique of Political Economy' (Foreign Language Press, 1976), 3


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CHAPTER THREE

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This idea is adopted from Gouldner, who has discussed the similarities between Parsons' social systems model and the Platonic concept of 'Eternal' or 'Universal Forms'. See: 'From Plato to Parsons: The Infrastructure of Conservative Social Theory', Chapter 11 of Gouldner, op. cit. note 4.

Both place their central value on social stability and order, on permanence rather than on change and growth. This is clearly inherent in the Platonic Theory of Forms, for these are conceived of as eternal and unchanging. Correspondingly, the Functionalist notion of Functional Requisites specifies Eternal Requisites of social stability, not Requisites of change...Both theories thus focus on the need and strategies for social order and not on the need and strategies for social change." Gouldner, op. cit. note 4, 416-417


A criticism of Gouldner's position on this point is to be found in:


This issue of the AJS also contains other critiques of Gouldner; earlier reviews appeared in Volume 77, No. 1. For other criticisms see:

J.Jurry, 'More Notes on Sociology's Coming Crisis', British Journal of Sociology, 1972, 23, 246-248

In the same series of reviews, a more positive critique comes from S.E.Deutsch, 321-326

For other critiques of Parsons' work see:

C.Wright-Mills, 'The Sociological Imagination' (Pelican Books, 1970), especially the chapter on "Grand Theory".

D.Lockwood, 'Some Remarks on "The Social System"', British Journal of Sociology, 1956, VII, 134-146


For Gouldner's reply to some of his critics:

A.W.Gouldner, 'For Sociology' (Allen Lane, 1973)

28) T.S.Kuhn, 'The Structure of Scientific Revolutions' (Chicago University Press, 1962)

29) Gouldner, op. cit. note 4, 145

30) Ibid., 141

31) Ibid., 142

32) Ibid.

33) Ibid., 434

34) Ibid., 343

35) Ibid., 342-344

36) Forrester, op. cit. note 11, 7

37) Forrester, op. cit. note 18, 44-45

39) Forrester, op. cit. note 9, 115


41) Harwood, op. cit. note 40

42) J.Mercer, J.Hultquist, 'National Progress Toward Housing and Urban Renewal', in J.S.Adam (ed.) 'Urban Policymaking and Metropolitan Dynamics' (Balinger, 1976)

43) Forrester, op. cit. note 11, 276

44) Harwood, op. cit. note 40

45) Forrester, op. cit. note 18, 253

46) Forrester, op. cit. note 11, 7

47) J.W.Forrester, 'World Dynamics' (Wright-Allen Press Inc. 1971), 11-12

48) Ibid., 5

49) Forrester, op. cit. note 18

50) J.W.Forrester, 'Global Modelling Revisited', Futures, April 1982, 107
In order to illustrate this difference, we can refer to Bernstein's example concerning families:

"I shall distinguish between families according to the strength of their boundary maintaining procedures. Let me first give some idea of what I mean by boundary maintaining procedures. I shall first look at boundary maintenance as it is revealed in the symbolic ordering of space. Consider the lavatory. In one house, the room is pristine, bare and sharp, containing only the necessities for which the room is dedicated. In another there is a picture on the wall, in a third there are books, in a fourth all surfaces are covered with curious postcards. We have a continuum from a room celebrating the purity of categories to one celebrating a mixture of categories, from strong to weak boundary maintenance." Ibid., 184

See also:

M. Douglas, 'Purity and Danger' (Routledge and Kegan Paul Ltd. 1966)


M. Douglas, 'Implicit Meanings' (Routledge and Kegan Paul Ltd. 1975)


3) Douglas, 'Natural Symbols', op. cit. note 2, 12

4) Bernstein, op. cit. note 1

5) In describing the development of his work Bernstein (op. cit. note 1, 139) quotes E. Sapir, 'Encyclopaedia of the Social Sciences', 1933, 9

"It is quite an illusion to imagine that one adjusts to reality essentially without the use of language and that language is merely an incidental means of solving specific problems of communication or reflection. The fact of the matter is that the real world is to a large extent unconsciously built up on the language habits of the group"}

6) Bernstein, op. cit. note 1, 144. Quoted in Douglas, 'Natural Symbols', op. cit. note 2, 43-43
7) For a basic discussion of the issues involved, see:

Open University, 'Language and Social Class', E202 Schooling and Society, Unit 23, Black IV (Open University Press, 1977)

8) Douglas, 'Natural Symbols', op. cit. note 2, 44

9) Ibid., 45

10) Ibid., 47

11) Ibid., 80

12) Ibid., 48

13) Ibid., 51

14) Ibid., 52


16) Douglas, 'Natural Symbols', op. cit. note 2, 52-53

17) Ibid., 136

18) Ibid., 81


20) Douglas, op. cit. Note 1, 36


22) Douglas, 'Natural Symbols', op. cit. note 2


26) Caneva, op. cit. note 23, 104

27) Ibid., 114


29) Hampton, op. cit. note 25


32) B. Barnes, S. Shapin, 'Where is the Edge of Objectivity?', British Journal for the History and Philosophy of Science, X, 1977, 61-67

33) D. T. Campbell, '"Degrees of Freedom" And The Case Study', Comparative Political Studies, 8(2), July 1975, 178-193

34) A. Lijphart, 'Comparative Politics and the Comparative Method', The American Political Science Review, 65, Sept. 1971, 682-693

35) A. Lijphart, 'The Comparable-Cases Strategy in Comparative Research', Comparative Political Studies, 8(2), July 1975, 158-177

36) Bloor, op. cit. note 21, 26 Journal of the History of Science, 11, 19, 1978, 26

37) Campbell, op. cit. note 33
Lijphart, op. cit. note 34

Lijphart, op. cit. note 35


40) Ibid., 30

41) Bloor, op. cit. note 21


H.Kahn, W.Brown, L.Martel, 'The Next 200 Years' (Associated Business Programs Ltd. 1976)


P.Checkland, 'Systems Thinking, Systems Practice' (J.Wiley & Sons. 1982), 134-141


47) MIT, 'Report of the Committee on Education Survey to the Faculty MIT' (Technology Press, 1949), 9

48) Ibid., 135

H.A. Shepard, 'The Engineer and his Culture', Explorations in Entrepreneurial History, 41, Series 1, May 1952, 211-219

MIT, op. cit. note 47

50) Ibid., 40

51) Ibid., 89

52) Ibid., 90


MIT, op. cit. note 47, 115

54) B.R. Snyder, 'The Hidden Curriculum' (MIT Press, 1970), 67

55) Ibid., 15

56) E. Zerubavel, 'Patterns of Time in Hospital Life' (The University of Chicago Press, 1979)

57) F.E. Wylie, 'MIT in Perspective' (Little, Brown & Co. 1975)

58) Nunn, op. cit. 46

59) Snyder, op. cit. note 54, 119

60) Ibid., 20

61) Ibid., 71

65) Riesman, op. cit. note 45, 597

Snyder, op. cit. note 54, 73


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64) Snyder, op. cit. note 54, 68

65) Ibid., 91


67) J.W. Forrester, 'Dynamics of Socio-Economic Systems', Proceedings of the Sixth IFAC World Congress, Boston, Massachusetts, Aug. 1975


69) Nature March 10, 1972, 236

70) The Economist, March 11, 1972, 242(6707)

71) Science, March 17, 1972, 175(4027)

72) Douglas, op. cit. note 2

73) K.C. Redmond, T.M. Smith, 'Project Whirlwind' (Digital Press, 1980), 17

74) Ibid., 38

75) Ibid., 135

76) Ibid.

77) Ibid., 131, 135

78) Ibid., 47

79) Ibid., 131


81) Science Policy Research Unit, 'Annual Report 1967'

Science Policy Research Unit, 'Annual Report 1976'

82) Ibid.,
83) D. Riesman, 'Notes on new universities: British and American', Universities Quarterly, 20, 1966, 128-146
84) Ibid., 143
85) Ibid., 140
86) Ibid., 142
87) A. Briggs, 'Drawing a New Map of Learning', in D. Daiches (ed.), 'The Idea of a New University' (Andre Deutsch, 1964), 60
88) Science Policy Research Unit, 'Annual Report and Ten Year Review' (1975), 14
90) Ibid., 9-10
91) Ibid.
92) L. Fleck, 'Genesis and Development of a Scientific Fact' (University of Chicago Press, 1979)
93) J. W. Forrester, 'World Dynamics' (Wright-Allen Press Inc. 1971)
95) Cole et al, op. cit. note 89
96) Ibid., 96
97) Forrester, op. cit. note 93, 80
98) Cole (et al), op. cit. note 89, 113
99) Ibid., 114-115
100) Forrester, op. cit. note 97, 15
101) Ibid.
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J.W. Forrester, op. cit. note 66

J.W. Brewer, Simulation, March 1976

I. Lakatos, 'Proofs and Refutations' (Cambridge University Press, 1976)

20) P.B. Feyerabend, 'Imre Lakatos', British Journal for the Philosophy of Science, 26, 1975, 1-18

21) S. Feferman, 'The Logic of Discovery vs. the Logical Structure of Mathematics', Philosophy of Science Association, 2, 1978, 309-327

22) Forrester, op. cit. note 93, 126

23) Wright, op. cit. note 106, 1092


25) Bloor, op. cit. note 21

26) Forrester, op. cit. note 66


28) Lakatos, op. cit. note 118


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94) Ibid., 116
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157) B.Latour, S.Woolgar, 'Laboratory Life' (Sage Publications Inc. 1979)

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159) I.Mitroff, M.Turoff, 'Technological Forecasting and Assessment: Science and/or Mythology', Technological Forecasting and Social Change, 5, 1973, 113-134

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162) Forrester, op. cit. note 136, 348


164) Meadows (et al), op. cit. note 94, 22

165) J.W.Forrester, 'Global Modelling Revisited', Futures, April 1982, 104

166) Meadows (et al), op. cit. note 140

167) Meadows (et al), op. cit. note 94


169) Forrester, op. cit. note 93, 43

170) Ibid., 11

171) Ibid., 5

172) Meadows (et al), op. cit. note 103, 151
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175) J.W. Forrester, 'Urban Dynamics' (MIT Press, 1969), 110
176) Meadows (et al), op. cit. note 103, 151
177) Forrester, op. cit. note 165, 99
178) Ibid., 109
179) Forrester, op. cit. note 163, 268
181) Meadows and Meadows, op. cit. note 166
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182) D.J. Meadows, 'Project on the Predicament of Mankind' (MIT, 1972), 5
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185) Mitroff and Turoff, op. cit. note 159
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198) C. Freeman, 'The Luxury of Despair', Futures, Dec 1974, 457

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202) C. Freeman, 'Technical Assessment and Its Social Context', Studium Generale, 24, 1971, 1042

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2) D. Bell, 'The End of Ideology' (New York: 1961)

For further information and a critique of these positions see:

J. Habermas, 'Technology and Science as "Ideology"', in 'Towards a Rational Society' (Heinemann Educational Books Ltd. 1971)

"Marx, to be sure, viewed the problem of making history with will and consciousness as one of the practical mastery of previously ungoverned processes of social development. Others, however, have understood it as a technical problem. They want to bring society under control in the same way as nature by reconstructing it according to the pattern of self-regulated systems of purposive-rational action and adaptive behaviour."

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3) M. Greenberger, M.A. Crenson, B.L. Crissey, 'Models in the Policy Process' (Russell Sage Foundation, 1976), 324

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G. Brewer, 'Politicians, Bureaucrats and the Consultant' (Basic Books, 1973)

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18) Ibid., 128
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20) Ibid., 127-128
21) E.Goldsmith, 'Bringing Order to Chaos', Ecologist, 1970, 1
22) Forrester's paper 'Counterintuitive Behavior of Social Systems', see 'The Collected Papers of Jay W.Forrester' (Wright-Allen Press Inc. 1975), was presented on October 7, 1976, in testimony before the Subcommittee on Urban Growth of the Committee on Banking and Currency in the House of Representatives.
23) Greenberger et al, op. cit. note 3, 68
The authors argue that there are several key similarities between Forrester and the outlook and policy conclusions of E.C.Banfield's 'The Unheavenly City' (Little, Brown and Co. 1970). Banfield's book is sociological in style, unlike Forrester's technical approach; however, Averch and Levine argue that the two books are notably conservative in their conclusions and that they share similar assumptions about lower-class people.
26) Greenberger et al, op. cit. note 3, 157
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31) K. Mannheim, 'Ideology and Utopia' (Routledge and Kegan Paul Ltd. 1936)

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44) Forrester, op. cit. note 1, 122

45) Forrester, 'Collected Papers', op. cit. note 22, 180

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49) Forrester, op. cit. note 22, 212-213

50) B.Latour, 'Give Me a Laboratory and I will Raise the World', in K.D.Knorr-Cetina, M.Mulkay (eds.), 'Science Observed' (Sage Publications Ltd. 1983)

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54) For examples of relevant texts see:


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