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Computer Aided Design in Great Britain and the Federal Republic of Germany

— Current Trends and Impacts —

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Abstract

A fact-finding trip to Great Britain was conducted in December 1979 as part of the sociological project on the consequences of computer application in the field of design. The present report reviews the current state of development of and discussion on C.A.D. and related information processing technologies.

The aims and background of the tour are presented in the first chapter. A comparison of state support for C.A.D. and trends in research policy in Great Britain and the Federal Republic of Germany follows. The chapter on economic consequences applies to information technologies in the broadest sense and is subdivided into effects on manufacturers, on companies applying the technology and on manpower. The consequences of computer application for the skills of labour employed in the use of C.A.D. are a central issue in the sociological project. In chapter 5 we investigate the question whether computers devalue traditional skills and aptitudes or whether they may be employed to enhance human experience. The problem of the effects of computers on skills is closely related to the design of interface and of communication between the human user and the machine. In the final chapter, methods of user participation in the design of the relationship between man and machine are discussed in addition to the potential of the computer as a means of the democratization of design procedure.

Computer-Aided Design in Großbritannien und der Bundesrepublik Deutschland. Absehbare Tendenzen und Auswirkungen

Zusammenfassung

Im Dezember 1979 wurde im Rahmen der sozialwissenschaftlichen Begleitforschung zur Einführung von Verfahren des rechnerunterstützten Konstruierens eine Informationsreise nach Großbritannien durchgeführt. Der vorliegende Bericht gibt einen Überblick über den derzeitigen Entwicklungs- und Diskussionsstand zu CAD und verwandten Informationstechnologien.

Im ersten Kapitel werden Ziel und Hintergrund der Reise dargelegt. Die staatliche Förderungspolitik für CAD und Tendenzen der Forschungspolitik in Großbritannien und der Bundesrepublik werden sodann miteinander verglichen. Es folgt in Kapitel 2 ein kurzer Überblick über Entwicklung, derzeitigen Stand und vorhersehbare Trends bei CAD. Das Kapitel über wirtschaftliche Auswirkungen bezieht sich auf Informationstechnologien im weitesten Sinne und gliedert sich in Auswirkungen auf Herstellerfirmen, Anwenderfirmen und Beschäftigung. Die Konsequenzen des Rechnereinsatzes für die Qualifikationen der Arbeitskräfte, die mit CAD arbeiten, stellen eine zentrale Fragestellung der sozialwissenschaftlichen Begleitforschung dar. Im fünften Kapitel wird der Frage nachgegangen, ob der Computer traditionelle Qualifikationen und Fertigkeiten entwertet, oder ob er auch zu einer Anreicherung des menschlichen Erfahrungsschatzes beitragen kann. Eng verbunden mit dem Problem der Auswirkungen des Rechners auf Qualifikationen ist die Gestaltung des Interfaces und der Kommunikation zwischen dem menschlichen Bediener und dem Rechner. Möglichkeiten der Beteiligung von Benutzern bei der Gestaltung des Verhältnisses zwischen Menschen und Maschine werden im letzten Kapitel zusammen mit Möglichkeiten des Computereinsatzes zur Demokratisierung von Konstruktionsprozessen erörtert.

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Preface

In the "good old days" before the advent of the horseless carriage and before modern communication techniques were fully developed, the traveller could lay some claim not only to broadening his own horizon but also, on occasion, to acting as the promoter of innovation. Modern technology enables free and convenient access to the written and the spoken word and thus apparently encourages a new variety of provincialism. The researcher seldom offers his readers works which are spiced with the doubts, without which science and technology would soon be paralysed. Thus journeys abroad still represent the appropriate means to learn about research results and programmes and to discuss arguments and motives which are not yet ripe for publication. The traveller's role as recipient of information is but one side of the story.

A German proverb says that man's experience in a foreign environment does not necessarily contribute to his becoming wiser. Such experience is obviously only useful, after man has reflected on what he has seen and what has happened to him. The report which follows has the purpose of just such a process of reflection. It is based largely on interviews conducted by the authors with British computer experts in December 1979 and on reports generously presented to us. Special thanks are due to Mike Cooley of Lucas Aerospace and the A.U.E.W./T.A.S.S. for opening so many doors to us. We also gratefully acknowledge the time and hospitality so freely given to us by the following people: Andrew Cunningham, Prof. Enid Mumford, Prof. Howard Rosenbrock (Manchester Business School); Ron Brown, Larry Farrow (National Computing Centre); Rod Coombs (Department of Managerial Sciences, University of Manchester Institute of Science and Technology); Prof. Michael Gibbons, Ken Green (Department of Liberal Studies in Science, University of Manchester); Alan Bridges, Morven Hirst, Harvey Sussock, Julian Watts (ABACUS-Group, Strathclyde University); Harold Thimbleby (Computer Science Laboratory, Queen Mary College, University of London); Martin Bell, John Chesshire, John Clark, Prof. Christopher Freeman, Jay Gershuny, Keith Pavitt, Peter Senker (Science Policy Research Unit, University of Sussex); Malcolm Sabin, Michael Watt (Computer Aided Design Centre); Arthur Llewelyn (Cambridge); Bob Kenyon (Computer Aided Design Research Unit, Department

of Environmental Design, Polytechnic of North London); John Hillier (Council for Science and Society). Special mention must be made of our colleagues Ingrid von Berg, who conducted and transcribed some of the interviews, and Gabriele Kaufmann for transforming what must have been a difficult and illegible text into a highly professional manuscript.

The subjects covered by discussion embrace the whole range of issues involved in the process of computerization. We cannot, therefore, hope to do anywhere near sufficient justice to any of the issues touched and have imposed severe limitations on ourselves in regard to the time spent writing up the report. As it is, we have delayed the report further than one could reasonably demand of our hosts' patience.

Although one of us spent part of his childhood and adolescence in Great Britain and is reasonably fluent in conversation, neither of us is accustomed to conducting scientific discussions or writing reports in English. We therefore apologise most sincerely in advance to anyone whose views may have been misrepresented for reasons of the language barrier, or indeed simply due to inability to comprehend on our part.

Finally, let us state that we thoroughly enjoyed meeting all the people involved and exchanging views. We found the discussions most stimulating and sincerely wish that our efforts will prove of interest to our hosts and will, in some small way, make recompense for their kindness and patience. May our trip have been but promising start of a long and fruitful interchange.

1. Aim and Background of the Tour

a) Aims

A review of the interviews conducted and of part of the literature, so kindly provided for us by our partners in discussion, quickly revealed that a number of basic arguments recurred despite the large variety of uses for C.A.D. and the varying fields in which our partners worked. In the same way modern technologies are becoming a world-wide phenomenon, arguments for and against the technology are being exchanged in a world-wide forum. Because of the interdisciplinary nature of our own research, we are incorporating technical aspects along with economic and social aspects, and these in turn are being connected to philosophical considerations. The primary aim of the evaluation of the interviews and literature is therefore to sort the arguments, confront them with each other and, where possible, to sketch out solutions. Technical detail is secondary to this aim.

A more down-to-earth reason for the journey was simply to get acquainted with the situation in Great Britain. On the one hand this applies to concrete research projects which are comparable to our own. On the other hand we wanted to learn about the situation of research subsidization and attempts to direct socio-technical change. The computerization of construction and development is but one phenomenon in a pattern of a widespread trend towards the modernization of Western societies by means of information technologies.

b) Our own project

Our own empirical project was originally proposed in Autumn 1977 by the project management group, which is promoting C.A.D. research projects on behalf of the Federal Ministry for Research and Technology. It was designed as a study to accompany the innovation and implementation processes. By this means we hoped to identify typical difficulties and problems and thus, be able to make recommendations to companies encountering such problems. Moreover, we hoped to demonstrate to the Ministery both current and more basic problems arising as technologies are introduced. The results of our research

are also aimed at the trade unions, whose claim to the right to participate in the decision-making process on the introduction of technologies is gaining increased recognition.
At the outset, a pilot survey of 14 companies which used or developed C.A.D. systems was conducted, interviewing representatives of managerial and supervisory staffs as well as employees working with C.A.D.. Our aim at that stage was, however, not the exhaustive collection of all relevant factors but rather an observant exploration. The results of the pilot survey have been published as a book (Bechmann, Vahrenkamp, Wingert 1979). The project will be continued until 1981, in order to obtain insight into the ongoing implementation process by close observation.

At present, six scientists are involved in the project: a psychologist (Bernd Wingert, project leader), 2 sociologists (Michael Rader and Ulrich Riehm), and an economics engineer (Werner Duus), full-time; a jurist (Gotthard Bechmann) and an economist (Richard Vahrenkamp) are involved on a part-time basis. The interdisciplinary composition of the team is to some extent due to the composition of our Department of Applied Systems Analysis; in part, it is also determined by the nature of the project, which requires a definite interdisciplinary approach. This becomes apparent when we look at the main points of interest:

- Which course do the company's decision-making processes take with regard to the introduction of C.A.D. and which factors determine content and goals of the decisions? (Innovation aspect)

- In which manner is C.A.D. applied in the various companies and which technical, organizational and staffing measures are employed? (Implementation aspect)

- Which effects on jobs, work load and especially, skills are attributable to the application of C.A.D.? (Impact aspect)

As our point of departure we submit a simplified model of innovation which neglects the finer details and relationships (cf. fig. 1). Market forces , technological developments, other innovators and public subsidization represent incentives and pressures to take advantage of a new technology.

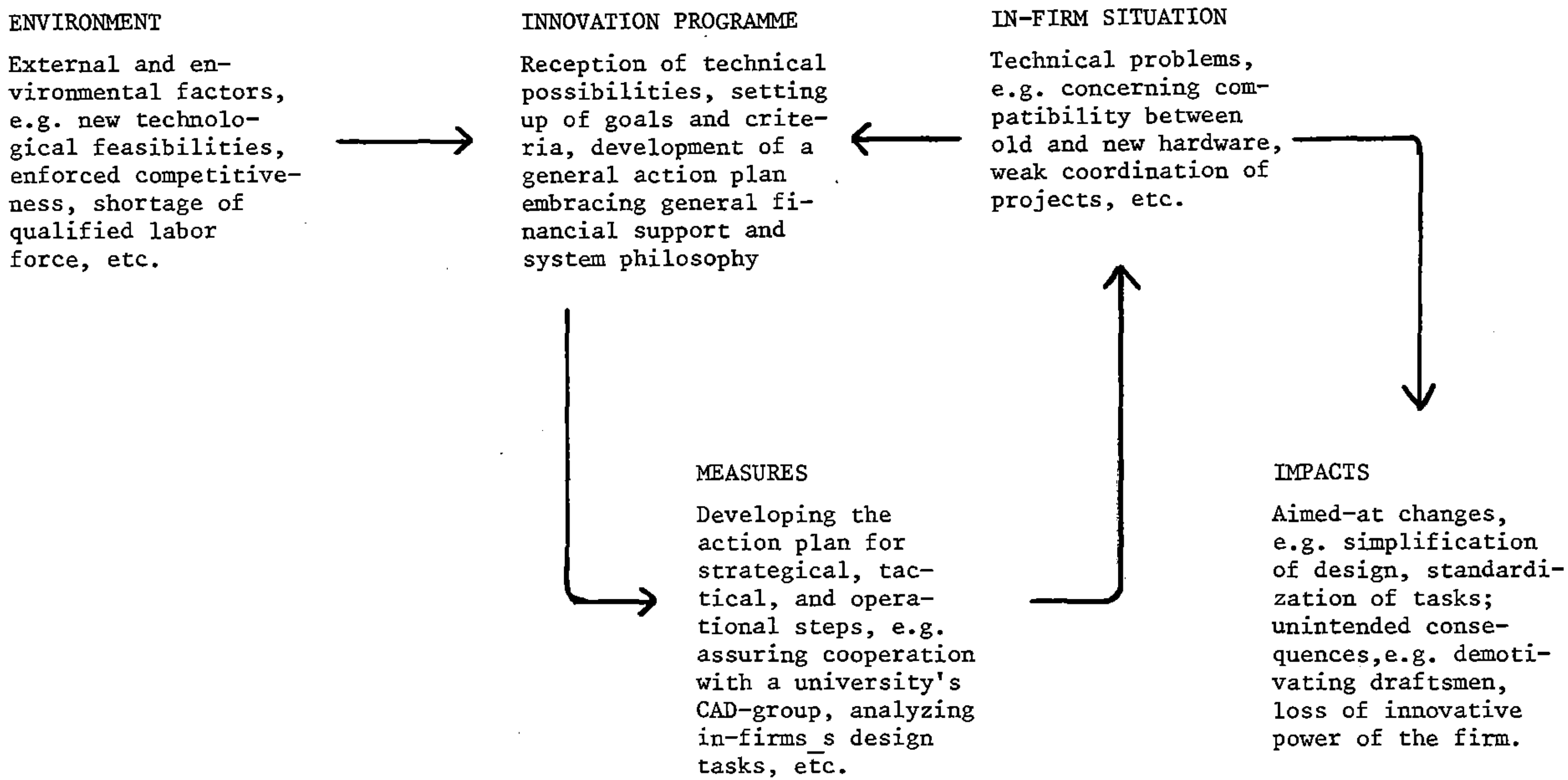


Figure 1: A simplified model of the innovation-implementation process

Examples of such external factors are keen competition in the market for a product or a shortage of skilled labour. However a company will hesitate to adopt the new technology as long as internal factors do not constitute an equivalent pressure. The high costs and the volume of time required by C.A.D. are repeatedly mentioned in this respect. Such internal and external factors are responsible for a new technology being considered by management, supervisors and other staff. This is the first step in the process which terminates after much consideration and complex decision-making procedures in the shape of an "innovation programme". This we regard partially as a diagnosis of problems, partly as an abstract plan of action.

In a second step, the programme takes more concrete shape through strategic, tactical, and operational measures. This could, for example, mean a company's taking part in the demonstration of a C.A.D. system and deciding on a trial with a few limited applications. It could then either develop its own system or modify a part of an existing system to suit its requirements. Alternatively, it could mean that the company decides to adopt the technology on a large scale, planning the introduction of the technology minutely. In this case there are a large number of alternative planning and implementation measures, all of which depend on an equally large number of factors. The measures in turn influence the internal situation.

The registration of these changes (impact) and the controlled further preparation and realisation may be considered as a third step. Once again, a large number of individual aspects command our attention. In the case of C.A.D. we are mainly concerned with the organization of work, working skills and work load. This brief presentation of our process-oriented model of innovation reveals an obviously sociological approach. This by no means should be interpreted as saying that we do not acknowledge the importance of technological and economic considerations for decision. It simply means that these too should be socially defined, negotiated and realised. We do not intend to present the results of our study at length and shall merely quote from them in the appropriate sections of the present report.

In the following section we briefly review the most important aspects of the interviews. In subsequent sections we will be considering the more basic points of the interviews and the general debate on the matters in hand.

c) Brief Summary of Discussions

A fact-finding trip to the United Kingdom was conducted from the 3rd to the 14th of December 1979 as part of the project on the social impact of Computer-Aided Design, currently in progress at the Karlsruhe Nuclear Research Centre's Department of Applied Systems Analysis. The main aims of the mission were to become acquainted with the current state of development and application of C.A.D. in Great Britain and discussion on the social impact of the use of C.A.D. and also, to gain insight into the British system for the subsidization of research. We did not, however, confine our interest strictly to Computer Aided Design. Discussions also took place with individuals or groups working on problems of computer interface or on the design of computer systems.

Professor Howard ROSENBROCK (Manchester Business School) is engaged in the production of EDP-programmes for the development of control systems. These programmes differ from conventional programmes in that they do not attempt to produce an "optimal" solution, which, according to Rosenbrock, does not exist in the first place. They rather leave the final decision on the best solution in the circumstances to the designer. Designers' decision processes embrace a large number of parameters which cannot be recalled at will, but are activated in situations where they are relevant for decision (the so-called tacit knowledge) and which are thus difficult to transfer to the machine. Programmes produced according to such a philosophy keep the control over the design situation firmly in the hands of the design engineer which is the reason why they are favoured by trade unionists, for instance Mike Cooley who recommended Rosenbrock to us. Professor Enid MUMFORD is also on the staff of the Manchester Business School. She is one of a group of people working on a consultancy basis for firms wishing to introduce computer-based information systems into their offices by designing the systems in close cooperation with office staff. By this means it is hoped to create a humane office environment and to contribute towards the acknowledgement of such information systems by the user. In general, Ms. Mumford regards her design process as successful. There is little or no resistance to the information systems since they are not seen as an immediate threat to employment.

One of the main aims of the National Computing Centre in Manchester is to provide companies contemplating computerization with the appropriate information and advice. Our main partner in discussion was Larry FARROW who has prepared a report on companies' strategies for the introduction of computerization and at the same time examined employee attitudes towards computers in relation to previous experience with data processing, company history, labour relations and other factors which could contribute towards colouring these attitudes. The insight gained in the course of investigation for the study served as the foundation for the National Computing Centre's "Computerization Guidelines", also authored by Larry Farrow.

Rod COOMBS (UMIST) and Ken GREEN (Dept. of Liberal Studies in Science, University of Manchester) have been examining the impact of micro-electronics on the labour market of one clearly defined region (Tameside). They were of the opinion that the very high costs and technical problems would lead to new technologies being adopted by industry at a much slower pace than has been generally assumed.

The ABACUS group at Strathclyde University in Glasgow has developed C.A.D.-systems which enable people working or living in buildings to participate in their design. The system is operated by a computer specialist acting on the suggestions and wishes of the users of the building. One member of project staff was trained as a computer psychologist. The training of architects at Strathclyde University incorporates computer application and in this respect differs from traditional teaching methods employed at Glasgow University.

Our host at the Computer Systems Laboratory at Queen Mary College, London University was Harold THIMBLEBY who is concerned with problems of computer interface, especially in office typing systems. In his opinion, programmes should be constructed in such a way as to enable the user to design a system adapted to his own problems. He advocated access to computers by the means of games in order to prevent the naive computer user from over-estimating the abilities of the computer.

In the course of our visit to the Science Policy Research Unit (SPRU) at the University of Sussex near Brighton, we discussed the possibility of cooperation between the Department of Applied Systems Analysis and S.P.R.U. in a project, possibly on C.A.D.. The head of the research group, Prof. FREEMAN would welcome such cooperation. A member of the unit, Peter SENKER, has already done work on the impact of new technologies on skills and will be part of the group working on a SPRU-project on C.A.D. which is to begin in 1980. Jay GERSHUNY, who has worked on the development of the services sector, thought that computers could be employed to improve the standard of public services and thus partially help to counteract current public listlessness with regard to the state. He suggested unusual data sources for research purposes. After a certain amount of research, he was able to use BBC listener surveys as a source for information on leisure activities. Some years ago, Martin BELL, now also a member of SPRU staff, developed a taxonomy for the various mechanization stages in processing industry. In the mean time his interests have shifted to problems of industrialization in the Third World. However, he was able to make valuable suggestions. For example, Bell does not expect widespread redundancy as a consequence of computer application, especially of C.A.D.. He rather expects a so-called Xerox-effect: the volume of paper produced, in this case of alternative construction plans, is increased by the potential of the technology.

The C.A.D. Centre was founded about 10 years ago as a prototype of a new type of government centre. The terms of reference were to develop, demonstrate and provide C.A.D. to industry. The primary aim was to create multi-discipline teams of engineers to develop C.A.D., through application projects with industrial partners, which could be used across industry as a whole. The secondary aim was to provide C.A.D. facilities (through networks, hardware and software) and customer services to industry. The long term aim was to become financially self-supporting. Dr. Malcolm SABIN of the centre, gave us an introduction into the British system for the subsidization of research. On the one hand the system is far more fragmented than in Germany, on the other hand subsidy funds have by far a smaller volume. Dr. Sabin thought that anxiety regarding the repercussions of C.A.D. on employment were exaggerated since fruitful employment of C.A.D. requires a minimum size for an enterprise employing it. Furthermore, there is an extreme shortage of skilled labour in those fields where C.A.D. is employed. This is a motive often pointed out to us in the course of our own pilot study on the introduction of C.A.D.. In general, C.A.D. is not developed noticably further in Great Britain than it is in Germany, but Dr. Sabin has gained the impression that its diffusion in Germany is more confined to Universities than it is in Britain. The former Director of the C.A.D. Centre, Arthur LLEWELYN, largely as a result of the study he undertook for the European Commission (1978) was much concerned by the shortage of skills which seemed likely to inhibit the future spread of C.A.D. throughout industry. In his opinion the chief problem was a mismatch between the educational system (content and curricula) in schools and universities and the needs of industry and society, which prepared pupils insufficiently for work with the computer. Fundamentally this was a question of understanding and approach and the priority need was to educate the educators!

Arthur Llewelyn thought there was practical evidence to show that designers' ability could be enhanced by C.A.D.. Those who had previously worked more or less intuitively, by giving them additional experience impossible in practical life, gained extra insight into the scientific background of their work and by testing out many more possibilities were enabled to arrive at better solutions. He also pointed out that C.A.D. systems by virtue of their interactive nature provided a means of integrating teams of specialists who could find solutions to complex problems beyond the limited experience of any one individual.

Bob KENYON, who is Director of the Computer Aided Design Research Unit at the Polytechnic of North London, is engaged in work on programme packages for architects. Through his contribution to C.A.D., he hopes to help prevent the deterioration of the privileged working style of architects to a production line-type environment.

Many of the contacts to people we visited were established for us by Mike COOLEY, a past president of the Amalgamated Union of Engineering Workers/ Technical and Supervisory Section. In our unfortunately short discussion with him, he conceded that C.A.D. was indeed filling a gap but explained this by stating that the shortage of highly skilled staff had been deliberately created by enterprise to facilitate the introduction of the new technology. Mr. Cooley illustrated with very vivid examples his further assertion that C.A.D. generally contributes towards the deskilling of labour operating it. On the other hand he pointed out developments aimed at counteracting this tendency, among them Howard Rosenbrock's interactive system.

The Council for Science and Society was established at the beginning of the 1970s by well-known scientists and other personalities as John HILLIER pointed out. New members are coopted. The Council's best known members in Germany are probably Ralf Dahrendorf and Sir Karl Popper. The council establishes working groups on subjects of widespread societal interest. The members of the working groups, who donate their services, represent a wide range of opinion on the matter in hand. The groups make no recommendations as to solutions for the problems under consideration but they do aim to provide criteria to assist in arriving at a solution which can be considered societally useful. Reports are aimed at administrations and Parliament. Reports have been published on, among other subjects, energy policy, the acceptability of risks and socalled superstar technologies, i.e. technologies where nearly all the technical expertise is employed by the interested parties. Work is currently in hand on a project on "artificial intelligence" in industry. Among the members of the working party on this subject are Mike Cooley and Howard Rosenbrock.

2. Governmental Policy in Stimulating New Technologies

2.1 Introduction

(1) Whilst, in the heading to this chapter, we speak generally of governmental policy, we should more properly distinguish between those tasks imposed on the state by objective changes (e.g. on the world market or within the structure of a national economy) and those policies and plans of action of respective governments, determined - at least in industrialized countries

- by political parties. A simplified approximation would be to say that respective governments, on the basis of their programmatical and ideological backgrounds, interpret objectively delineated problems and, in negotation with social groups, develop plans of action to deal with them. It is important to recognize the condition that the development of governmental and state programmes on technology development and application is subject to internal organizational conditions (e.g. division of tasks, structure of departments, nature and effectiveness of advisory system). The decisive influence of this kind of restraint may be judged by examining the development, implementation and control of such programmes.

(2) Besides the subject background of technological programmes, the amount of control which may be exercised is of equal importance for the effects and adequacy of measures. Referring to a North American programme for the support of regional economies, Pressman and Wildavsky made the following, appropriately ironic remark: "Implementation. How great Expectations in Washington are dashed in Oakland; or; Why It's Amazing that Federal Programs Work at All, This Being a Saga of the Economic Development Administration as Told by Two Sympathetic Observers Who seek to Build Morals on a Foundation of Ruined Hopes" (1974).

(3) Increasing state committment to technology policy is a common feature which may be observed in all Western industrialized countries. C.A.D. is but one link in this chain and the U.K. and the Federal Republic of Germany provide but two examples of the ways and means by which such problems may be tackled. A comparative study of British and German support for C.A.D. is thus both important and revealing.

(4) Our opening remarks, which are of necessity extremely abstract, serve to demonstrate the complexity of the issues involved. In the field of technology policy, especially, scientists are ever quick-to-hand with well-put questions and state administration, thus challenged to act, is rapidly overtaxed in trying to retain control over the situation in which it must act. Suggestions for solutions must consider the structure of administration. Nonbureaucratic propositions are often well-meant but probably ineffective:

"The idea of creating a nonbureaucracy within a bureaucracy was strictly a one-time short-run theory. No one expected it to last. It was designed to get something done in a hurry, after which it would presumably be all right for events to take their usual course. But that very short-run orientation - get in fast, get the job done, move out, turn it over to the bureaucrats - suggests an orientation to time that is unlikely to coincide with the requirements of a program designed to make a permanent and significant decrease in minority employment. The in-and-out perspective also speaks to the personal orientation of the key men involved? antibureaucratic men are unlikely to stick around long enough to shepherd the implementation of their program after it is started" (ibid., p. 131).

Pressman and Wildavsky no doubt do not wish to suppress such extrabureaucratic forms. They are however quite right in their skepticism in regard to the efficiency of this kind of "safari research".

2.2 The Funding and Promotion of C.A.D. in the U.K.

(5) We received detailed information on the British system for the support of research, in particular for C.A.D., in talks with Dr. Arthur Llewelyn (former Director of the C.A.D. Centre in Cambridge), Dr. Malcolm Sabin (currently at the C.A.D. Centre), Ron Brown and Larry Farrow of the National Computing Centre and John Hillier of the Council for Science and Society. Our partners repeatedly affirmed that the British R & D support system is extremely complicated, primarily because there is no one focal point of responsibility and decision making is split between many departments of government each having a large degree of independence. We therefore cannot hope to give a complete survey of the situation and restrict ourselves to those aspects of importance for C.A.D..

(6) The Department of Industry runs 5 research establishments: The National Physical Laboratory (concerned with standards etc.); the National Maritime Institute, the National Engineering Laboratory (some interest in C.A.D., but now more concerned with manufacturing robotics), the Warren Spring Laboratory

(receiving significant funding aimed at microprocessor application projects), the Laboratory of the Government Chemist (small and specialized, concerned with purity of chemicals) and the C.A.D. Centre in Cambridge.

The mandate of the C.A.D. Centre and its terms of reference were agreed by the original Ministry of Technology (now incorporated in the Dept. of Industry) and as with all such actions by Treasury. The Science and Technology Act empowers the Department of Industry to undertake many actions and responsibilities across industry and not specifically to apply to the Centre or industrial establishments which were in existence long before the Act came into force. Although the Centre is a government research establishment, only about 10 out of 150 of the people working there are civil servants. For the most part they are employees of ICL Dataskil which has a contract with the Department of Industry. The budget of the C.A.D. Centre is borne by the Department of Industry. Funds and resources for projects may come from other government sources e.g. Dept. of Health, or government agencies such as S.R.C., N.R.D.C., or N.C.C. or from industry. Approval for projects has in recent years been concentrated in the hands of Requirement Boards, Committees of government and industry appointees with no executive authority but only the power of recommendation. About half of the money stems from customers in Industry contracting with the C.A.D. Centre on the basis of specified projects.

The greatest part of the Centre's work is understanding application problems in the industrial environment, defining specifications and formulating a strategy for building modular C.A.D. systems with as much common software as possible. The least difficult part is writing software when the specification has been formulated! The Centre's main areas of work are mechanical engineering (at present the largest area and still expanding), process industry projects (one example is a large software package for the design of piping), and basic software (e.g. graphics packages for use in application software). Because the Centre is a Government establishment it cannot itself sell hardware. So the normal arrangement is with agents getting licences from the Centre.

(7) The Department of Industry has the previously mentioned research establishment and, in response to the so-called Rothschild Report, established Requirements Boards, which are empowered to give 25 % grants to firms or 50 % loans to be repaid in case of economic success of the project. One of the Requirements Boards is the Mechanical Engineering and Machine Tools Requirements Board. Another is the Computer Science and Electronics Requirements Board. The mandate of the Requirements Board is to subsidize research and development, based on the Science and Technology Act. There is another Industry Act which funds other Department of Industry Schemes which are for the support of industry and can fund use of equipment. Also funded by Department of Industry is the Software Products Scheme administered from the National Computing Centre. There are also industrial confederations and research associations funding research with money from their members. They in turn may come to the Requirements Boards asking for money for specific projects. There is also the National Research and Development Corporation which can fund on a loan against levy basis. On the other side, the Department of Education and Science funds the Research Councils, one of which is the Science Research Council, funding research within the universities.

(8) The Science Research Council and the Mechanical Engineering and Machine Tools Requirements Board have a joint panel on Computer Aids to Engineering (CAE), mostly with industrial and academic members and no unionist representative at present.

(9) Design analysis, drafting, process planning, production control and programming are the stages of the C.A.D./C.A.M. process with which the CAE Panel is dealing. Dr. Sabin who runs the Panel's support unit within the C.A.D. Centre: "Our main funding efforts are in tailoring drafting, that is making the drafting do specific jobs. There is a thought which is becoming accepted here and that is that there is a trade-off between the power of a system and its generality. If you have a drafting system capable of drawing anything, it is capable of drawing Mickey Mouse or Peanuts cartoons or crosses in a corner. That is the result of a very general system which therefore loses power. If you have a system which will only draw determined parts it is possible to do the process planning almost automatically, and it is possible certainly to produce automatically dimensioned

drawings from a few statements". Dr. Sabin mentioned a system for the design of large liquid storage tanks, getting all the manufacturing drawings out of an input of 20 variables.

(10) In about 1977 the Mechanical Engineering and Machine Tools Requirements Board funded the installation of some turn-key drafting systems on the basis that they could demonstrate the effects and all the lessons learned would be visable to other people who intended to buy such systems. "We are now taking the line, that a turn-key drafting system needs no further demonstration. What is subsidized now will be first of all the integration of different stages of the design process because we feel there are great benefits to be had from that. On the top of turn-key systems and data-processing systems possibly specific development systems will emerge" (Interview Sabin).

(11) Use of equipment in smaller companies which would otherwise not be able to afford such systems is at present not being subsidized - though there is always concern for small companies. Dr. Sabin: "It may well be that the right way of assisting small industry is by subsidizing some bureau to provide computer based design analysis services. But this is something we are exploring, not something which is happening". In Germany parts of this function are fulfilled by the Fraunhofer Gesellschaft and the Arbeitsgemeinschaft für Industrielle Forschung (AIF).

(12) In Germany there is great concern about redundancy effects of new technologies, e.g. Microprocessors, but also C.A.D.. Commenting on this topic, Dr. Sabin explained: "In Britain there is a terrible shortage of skilled people and one of the major incentives for the installation of, for example, drafting equipment is that we can't get the draftsmen. We have got to increase the productivity just with the ones we have got just to do the work! It is anomalous that we should have that situation and at the same time high unemployment, but those are the facts. Skilled people are in dire shortage and there is no danger of redundancy being created".

(13) Arthur Llewelyn gave us some very valuable comments on the history of the C.A.D. Centre and the change in tasks coming about since its establishment in 1969. Discussion however began well before this deadline, in

the early 1960s. "The problem was, that although there had been a discussion for about 10 years, no one but a handful of people knew what C.A.D. was". The actual founding of the Centre took place in 1969 in the form of a compromise: "If you supported something in industry it benefited one firm - it would not go very far to the rest of industry. If you supported R & D in a university it wouldn't go out to industry at all. If you created a government establishment it would be a nice bright centre to attract people but it would not neccessarily benefit industry. The compromise was to set the Centre up as a government centre but in a joint group way with the universities, to start with and to get the benefits of their experience and also - a very important thing - to make sure that the people at the Centre would not be Government servants but contract people drawn from industry. This worked very successfully for the first five years to about 1975". Then in response to the Rothschild Report a whole row of Requirements Boards were set up to decide on projects. This complicated the decision procedures: "That really crippled me at the Centre because it destroyed the synenergy of the multi-discipline teams, made co-operation with universities and other establishments almost impossible since one had to divide up a coherent programme into separate projects addressed to separate decision making Boards. In addition one had to wait for approval from the Requirement Boards which met every three months, so then it took about 9 months to get approval. By the time I got the approval, people changed their mind and took on something else. It crippled the whole dynamics of the project organisation. And that was a great pity".
Compared with the highly fragmented support situation in the U.K., Arthur Llewelyn found words of praise for the organization of projects in Germany and France, which at least guaranteed that projects could be coordinated with each other.

(14) The Council for Science and Society which was established in 1973, is an organization in which scientists cooperate on a voluntary basis and work on selected problems of technical change, e.g. on the effects of automation. The council is unique, even in Britain and the idea of its founders, i.e. research into the social effects of science and technology and of disseminating the results thereof to the public, its method of operation and the funding by foundations, is probably typical of the situation

in the U.K.. Working parties are consciously composed heterogeneously. Its aims are not definite recommendations but rather methodological guidelines and the review of issues. The reports are phrased in everyday language and are intended as a basis for public discussion. As an example, the council set up a working party on risks connected with new technologies before the problem was an issue of general public concern.
In reply to our question, whether the probability of deskilling was minimized in the U.K. by a shortage of skilled labour, John Hillier pointed out that apprenticeships and training schemes were reduced in times of economic crisis. De-skilling should also be looked at considering the wealth of unused creative potential that many workers have. This could be confirmed by the fact that so-called unskilled workers could learn how to do their skilled colleagues' jobs simply by watching them.

(15) Compared with the Council for Science and Society, the National Computing Centre in Manchester is concerned with the more down-to-earth matters of the introduction of EDP. As Ron Brown and Larry Farrow told us, the NCC was founded with public funds in 1967. At present, the centre is financed by membership dues, developing training material and courses, project funding and offering a consultancy service. About 1800 organizations are members of the association supporting the centre, among them companies, employers' federations and trade unions. The centre's main aim is to promote the purposeful use of computer technology. There are 4 main fields of work:

- The liaison between school training and industry;
- The appraisal of hardware and software;
- Research and consultancy services for computer based teaching;
- Further development of training from the viewpoint of company instructors.

The centre's main fields of activity are consultancy and training courses. These services are aimed mainly at the smaller company using EDP for the first time. The NCC's conception is not restricted to technological matters. Human factors are seen to be of equal importance. This line of interest can be followed back to the NCC's very early days and is a result of the realization that the success of a computer system depends as much on the incorporation of the human being as it does on the machine configuration. One result of this orientation are the "Computerization Guidelines" which were produced by Larry Farrow drawing upon, among other sources, interviews conducted in companies using EDP.

2.3 The German Situation

a) Background of Research Policy

(16) A separate Ministry for "Research and Technology" was established as late as 1974. It was created as the result of dividing departments of the Ministry for Education and Science. Such divisions result in a potential for more intensive concern with individual problems. They do, however, also regularly create problems of coordination. For instance, when one is looking into the effects caused by technological change, the connection between new technologies, changed skill requirements, teaching aims and contents are neglected (cf. Bräunling 1979, p. 141). Public institutions attempt to keep track of the problems due to technological advance and its effects and try to encounter these by the development of appropriate measures.

(17) According to Bräunling and Harmsen(1975) and Naschold (1979), research and development policy in the Federal Republic of Germany may be divided into about 4 phases. The first of these, from about 1949 to 1957, was characterised by an isolated approach to the solution of problems. Support was given to existing technologies. Subsidization was widespread and given to institutions. The underlying model proceeded from the assumption that technical advance was more or less subject to its own laws: new technologies encourage economic growth and thus contribute to general welfare and the quality of life. During the second phase (till about 1967) programmes supported peak technologies (nuclear research, air and space travel) to assist in their attempt to achieve world standards.

The third phase may be seen as an attempt at sectoral support, i.e. structurally weak branches of industry are supported and subsidized. This is necessary because of the extreme complexity of world economy and because of competitive pressure. These factors lead to demands on the individual company for better quality products, flexibility of production and shorter delivery times. This phase lasted until about 1972. The fourth phase may be labeled "comprehensive modernization policy". The term "comprehensive" is employed since support was not confined to individual developments but also embraced entire technological branches (for instance in the federal Republic of Germany the production of standardized, prefabricated elements and EDP), and since the assessment of economic and social consequences was acknowledged as a public task. This was because the negative effects of modern technology (environmental risks, threats to the quality of urban life, risks involved in chemical and nuclear super technologies) led to an increasing reluctance to accept them. This kind of social phenomenon thus becomes part of political process and is capital which may be deployed in the process.
Increasing awareness of government agencies in regard to the consequences of technologies leads in turn to the attempt to control the course of application by systematic task definition and consultancy methods. Bräunling and Harmsen (1975, p. 11) give an excellent representation of the individual phases (figure 2).

(18) A most interesting aspect is the programme for the humanization of the working environment (Humanisierung des Arbeitslebens, abbreviated HdA) which was initiated jointly in 1974 by the Federal Ministry for Research and Technology and the Federal Ministry of Labour. Initially, the programme neither involved the trade unions to a great extent, nor did it receive much support from them. However, they have since become one of the programme's main pillars of support. The programme thus also represents an attempt to closely involve the trade unions in the process of consulting on, planning and carrying through projects, the majority of which are concerned with technical change and innovation in individual companies. Lately, however, projects have been added that affect whole branches of industry (e.g. the clothing industry).

Figure 2: Development of the German technology policies

Charac-teristics / Development phase (strategical orientation)	Central economic and social-political aims	Focus of acting	predominant principles of support	predominant instruments of support
Laissez-faire (~1949- ~1957)	"Reconstruction"	Establishment & expansion of research capacity inside and outside university	general support	support for institutions
Imitation (~1955-~1967)	"World standards"	Nuclear Research and development of nuclear technology; Armaments research; Air travel and space research	support for programmes ↓	institutional support for big science research establishments; institutional and project support for international projects ↓
Recovery and Innovation (~1965-~1972)	"Qualitative Growth" ↓	Data processing; new technologies;	↓ structural support ↓	↓ support for industrial project; indirect support; ↓
Increase in efficiency (~ from 197o)	↓ "crisis management" creation of recources for legitimation;	Innovations; Public demand;	↓ ↓	↓

(Source: Bräunling & Harmsen 1975, p. 11)

(19) Science is involved mainly in the form of accompanying scientific observation and analysis, so-called "Begleitforschung". The most appropriate English equivalent would be "research on implementation" or "impact analysis". The German term "Begleitforschung" implies close links with industrial measures and the people carrying them out and thus also implies potential social conflict. It also expresses an intention to keep at an analytical distance and to confine oneself to the mere observation of things as they happen. This nuance is not stressed at this juncture without purpose: German law on company constitution, the so-called "Betriebsverfassungsgesetz", provides for the information and consultation of workers' representation when new technology is introduced and the "confirmed knowledge of labour sciences" must be taken into consideration. Obviously, there is conflict on what "confirmed knowledge" is, e.g. the tension which may be expected to be suffered by people working at display screens. On the other hand, the humanization projects have been employed in an attempt to closely link social research with the projects, obviously also with intention of legitimizing the projects. However, social science research has not yet reached - and indeed may never reach - the stage where it can be used to make or justify suggestions for the design of technology. The support for C.A.D. must be considered with this background in mind.

b) Support for C.A.D.

(20) As was the case for the humanization project, a so-called project management (Projektträger) was established in 1974 for the support of C.A.D. and C.A.M. in addition to a related project (PDV - Prozeßsteuerung mit Datenverarbeitung, control by data processing). Management is situated at the Karlsruhe Nuclear Research Centre. Its main tasks are to decide on applications for funding from universities and industry, to consult applicants and to appraise the scientific quality, necessity for and worthiness of support for the industrial applications in addition to the distribution of funds and the control over their uses for the purposes for which they were intended. Results are published in the form of a report after completion of the projects. The distribution of results is another task of the project management. Individual projects can be either entirely or partially funded with public money.

(21) Support for C.A.D. is currently not being provided in its original form. Support for C.A.D./C.A.M. as a separate project came to an end with the termination of the Federal Government's Third Data Processing Programme in 1979. New emphasis was placed on the field of "Production Technology" which incorporates both C.A.D. and equivalent projects from the humanization programme. The new programme is scheduled for 1980 to 1983 and will be worth about 250 million DM. It consists of the following subjects:

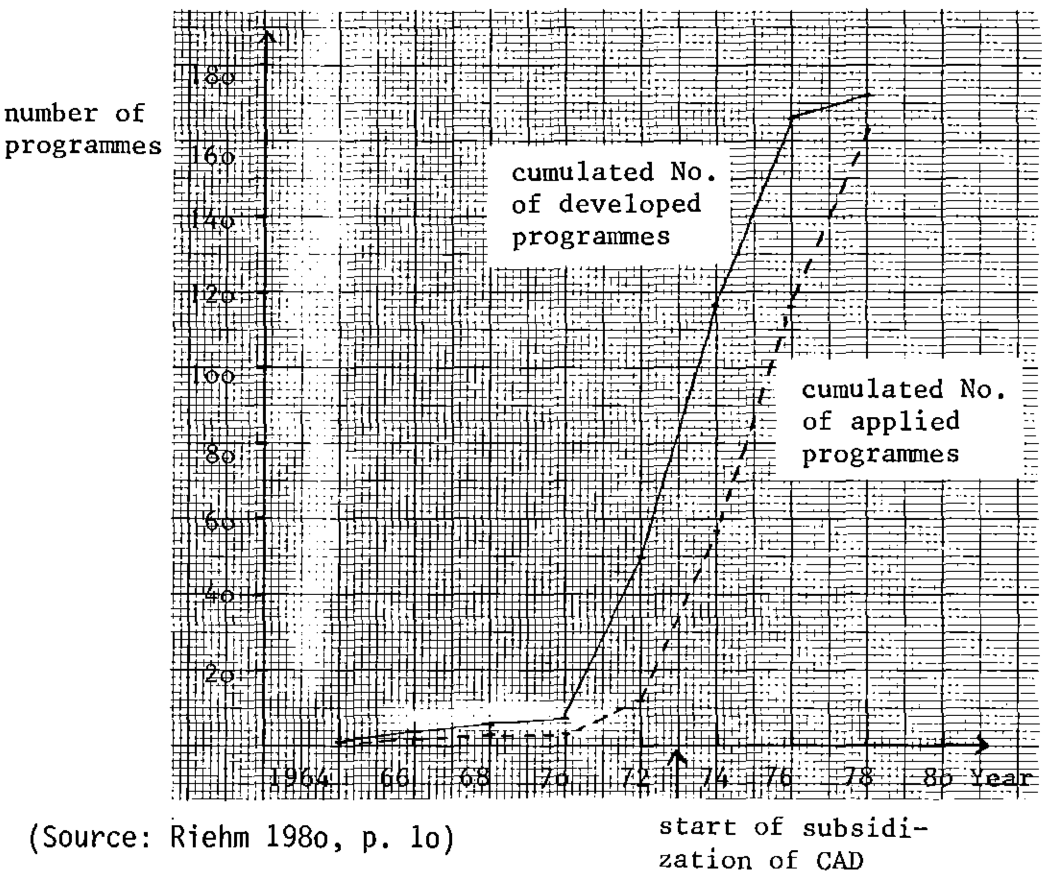
- Development, construction, design and preparation in industrial production (the former C.A.D. programme);
- flexible systems and equipment for manufacturing purposes;
- improved production structures;
- Technologies and processes for production and guarantee of standards;
- Accompanying research in the fields of social science, economics and labour science;
- Technology transfer.

Support is expressly aimed at small and medium sized companies.

(22) A complete report on the status of C.A.D. in the Federal Republic is extremely difficult, since governmental support is provided for only part of the applications and C.A.D. cannot be defined with sufficient accuracy to decide whether each small change in the construction process should in fact be defined as C.A.D. or not. An impression of the volume of supported C.A.D. projects may be gained from chapter 3 and from the following figure which uses data from a survey conducted by project management. It shows both the cumulated numbers of programmes under development and the number of programmes in application. Public support was first given to C.A.D. in 1973. The rapid increase in the number of programmes developed in 1973 is due to activities at universities. This table does not provide the answer to the age-old question posed in connection with governmental support everywhere, whether it merely serves to amplify an existing trend (and is thus really unnecessary) or whether it in fact creates the trend (so that it would

not have come about without the support). Any interpretation of the trend is in itself to a large extent politics.

Figure 3: Number of developed and applied CAD-programmes in Germany (subsidized programmes)

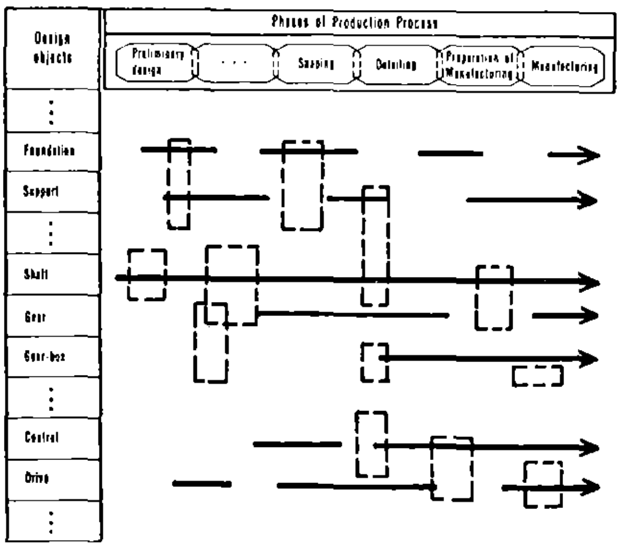


(Source: Riehm 198o, p. 1o)

(23) This is obviously not the place to present the results of support for individual C.A.D./C.A.M. projects in any detail. This has been done in a series of individual reports published by the project management. We only wish to comment on three issues. The first of these concerns the system conception followed and thus the aims of development.

Project management came to the conclusion that isolated tasks in the civil, mechanical and electrical engineering industries are accomplished with the aid of EDP and that there was no integration of individual steps. The projects were intended to make such integration possible by using EDP's capacity for the transportation, evaluation and dissemination of information, thus avoiding many errors which occur in the conventional process of design and manufacturing. For this purpose it is, however, necessary to build up data sets and programmes tailored to specialized subjects. The objective is to provide C.A.D./C.A.M. programme packages for the design of a limited series of objects combining the individual steps in design and manufacturing at a series of exactly defined intersections. This is illustrated in the following figure.

Figure 4: Assignment of Multi-purpose Program Elements to Object Dependent Program Chains



(24) So called generally applicable programmes are of importance for the construction of module-based C.A.D./C.A.M. packages. These apply to basic problems encountered during design and manufacturing. Examples of this kind of programme are finite element methods, packages for processing geometric data for construction purposes and regulations and components for C.A.D. working stations.

The observance of regulations for the construction and presentation of software and the promotion of the exchange of experience between developer and companies is of great importance to the success, i.e. the actual application of projects supported in the companies. The combination of this kind of task and those concerned more with technology and software constitutes a comprehensive and complex programme of innovation management for project management.

(25) Our own project was begun in Autumn 1977 in cooperation with C.A.D. project management. Its main aims were to look into programme implementation and to assess effects on jobs and labour. Despite the close cooperation with project management, the group at the Department of Applied Systems Analysis conducted its research independently.

2.4 Technology and Internationalism: A Case for C.A.D.?

(26) Two major components of internationalism are the spread of scientific knowledge and the intrusion of technology into society. One effect is to facilitate communications across frontiers, another is the smoothing away of cultural differences. Economic development towards supranational markets and companies may find its equivalent in a similar development of technology. Whilst governmental support for C.A.D. might never have come about had there not been concern on account of declining competitiveness of European economies, the supported technology could contribute to exactly the opposite effect, as Hatvany, Newman and Sabin suggested in their report. This could come about by means of thematically limited contact between C.A.D. experts using information networks: "We believe, however, that one of the greatest benefits that computer networks can offer is their ability to bring C.A.D. users in contact with each other. This is clearly illustrated by the way in which the ARPA network has brought together groups of research workers with similar interests, permitting them to work collaboratively despite being widely separated geographically. Networks can also make the distribution of publicity and documentation about C.A.D. programmes much more effective. For these reasons we believe that large computer networks will play an increasing part in C.A.D. in the future" (p. 91).

3. Current State of Development and Application in Great Britain and the Federal Republic of Germany

3.1 Introduction

(27) To the best of our knowledge, there are no reliable statistics on the numbers of C.A.D. systems currently in operation throughout the various countries. It has been estimated that there are at present about 150 C.A.D. systems in Germany. A recent survey conducted by the management of the German C.A.D. support project suggests a similar figure (cf. Riehm 1980). However, a recent paper on the effects of microelectronics quotes the more conservative figure of 150 installations for the whole of Europe (cf. Warnecke, Bullinger, Schlauch 1980, p. 6). The number of systems operating in Great Britain is probably approximately equivalent to the German figure. However, in an interview, Sabin stated the opinion that German systems are concentrated more at universities than they are in Great Britain.

3.2 Historical Development of C.A.D. in Great Britain and the Federal Republic of Germany

(28) Although the first C.A.D. programmes were developed at roughly the same time - 1963 in Great Britain and 1964 in Germany - public subsidization and subsequent proliferation of the technology started about 4 years earlier in Britain than it did in Germany. This is documented by the setting up of the C.A.D. Centre at Cambridge in 1969, a development approximately paralleled by the establishment of C.A.D. support project management at Karlsruhe in 1973. The somewhat earlier public support of C.A.D. in Britain is probably due to the aircraft industry's more prominent role in the economy (Interview with M. Sabin, lecture by M. Cooley). Prior to its application in industry, C.A.D. was used for military purposes (interview with A. Llewelyn).

(29) There has been comparatively little resistance to the introduction of C.A.D. in Great Britain, apparently due to a shortage of skilled staff for

the tasks taken over by C.A.D. (Sabin, Llewelyn in interviews). Whilst Cooley agrees with the statement on shortage of staff, he also feels that the gap between supply and demand for draftsmen was created artificially in order to alleviate the introduction of the new technology. In support of this argument, Cooley quotes Noble (1977) who seeks to demonstrate that enterprise attempts to structure the labour force in accord with its own requirements, which in turn also largely structure the technology employed. Cooley asserts that the traditional 7-year apprenticeship for designers was brought to an end in the mid-1960s and replaced by the redistribution of tasks among university graduates and detail draftsmen as "drawers of lines". This trend was paralleled in the United States by the Department of Labor's forecast that the occupation of draftsman would have died out by the mid-eighties. The shortage of draftsmen is not paralleled in Germany and trade unions are anxious about possible effects on employment.

3.3 Current uses of C.A.D. Systems, Forecasts for the Future

(30) As stated previously, C.A.D. was initially employed in the British aircraft industry. However, Sabin feels that early development was one-sided and went into the wrong direction since it was concentrated on NC mills while German development concentrated on turning systems which were in greater accord with industrial demand. Computer aids have been employed in chemical engineering for a comparatively long time. Sabin sees great potential for further development and increased use as computer time costs decrease. He also forecasts rapid proliferation of use in the fields of mechanical and electrical engineering in the next 5 years. Attempts to apply C.A.D. in building design and construction work have encountered some resistance, although its potential in this field is great. The shipbuilding industries in both Britain and the Federal Republic of Germany have widespread use of computers to assist in design. However, both industries are experiencing an economically rough period and will probably have to be completely restructured in order to survive in the face of international

competition. Disregarding programmes developed at universities, in the Federal Republic of Germany the vast majority of C.A.D. programmes are employed for building and civil engineering purposes. The next most important field of application for C.A.D. in Germany is shipbuilding followed by mechanical engineering. It is, however, important to emphasise, that the figures available to us apply only to subsidized projects, which were designed to give aid mainly to smaller companies so that the automobile industry, which is also heavily involved in the development of C.A.D., is excluded.

(31) Whereas the German C.A.D. support project is aimed principally at smaller companies - according to the July 1978 status report 30 % of the companies funded were of small and a further 40 % of medium size - small and medium sized companies are not subsidized in Great Britain, since no effective procedure for this has as yet been developed (interview with M. Sabin). Systems developed for the larger companies cannot readily be adapted to the requirements of the smaller companies. Llewelyn believes that the correct procedure for the smaller company is to first install an office information system and to gradually expand this, adding applications where they are feasible and building up eventually to an efficient design system.

(32) In addition, in Great Britain turn-key drafting systems are no longer subsidized since their advantages are by now widely recognized. More effort is being put into the integration of the various stages of the design process, an approach also favoured by German project management (cf. Lang-Lendorff, Rothenberg 1979, p. 3ff.) Sabin forecasts that all available turn-key systems will be filled out with options for 3-dimensional geometric modelling within the next 3 years (interview).

(33) Whilst the future development of hardware would seem to present no serious problems, rising software costs - especially for programmes intended only for intermittent use - could lead to pressures such as the introduction of shift-work or the use of obsolescent programmes. This forecast tallies with the conclusions of an expertise commissioned by us, which states that software costs will prove the greatest barrier for the spread of C.A.D. to small and medium sized companies. In future, the hardware can be thrown away with the software (Llewelyn, interview).

4. Effects of Information Technologies on the Economic Structure

4.1 Introduction

(34) None of our partners in discussion was involved in research exclusively concerned with the effects of computer aided design on the economy. However, a project on this subject is planned for 1980/81 by the University of Sussex's Science Policy Research Unit (S.P.R.U.). This review is thus confined to a discussion of the effects of computers in general on the economy.

(35) For a number of years, work has been done by several people at SPRU on the effects of microelectronics on the British economy. Two recent books (Barron and Curnow, 1979, Jenkins and Sherman, 1979) are based, at least in part, on the results of this research work. Some members of SPRU have used a review of the theory of the firm as the basis for studies on the implications of technical change for manpower and skills. Ken Green and Rod Coombs of Manchester University have examined the effects of micro electronics at a local level (Tameside). Finally, a group at the Computer Systems Laboratory at London University's Queen Mary College has examined the potential for integrated office information systems (Coulouris et al. 1977).

(36) The present review will be divided into the following sections:

- Special Features of Information Processing Technology
- Effects of information processing technology on industry
  - a) manufacturers of components and configurations,
  - b) companies using the technology,
  - c) employees in companies using the technology.

4.2 Special Features of Information Processing Technology

(37) The advent of the microprocessor has frequently been hailed as the dawn of a new "industrial revolution". Whilst it is not yet possible to say whether

such a view is exaggerated, it is most certainly true that microprocessors are showing a profound effect on economy, if not by their actual impact then by their very existence.

(38) In a recent lecture at the 1980 Fraunhofer-Institut für Systemtechnik und Innovationsforschung Colloquium, Prof. Christopher Freeman (S.P.R.U.) has compared the proliferation chances for micro electronics with those of nuclear energy and supersonic flight. He considered that the following factors were of importance for the diffusion of a technology:

- Profitability and pressure through competition as a guiding principle;
- The volume of necessary capital investment;
- Change agents;
- Acceptance of the technology.

Public acceptance of a technology depends on such factors as environmental effects, safety, technical dependability and performance characteristics. Micro electronics were initially subsidized both in the United States and in Europe, but Freeman considers that the technology would have asserted itself even without state backing. Micro electronics are being backed by many governments, by multi-national enterprise, by smaller companies and scientific institutions. Because of their potential for savings and energy, micro electronics are even favoured by a number of ecologists. The major problem with micro electronics would appear to be the threat of mass unemployment, which subject will be dealt with later on. Freeman's main conclusion is that conditions are more favourable for the diffusion of micro electronics than for any major new technology emerging since the end of the 2nd World War.

(39) Curnow and Barron (1979) have written a whole book on "The Future with Microelectronics". We shall present a brief summary of their conclusions. One conclusion is that contemporary information technology for the first time provides a closed system for the handling of information (p. 13). Whereas in the past, the development of computing was to a large extent determined by the pattern of technology, in 5 years' time the existing technology will have potential for fundamental changes in the economic and

the social order. The sequence and timing of change will no longer be determined by technological factors but by social and economic considerations (p. 14).
The costs of microelectronics will be such, that information processing and storing techniques will be available for everyday uses (p. 14). The key technological development in this process will be the microcomputer, which should be available in an effective form in the next 2-3 years according to Barron and Curnow (p. 14 f.). The main barrier to mass diffusion of computing in the near future should prove to be software costs, a view also stated in an expertise prepared for AFAS' C.A.D. project. In Barron and Curnow's view these costs will best be reduced by selling multiple copies and no longer programming tailor-made to customers' requirements. The competitive pattern will be similar to that of the market for semi-conductors with strong price competition, the need for large active markets and with pressure to innovate (p. 16). The structure of the computer industry will also change considerably, due to the decrease in importance of main-frame computers. "The existing capital investment in large-scale computers for data processing means that this area will be relatively slow to adapt and take advantage of the new technology, and will be overtaken in innovation and size by other markets" (p. 16). It is to be expected that components will be specialized in order to handle different types of information. Large scale markets will be established in the area of handling textual information (p. 17). In general, Barron and Curnow expect a tendency towards an electronic information society which can only be delayed by a lack of adequate telecommunications capability provided by the post office.

4.3 Effects of Information Processing Technology on Industry

(40) The next section of this discussion is not concerned solely with the effects of microelectronics on industry, but also with the conditions under which industry can successfully exploit the new technology. Thus we will be considering marketing strategies, sources of resistance to the technology

and any other factor which may contribute to the success or failure of a potentially saleable commodity.

a) Manufacturing Industry

(41) The opinions we heard in Great Britain do not allow a systematic differentiation between manufacturers of component parts and manufacturers of complete computer units.

(42) As mentioned before, Barron and Curnow expect a complete restructuring of the computer manufacturing industry. Whereas the main-frame computer industry is on the decline, the software industry has considerable potential. However, Barron and Curnow also state that the national U.K. market for software is not sufficiently large to provide a base for competition. They come to the conclusion that it is more important for the U.K. to use the technology than to provide it.

(43) The group at Queen Mary College (Coulouris et al.), writing on office information systems, take a slightly different view. They consider that the United Kingdom has more of the essential technological capabilities for this area than any other country except the United States and that the U.K.'s secondary rating on the market was due to management's failure to market products aggressively enough: "However, the technical expertise is highly dispersed at present, and it is not matched by equivalent management and marketing experience. Our provisional assessment, based on the limited survey that we have been able to carry out, is that no U.K. company has the right combination of technical expertise, management vision and marketing organization to enter the integrated office systems market" (Coulouris et al. p. 13).

(44) The Federal Republic of German Government foresees that manufacturers of large and medium sized computers will be able to assert themselves on the market without subsidization by the early 1980s (Bundestagsdrucksache 8/2107, p. 4). Subsidization of the manufacturers of small computers and terminals

and the advance of microelectronics have led to a restructuring of this branch. Turnover increased by 40 percent from 1974 to 1977. However Government believes the restructuring process is not yet over and that considerable subsidies will be necessary to complete it and meet demands for more complex programmes. Despite these difficulties, German manufacturers of small computers and terminals have been able to assert themselves on the international market: a major proportion of production is in fact exported. A Government programme for the subsidization of electronic components is deemed successful, since turnover for individual components on both the domestic and the U.S. market was increased. Further subsidization is considered necessary in order to keep pace with technological development and market demand (Bundestagsdrucksache 8/2107, p. 5).

(45) A report published by the European Trade Union Institute reviews the development of the structure of the electronics industry in Europe. The comparatively poor position of the European electronics industry in competition with the United States and Japanese industries is attributed to government intervention, partly in the form of military contracts (U.S.), and in the shape of controls on imports and investment in addition to government expenditure of 500 million dollars on research and development in Japan.

(46) Although the equivalent of more than two billion dollars have been given by European governments in support of their domestic data processing and advanced electronic industries, support at a European or EEC level has not been highly coordinated. Indeed, plans for closer cooperation between European manufacturers failed following the withdrawal of support by the French government. In July 1979 the EEC approved a programme to encourage standardization and technical harmonization within the data processing and advanced electronics field at a European level as well as resources for research into the development of new uses. The total programme of expenditure is, however, small in relation to the total amounts of expenditure on research and development in the data processing and advanced electronics industry.

(47) The report comes to the conclusion that United States and Japanese companies are in control of the diffusion of the new technology into commercial

applications and that only in telecommunications have European companies been able to maintain substantial market shares. In general the report seems to forecast a fairly bleak future for the European data processing industry: "In the 1980's, the danger of increasing American and Japanese domination in components and computer manufacturing in Western Europe must give concern on both strategic and direct employment grounds" (p. 39).

(48) Barron and Curnow (p. 20) also believe that telecommunications have the greatest potential for the (in this case British) economy and that positive effects could be achieved by an active programme of investment in this area.

(49) Additional problems that have been mentioned in connection with the competitive position of national electronics industries are the lack of backing-up services provided by manufacturers (such as learning aids, organizational conceptions, software etc.) (cf. Bierhals 1979, p. 51) and their failure to meet delivery deadlines. Of course, this kind of experience leads to a lack of confidence in the industry and is in strange contrast to the reliability attributed to its products.

b) Industry using the Technology

(50) It is a well-known fact that costs for data processing have declined rapidly making computing a feasible proposition not only for large companies but also for small and medium sized companies. The major obstacle to widespread use of EDP are software costs, which in many cases will be greater than those for hardware. A possible solution to this problem is the standardization of software mentioned previously. However, in some cases the ready-made packages have to be adapted to the requirements of the company. A German C.A.D. expert mentioned a period of up to a year as necessary for the adaption of turn-key systems to company requirements. We gained similar results in our pilot study on C.A.D.. The amount of work involved in the modification and adaptation of programmes is regularly underestimated by the firms.

(51) In the special case of C.A.D. Malcolm Sabin, of the C.A.D. Centre at Cambridge, doubted whether it was at all a feasible proposition for smaller

companies. This would apply especially if the problems tackled by C.A.D. occurred only infrequently. The proper solution in this sort of case would be to give subcontracts to firms using C.A.D. on a consultancy basis.

(52) The former director of the C.A.D.-Centre, Arthur Llewelyn, favours a slightly different approach, which need not, however, directly contradict Malcolm Sabin's position. In the past, computing systems were built up mainly in-house by larger companies, tailored to the company's requirements. This meant that systems were unique and could not readily be transferred to other companies. The solution to this problem must lie in structured and modular systems using building blocks and this can be achieved through some catalyst able to incorporate application experience into system software - ideally some combination of certain elements of the UK's C.A.D. Centre, France's MICADO, and the Data Processing Programme of Germany.
In order to obtain the greatest benefits from EDP Arthur Llewelyn thinks, based on surveys he has carried out, that smaller companies are likely to make a start with word processors that could be used for communication between engineers, administration and management on such matters as billing, ordering parts, making up inventories and so forth. To a basic system such as this the firm could add built-in options in a selective manner, gradually building up a powerful system, catering for the firm's own requirements. A process of this kind could take up to 10 to 20 years. In many sectors of industry however C.A.D. would seem essential to survival and to cope with rapid changes in market demand.

(53) Despite the existence of turn-key systems, C.A.D. would seem to be an unrealistic proposition for smaller companies in the immediate future, which would mean the diffusion rate is slower than optimists for reasons of technological progress or pessimists for employment reasons would have us believe. This view was shared by almost all of our partners in discussion in the United Kingdom.

(54) Members of the Science Policy Research Unit at the University of Sussex have reviewed economists' theory of the firm. A brief summary of this review follows (cf. Sciberras, Senker, Swords, 1977).

- Sylos-Labini disagrees with short-term profit maximization as an innovation motive. Profit maximization is a long-term goal which takes into account both market variations and changes in customer demand.

- Joan Robinson believes that the profit motive is secondary to the goal of an organization's survival.
- H. Simon argues that the motive of profit maximization requires the firm's having perfect knowledge and information. In his opinion, company goals are set by means of internal negotation whereby conflict is never finally resolved.
- Galbraith asserts that the social values of the techno-structure will manifest themselves in the aims of the firm due to the separation of ownership and control.
- Williamson believes that the goals of industrial managers will assert themselves, due also to the separation of ownership and control.
- According to James Earley, profits are the prerequisite for the fulfilment of manifold goals, not all of which are necessarily profit orientated. "High and rising profits are hence an instrument as well as a direct goal of great importance" (Scriberras et al., p. 12).
- Baran and Sweezy regard profit as an important motive, determined by both external market pressures and from inside the firm. Strength, rate of growth and size of the firm can all be attributed to the common denominator, profit.
- Sciberras himself has attempted to develop a dynamic conception of the profit motive in contrast to the conventional static approach. Hence, it is perfectly rational for a firm to accept losses as a new product is introduced into a market in anticipation of increasing gains as the product reaches maturity.
- Lamfalussy differentiates between a firm's investment behaviour in expanding markets and defensive investments in declining or stagnating markets.

(55) Despite these manifold approaches to the problem of firms' behaviour in regard to investment, a number of important questions remain unanswered: "For example, do firms with different production organization, flow, batch, mass or unit, tend to adopt different goals and strategies? Do different firms within each category adopt different priorities? In what way do different goals and strategies affect competitive behaviour and competitiveness of firms, particularly as this may influence technical change?

Do firms in an industry change goals under different economic conditions, and if so, are unit, batch, mass and flow firms different in this regard?" (p. 14).

(56) The book on our pilot study on the social effects of C.A.D. (Bechmann, Vahrenkamp, Wingert, Section 5.1) also briefly reviews the various theoretical approaches to innovation. The open questions posed by Sciberras et al. will be one subject of the larger-scale investigation planned for 1980-1981 in addition to the influence of such factors as company history, industrial relations and so forth on investment behaviour.

(57) Sciberras et al. also examine the effects of technological change and investment behaviour. Whereas the neo-classical school regards technological change as an exogenous variable, Schumpeter's approach claims mutual dependence between technological equipment, innovation and competition in the market. "Economic progress means essentially putting producing resources to uses hitherto untried in practice and withdrawing them from the uses they have served so far. This is what we call 'innovation'." (Schumpeter 1928). There is a marked tendency towards equilibrium, caused by other companies in a market following the pioneer's example.

(58) New approaches, e.g. J. Bain, emphasize factors which protect a firm's position in the market and prevent new competitors from entering the market, e.g. the use of patents.
The existing theoretical approaches are considered by Sciberras et al. as useful pointers. However, in concrete case studies they do not satisfactorily incorporate the situation of the firm and the interplay between different factors. Among the open questions are the following:
Does the manner in which forces of competition operate encourage the imitation of innovation and thus dissipate the temporary benefits for pioneers? What, if this is the case, are the long-term effects on the economy? Alternatively, the easy entry and imitation could encourage the rapid diffusion of technology or the early dissipation of advantage could discourage the innovative firm, thus in the long term negatively influencing the prospects for technical change.

(59) Clark suggests in contrast, that the forces of competition operate in such a manner to compel leading firms to renew their competitive lead by repeating innovative efforts in order to renew monopoly profit levels. In this case, a sufficient period of monopoly profit is necessary to be able to finance rapid change in addition to sufficiently innovative and aggressive management to adopt a policy of rapid technological change. Other important questions concern the effect of the competitive environment on the firms that are followers, chances of survival and the effects of the resulting increased concentration on technical change.

(60) According to the conventional theory of the firm, the product spectrum depends largely on price policy. This does not, however, suffice to explain the relationship between technical change, manpower requirements and competitiveness. Product policy, especially in regard to variety and standardization, must be taken into consideration. Standardization has the advantage of enabling mass production and the benefits of economies of scale. Joan Woodward quotes the example of a company being able to market its products successfully only as long as it was additionally prepared to cater for its customers' individual requirements. General Motors were more successful in the market with a broad programme of models in comparison with Ford's more limited, standardized programme.
Advantages may be secured by a standardization of parts and variety in assembly, enabling a firm to take advantage of both the lower costs of mass production and being able to cater for individual customer demands. The relative costs for servicing decrease with the increasing rate of diffusion of products on the market. Old and proven component parts can be included in new models and products in order to secure advantages in repairs and spares services.

(61) Sciberras et al. criticize contemporary marketing conceptions on the grounds that they are too vague and often restricted to price policy, which is too narrow a definition as marketing embraces many functions of the firm. In the view of many theorists, marketing is concerned with what management should do and not with what it actually does. Thus, marketing

does little to add to our knowledge on what happens in reality. Whereas after-sales service is of great importance for the success of the firm, this area is often neglected by marketing.

(62) Multinational companies pose a challenge to the theory of the firm, which was hitherto concerned only with uninational firms. According to Penrose, increasing firm size leads to decreasing efficiency because of problems in coordinating and controlling. The actual situation does nothing to confirm this theory. Findings on the coherence of aims in multinational firms are contradictory. Multinational companies' strategies in regard to technical change and product diffusion vary from most rapid diffusion to delayed diffusion. According to some theorists, the firms spread production from the firm's mother country to other countries, however some studies have shown that the speed of product diffusion is dictated by interests of world-wide profit maximization.

(63) These considerations can be applied in part to both the manufacturers of C.A.D. components and configurations as well as to the firms using them as part of a strategy to secure or improve their competitive position in the market. In the course of our project we will also be closely concerned with the decision making processes inside the firms and with the attitudes and actions of individuals which can either promote innovation or act as a barrier to its diffusion.

(64) We have already mentioned the view of some of our partners in discussion, that technical know-how was not in all cases matched with the equivalent skills in management and marketing. Peter Senker has argued that resistance to new technologies in both Great Britain and the Federal Republic of Germany was greater in management than it was on the shop floor. This was due to management's reluctance to undertake the responsibility for change. Resistance was however greater in Great Britain than it was in Germany, due to everybodys' being consulted in that latter country (laws on employee participation, "Betriebsrat"). Nobody can be held directly responsible for failures, whereas in Great Britain management feels that it

might be held responsible. Hence, when teething troubles crop up during the introductory phase, resistance is created to further purchases. Senker believes that the greater resistance in Great Britain is due to the poorer organization, training and education of management than in Germany rather than to resistance from the trade unions or the shop floor. In another paper, Senker attributes part of management's resistance to modernization to a lack of the engineering skills necessary to obtain the full benefits of automated equipment, a point which is discussed more fully in another section of this review.

(65) Trade unions would appear to have become aware of this deficiency on the management side due in part to the publication of two investigations commissioned by union representation. The first of these, on behalf of the Coventry Machine Tool Workers' Committee, came to the conclusion that British companies adjusted their supply to markets where demand could be met with the aid of obsolescent manufacturing techniques, simultaneously letting themselves be edged out of markets requiring the new technologies. Among the recommendations was that the companies concerned be nationalized. The second investigation, this time on behalf of the Churchill ltd. Shop Stewards, comes to similar conclusions without, however, recommending nationalization. These two investigations have had the effect of increasing militancy. It is also suggested that the failure to introduce technical change could lead to a deterioration of industrial relationships because of the possibility of long-term redundancy.

(66) To conclude this section, we will briefly present results on the actual impact of a technology, in this case numerically-controlled machining. Peter Senker et al. (1976, p. 50) report that shortage of labour as a motive for modernization was more important for contract toolmakers than it was for in-house toolrooms. Although the contract toolmakers tended to offer better pay, job security was perceived as greater for in-house toolrooms. The application of numerically controlled machining has in some instances led to significant increases in productivity. The impact of the technological change was closely related to the nature of

products being manufactured. Most significant gains in productivity were shown by those toolrooms willing to change aspects of their operations, a matter that will be considered in a later section of this paper (cf. Senker et al. 1976, p. 50). In some cases, the productivity gains were greater than would have been required to compensate for the labour shortage. If this was the event, companies would operate voluntary redundancy policies. The level and mix of output can vary significantly at such times, so that it is difficult to isolate the specific impact of technical change on manpower requirements.

c) Manpower Requirements

(67) The greatest concern created by the new technology has been about its possible effects on employment. The microprocessor has been described as a job-killer and no one would claim that significant numbers of new jobs could be created by them. Most predictions on the employment level in the 1990s seem to agree that microelectronics will lead to about 4 million unemployed in the U.K. by the end of the century, if employment patterns are unchanged. Predictions for other countries including the Federal Republic of Germany produce very similar results. However, as hinted at before, failure to introduce the new technology can lead to long-term unemployment. Jenkins and Sherman (1979) quote predictions that the failure to introduce new technologies will in the long run lead to a higher level of unemployment than is created by job displacement effects of the new technology.

(68) Barron and Curnow expect the impact on direct manufacturing activities to be small with the main immediate impact on the information sector with secretaries, typists, clerks and managers, the professions and jobs affected to the greatest extent. Since up to 65 % of the working population are employed in the information sector, predictions for unemployment quote figures of 10 to 20 % of the work force.

(69) Whilst experts are almost unanimous in their assessment of the magnitude of labour displacement effects, it should be pointed out that most also

feel that the effects will be slower in making themselves felt than the popular media would have us believe. This was confirmed by Rod Coombs and Ken Green, who have carried out a study on the effects of microelectronics on the local economy of Tameside. They also pointed out that the main arguments from the debate on automation were being repeated in the debate on microelectronics.

(70) There is also a lack of consensus on the evaluation of the displacement effects created by microelectronics. It has often been pointed out that the jobs replaced by microelectronics are in general monotonous, tedious and thoroughly unpleasant. On the other hand, work has values not immediately connected with its actual nature. At present, most people would prefer even the more unpleasant jobs to being out of work. Most authors appear to agree on the obvious remedies to the problem, most of which however require new attitudes to work as we now know it. The chances of these remedies actually being employed are judged with varying degrees of optimism. Microelectronics offer the opportunity to significantly increase the level of productivity in industry and society could reap the benefits if these are distributed equally.

(71) Among the measures that could be employed to counteract mass unemployment is shortening working hours, whether by reduction of the number working hours per week, by granting longer vacational periods, by lowering retirement age or by other means such as sabatical years, vacations in early parenthood and periods of vocational training. Measures such as these depend largely on the results of negotations between employees' and employers' organizations and also on the relative competitive position of the economy.

(72) Another obvious remedy is the redeployment of people displaced by microelectronics to jobs in the service sector. Some experts see a distinct tendency of Western societies towards service-based economies. Increased leisure time will create additional demand for recreational and educational services as well as for various kinds of entertainment. Another possibility is the improvement of health care and services provided for so-called mar-

ginal groups such as the aged or children. There is, for instance, no real reason why the present staff to patient ratio in hospitals should not be balanced more in the patient's favour with each patient eventually being attended by 2 or 3 nurses.

(73) Obvious though this kind of solution to the employment problem may be, it does require the money to pay for the services provided. This means that those in currently accepted jobs must be willing to pay for the services offered by those entering the new, socially hitherto not accepted jobs and that attitudes must shift towards accepting a service-based economy. There is, of course, no real barrier to this since it has happened continually in the past. No manufacturing worker would, for example, seriously accuse an office worker of being a parasite, simply because the work the latter did produced no immediately tangible (i.e. consumable) results. It should, however, be pointed out, that office jobs are often eyed with suspicion by people involved in the production of goods since we cannot, after all, eat or wear a bill or a customer file. However, as fewer people are employed in actual production, this sort of attitude will probably disappear altogether.

(74) Incidentally, while on the subject we should mention that Jay Gershuny, a member of S.P.R.U. who has done work primarily on the service sector, believes that computers could be gainfully employed in improving the quality of services offered, thus enhancing their acceptability to the general public and increasing its willingness to pay for the services.
This willingness to pay, however, depends largely on the availability of money which depends in turn on the benefits of new technologies being distributed equally throughout society. This would mean the benefits being enjoyed not only by those immediately involved in the production of the new technologies or in control of them and thus once again implies a shift in values, and possibly in the distribution of power.

(75) Computer aided design is but one small segment of the overall picture and much of what has been said applies to this technology. In part, the jobs which will undoubtably be destroyed by C.A.D. are extremely tedious,

such as adding up columns of figures or drawing lines. It is also true that those jobs that will be left when the unpleasantness is taken out, will be highly qualified and personally satisfying although they may also have more unpleasant sides, dealt with more fully in the section on skills.

(76) We should point out that most of the judgements cited above are from people with a value system that places great value on personal job satisfaction. They are in the main people with reasonably satisfying jobs, a privileged and pleasant working situation and a degree of freedom to communicate and exchange ideas. It is, of course, also perfectly valid to regard jobs as a means of procuring money to conduct other, more personally satisfying activities. This would shed a different light on much of what has been said. It can also be argued that many of the jobs created in the service sector are hardly more pleasant than those replaced by microelectronics. After all, it is not everybody's idea of ultimate fulfilment to tend to the sick or aged, however highly society as a whole may value such activities (which are incidentally usually poorly paid).

(77) A lot of what has been said above is highly speculative. Solutions to the problems require a great deal of imagination. We most certainly do not expect to contribute greatly to remedying problems of unemployment through our own project. What we can do and certainly hope to do is to add to the knowledge on the effects of information technology on employment and skills.

5. Computer Application and the Development of Working Skills

5.1 Introduction

(78) Harold Thimbleby provided us with a list of literature references on the social implications of computing. The list, which includes almost 200

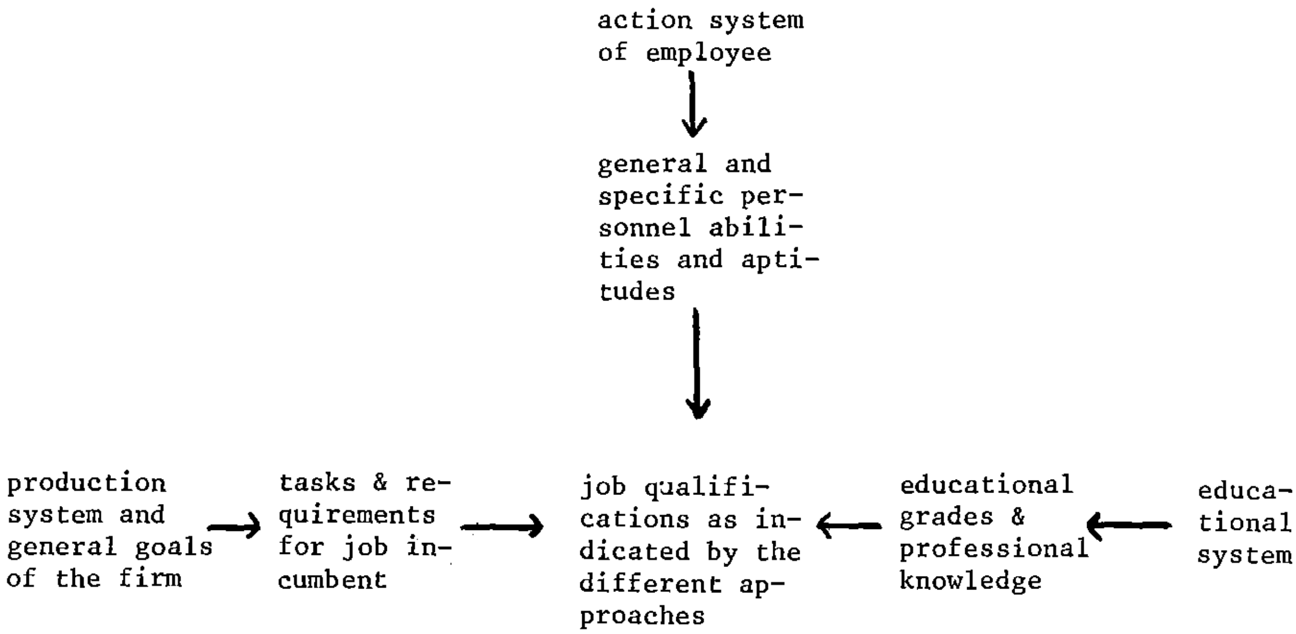
titles of books concerned with this kind of problem, was compiled by Thomas J. Houser of Millersville State College (USA) (1977). Its purpose was, among others, to serve as a basis for the computer science BS degree programme and it encompasses a large variety of issues. However, interestingly enough, the heading to this chapter is not included in the list of topics covered, neither are related topics such as "computer use and human labour force" or "impact of computer on job skills". The problem is no doubt dealt with under such headings as "effects of automation" or "impact on economy". The grid used for the selection of headings would suggest that new products and methods of production made possible by the application of computers in addition to the tasks involved in the manufacture of computers, electronic components, computer display facilities, plotters etc. necessitate new contents and forms of work. From this point of view, the manufacturing sector may almost appear as the cause of effects on sectors of society other than manufacturing, e.g. the cashless society, the privacy problem, computer crime. However, the development and application of electronic machines has always been accompanied by visions of fundamental threat to working people: the automatic factory, redundancy due to technology and complete control over the work situation.

(79) In the following section we will be concerned with these issues. How does the use of computers affect skills necessary to carry out tasks? This is one central problem in our project and the opinions stated by our partners in interviews demonstrated their earnest concern in regard to this issue, whether they came to a positive or a negative conclusion. Before we elaborate on the arguments stated, we should make an attempt to define the subject of our discussion. This is not as simple as it may seem since the term "working skill" is not as common in English and American usage as it is, for instance, in German research on the sociology of industry. We will take as our point of departure a standard text on industrial psychology by McCormick and Tiffin:
"If you are sawing a board on a power saw, you have to have the visual acuity to see the saw and the board as well as the hand steadiness to control the movement of the board. From such an example we can see a rather direct relationship between the job activity on the one hand and

the job requirements on the other. Job requirements (sometimes called worker requirements) in effect are the characteristics that the worker should have in order to perform the job in question" (1974, p.55). Kern and Schumann employ an almost identical formulation in an important work for German industrial sociological research, conducted on behalf of the "German industry's curatorium for Rationalization" (RKW): "Working skills are human abilities required by the work process, in order that it may be successfully accomplished" (1974, p. 67, Vol. 1). The essential question is the relationship between the demands the business system includes and defines and the conditions of performance which make it possible to fulfill these demands.
A substantial amount of the dispute over the term working skills is connected with two aspects. The first of these is that in analysis no clear distinction is made between demands (as the attribute of a task) and performance factors (as an attribute of human behaviour) and the second is that the relationship between these two factors is not always very close and the task can be accomplished by persons with very widely differing performance characteristics. The example described by McCormick and Tiffin could lead us to assume a generally close correspondence between object characteristics and the abilities necessary for their manipulation. McCormick and Tiffin however state that this is not the case in the same place:
"Although this example tends to make the question of job requirements seem relatively simple, we should be aware that there is some fuzziness on both sides of the relationship. (...) If we consider the jobs of medical technician, computer programmer, or design engineer, we can see that the fuzziness ... can become quite marked" (op. cit., p. 55f).

(80) New technologies also imply a shift in training requirements in general or vocational education. Once again, the same lack of exact definition applies, pointing to the dilemma of all educational research both from the sociological and the economic angles. No conclusion may be drawn from knowledge on impending technical change on the educational contents necessary, nor can we decide which knowledge will be necessary for which individual jobs.

Figure 5: Areas of indicators for working skills



In developing our model we have therefore proceeded from the assumption that working skills are a hypothetical construct. It may be approached from business' production goals and the existing method of production, or, on the other hand, from personal performance qualifications or from the angle of training content. It is only when one can indicate these job qualifications from different angles and when clear distinctions can be made between characteristics serving to label something (indicators) and those subjects labelled (indicatum) that one can avoid a great deal of pointless discussion. This situation is described in Fig. 5.

(81) We shall for a while continue making analytical distinctions. Although this may appear artificial, we wish to distinguish most precisely between job tasks and requirements on the one hand and workers' performance conditions on the other hand. In our opinion, the following dimensions are suitable for the description of the work situation.

- Specificity or generality of job requirements and workers' conditions. This includes the important question of how broadly or how flexibly once acquired skills may be employed.
- The temporal structure of requirements and performance conditions, i.e. are the requirements permanent or merely temporary?

- The amount of tension as the measure for (psychic) energy involved in qualifications, i.e. how easy or difficult is it to fulfill the tasks. Naturally, a large number of qualitative factors should also be taken into consideration at this point.
- The relative value of various skills, i.e. in particular the speed with which qualifications once acquired become obsolete or whether these are cemented, renewed or enhanced in the work process.

(82) Many of these issues have been the subject of research in German industrial sociology and psychology, for instance in work by Hegelheimer et al (1975), Mickler et al. (1976), Fricke (1975), Fricke and Fricke (1977) and Lempert (1977). Although the question of the down-grading and new formation of qualifications is obviously an important issue both for guaranteeing a qualified labour force and for the individual worker, there is very little validated empirical knowledge on this subject. This was, for instance, the result of a systematic literature review by Frei and Baitsch (1979) which included a large number of British and American journals. This project, headed by Professor Eberhard Ulich, is attempting to develop a taxonomy of favourable and unfavourable conditions in the business working situation and for individual willingness to qualify oneself.

We shall be concerning ourselves with this question in the course of our project, however more from the angle of whether new technologies devalue skills and encourage or obstruct the creation of new skills. The opinions of our partners in discussion gave us a series of important and interesting pointers to the development of qualifications in relation to the technology involved.

5.2 Empirical results

(83) Two of our partners were directly involved in collecting empirical data on the way in which qualifications of workers would develop assuming a future increase in the application of C.A.D. or more general technical

aids. The following section will therefore be employed to review some of the results and impressions in addition to our own results and those of other German studies.
The "World survey of computer-aided design", prepared by Hatvany, Newman and Sabin for IIASA (International Institute for Applied Systems Analysis), provides an excellent point of departure. Understandably, the survey is chiefly concerned with technical and organizational aspects of C.A.D. development. However a short section headed "administration of C.A.D." deals with social aspects, economics and government regulations and measures. In their introduction, the authors state: "The wide scale use of computers in design has a very different effect from the use of, for example, desk calculators. To put the computer's storage and communication facility to use must have effects on the methods previously used for these functions, and the ability to execute automatically fairly complex design algorithms is an entirely new phenomenon. The effects of the new methods will be fundamental and profound on the people whose work they touch, on the organization of companies, on inter-company communication, and ultimately on society at large" (p. 93).
Two aspects are of special interest to us: changes in job content and in job status. On the first complex, the authors make the following remark: "The act of design is inherently that of decision-making, and with C.A.D. the lower-level decisions are made by the algorithms in the machine" (a.a.O., S. 93). Whilst prior to the introduction of the machine, the designer made both the higher-level and the lower-level decisions, the introduction of C.A.D. has taken away from him the time he could use to consider both levels together. If work was, however, fragmented before the use of C.A.D., lower-level design work has been greatly devalued. In the light of our own survey, we have come to the opinion that the organization of work in individual companies has a strong, modifying effect.

(84) Hatvany, Newman and Sabin mention an interesting feature of the interchange between technical means, new skills, resulting job status and social acceptance of the system in the following passage.
"In a C.A.D. system, the algorithms for the low-level decision will often present the higher-level decision-maker with a ready-made situation. Much

of the basic decision-making power has gone over into the hands of those who write the design programs. It is therefore important to assure either a sense of involvement of the senior designers in the decisions made while writing the C.A.D. programs, or to have these made by someone whose technical and hierarchical competence no one will challenge. If this is not the case, the programs - and with them the whole C.A.D. system - will tend to be rejected" (op. cit., p. 93). According to our interviews, securing efficent cooperation between experienced designers and the programme developers represents a great challenge. In general, job experience does not play the dominant part - the course of development is often determined by technical competence and feasibility.
In the course of their survey, the authors gained the impression that social aspects were taken very seriously in general. We did not gain quite so convincing an impression ourselves. Whilst it was fairly obvious to most of the people we interviewed that social considerations could lead to the failure of C.A.D. and thus to a waste of a vast amount of money, the actual implementation was accomplished by relatively amateurish social management.

(85) The report by Senker, Huggett, Bell and Sciberras is not concerned exclusively with C.A.D. but more generally with "Technological change, structural change and manpower in the UK toolmaking industry" (1976). One main subject is NC machines and their utilization. The survey is of interest to us because of the methodological insight gained by the authors in the course of research and because of a series of hypotheses on the relationship between technological change and skills. Peter Senker told us during our visit to S.P.R.U. that this line of research is being continued.

(86) The previously mentioned research report is on a survey which may be seen as part of a long line of research projects (cf. p. 1-3) started by a study by Martin Bell on the "automation of batch machining". The underlying model was designed to identify particular new technologies which were likely diffuse in the UK engineering industry (cf. p. 1), develop a taxonomy of automation "designed to relate skill requirements to the

type and extent of automation embodied in the different classes of machine" (cf. p. 2), and then to forecast "changes in skill requirements arising out of changes in technology" (p. 2). Both this and a follow-up study revealed that the relationship is by no means unambiguous. "Bell and Tapp (1972) note that the 'skill requirements' of a job may not fully determine the 'skill intensity' of the manning pattern, and that employment patterns are not rigidly determined by the nature of the production technology in use. A host of other factors intervene to create considerable variability in the employment pattern associated with a given technology" (p. 3).

(87) We will concern ourselves no further with this methodological insight or with detailed results of the aforementioned research. The more recent study by and large confirms Bell and Tapp's statement. Management aims intervening between activities on the market and those inside the firm would appear to play a special part. "The relationship between technological change and manpower is not direct, but is enmeshed in the interactions of a wider range of factors. Specifically we found that the extent to which an individual technological change can be advantageous to a particular toolmaking organisation is dependent on the types of product made and on the extent of specialisation; opportunities for technological change are closely related to the organisation of production. We also found that the extent to which technological changes help to alleviate skill shortages is a function of management aims and policies, and possibly of trades union aims and policies as well. Similarly, the 'skill structure' of a particular toolmaking organisation is a function of manpower, training and job design policies, as well as of the economic and technological characteristics of the organisation's activities" (p. 51).

(87) In a brief conversation at S.P.R.U., Martin Bell warned against making deterministic hypotheses. In this, he fortified our previous approach by means of which we are attempting to display the intervening nature of management aims and of the organization of work. Martin Bell himself has withdrawn from the task of trying to fit together the parts of the puzzle of variables to whose design he himself has contributed, since he has

shifted his field of work to problems of industrialization in developing countries. We hope to be able to contribute to the unravelling of the mystery ourselves after the completion of our study. We believe that it is essential to regard the firm as a complex system interacting with the social, political and technological environment, trying to secure its own independence, deploying the in-house skill structure in addition to those skills available on the labour market to this end.

(88) This kind of conceptual framework is described in a paper by Sciberras, Senker and Swords on "The theory of the firm, technical change, manpower and competitiveness: Some theoretical foundations for industrial policy studies" (1977). Two basic questions involved are, which general and permanent goal structure of the firm may be assumed, for instance, if this part is played by profitability, and secondly, by which means effective manpower planning may be achieved. Data collected by Manab Thakur (1975) quoted in the report would appear to suggest that uncertainty on the management side is great and that the time horizon for which plans are made tends to be small. A conception embodying similar aims, i.e. the firm's striving for autonomy, is employed in an approach developed in the Federal Republic of Germany at the Institut für Sozialforschung (Institute for social research) by Altmann and Bechtle. Their central thesis is: "Enterprise autonomy strategies are aimed at organising the economic, technical and social structures of the firm necessary to achieve the production goals in such a manner that the company does not have to rely on services, the utilization of which implies dependence on conditions imposed on the company control system from outside the company" (1971, p. 13).

(89) In those fields of work where C.A.D. and related technologies are employed, one may ask the fascinating question whether computer aids to design do not in fact obstruct the endeavour for autonomy because the wealth of experience in design determines the company's innovativeness to a great extent. We shall deal with this issue later on. It does, however, serve to point to the central role played by skill structure in companies.

(90) In the course of their study, Senker, Huggett, Bell and Sciberras reach another important conclusion for us that applies mainly to the use

At least one gathers this impression when considering the growth of knowledge over the ages as Mike Cooley does in his C.A.D. book (cf. pp 72 et seq. German translation). The time one would need to invest to bring one's obsolete knowledge up to date is ever on the increase. According to model calculations discussed by Cooley in his book the investment would be about 15 % of daily working time or even more in especially dynamic areas of knowledge like the computer industry.

(108) This process is a special source of hardship for older workers as Mike Cooley stressed at the 1976 C.A.D.-Conference: "As there is no real or humane mechanism in our market economy for the retraining of older workers or the updating of their skills, the tendency is for employers to simply replace them by younger workers who are fresh from university with 'new knowledge'. The older members of the design community, who have devoted a lifetime to building-up the know-how embodied in the software packages, find that they experience a 'careers de-escalation'. At that stage, their status in the design team, and their salaries begin to decline, and graphs are presented at the conference to demonstrate this" (p. 310). This is an important field of activity for the unions. In the Federal Republic of Germany some unions have negotiated socalled "agreements on protection from rationalization" which include among other points interim periods of several years with opportunities for professional training or re-training.

(109) New technologies do not appear to lead in every case to traditional skills being directly replaced. Martin Bell stressed that relative distance is of importance. There is no unambiguous correspondence of technology to skill structure. When a new technology replaces an old one, the old structures are initially transferred to the new technology. If the new technology is however created in something approximating a vacuum, skill structure is adapted to the requirements of the new technology. When computers were first introduced there was reason to doubt their reliability, so that there was some justification in retaining old skill structures. As trust in the new technology increased, skill structures were adapted to its requirements. This demonstrates once again the necessity for a reliable taxonomy of mechanization steps or even of a scale for mechanization. Attempts to

(93) Our own data on changes in skills are based on a very narrow empirical basis of 14 interviews and will therefore not be presented in any detail as it was not possible to control for variables such as the prevailing organization of work, specific use of programmes or the existing skill structure. We do, however, think it important to regard C.A.D. as a possibility for the intensification of work, at least if it is in the shape of interactive graphics. This means not only a more rapid succession of steps in the design process but also an increase in the density of information as is the case when, for instance, using menu technology.

In our opinion, two general tendencies are connected with C.A.D. application.

- The first of these is a change in the manner in which one's own work is planned. In the design department iterative manners of working predominate making permanent corrections both necessary and possible. The use of the computer necessitates a change-over <u>from planning during work to planning before work</u>. This is of course a result of pressure to intensify the use of C.A.D. configurations due to their high costs.
- The second is a change in the order in which individual tasks are embedded in the departments down to manufacture. Real advantages may be gained from C.A.D. only when a certain degree of integration is achieved, i.e. when, proceeding from a model stored inside the computer, steps belonging to the planning, preparation and production stages of work may be carried out. Work organization must then take the shape of a chain of linked steps in which the preceeding step must be completed before starting the following step.

At this juncture we must raise the question whether the increase in resources deployed for planning purposes, the explicit definition of individual steps and the endeavour to find integrated solutions really contribute to increased flexibility and thus to increased competitiveness.

(94) Since we ourselves do not yet have a broad empirical basis, we shall briefly refer to a comprehensive survey on the effects of EDP application

on jobs and skills conducted by Werner Dostal in 1978 for the "Institut für Arbeitsmarkt und Berufsforschung" (Institute for research into labour markets and professions). According to his data, which are based on repeated surveys in various branches of industry, a substitutional effect of EDP cannot be denied. This is however due to a lesser extent to existing jobs being destroyed than it is to jobs, that would have been needed to continue old methods of production, not being occupied anew when they are vacated. In our context, the findings on changes in skill structure are of greater importance (Table 1).

5.3 Arguments and Opinions

(95) In the following section we shall be discussing some of the more basic arguments and opinions stated by our partners. Although we shall be mainly concerned with qualifications, we cannot avoid touching other topics, for instance

- issues involved in training and the development of professional knowledge;
- issues touching the design of man-machine interface, which will however be discussed in greater detail in the following chapter;
- the search for technological, societal and economic principles influencing development.

The change in working skills may be examined at a societal level, thus pointing out factors on which the economic strength of a country depends in addition to dangers which might arise. On the organizational level we are concerned with the availability of skills for a firm, whereas on an individual level we are concerned with the destiny of the individual job and with one of the most important sources of man's status and self-esteem. Working skills are closely linked with important phenomena influencing individual and societal life. Thus the lively controversy on this topic is hardly surprising.

Table 1: Changes in work requirements of white collar workers

job requirements	increase	decrease	rate of change on the basis of total amount (o/oo)* increase	decrease
professional education	1063	86	0,98	0,08
professional experiences	1467	30	1,34	0,03
responsibility				
- for own work	555	443	0,51	0,41
- for flow of work	1816	7	0,66	0,01
- for operational reserves	190	-	0,18	-
- for safety	17	14	0,02	0,01
Work strain				
- mental	4217	1660	3,88	1,52
- physical	122	683	0,11	0,63
Impacts from the Work environment				
- noise	290	5448	0,27	5,00
- hotness/coldness	13	302	0,01	0,28
- dirt	-	33	-	0,03
- risk of accident	-	665	-	0,61
- light, illumination, dazzling	-	623	-	0,48
total amount	9750	9894	8,96	9,09

*) The rate of change results from the number of working places, that underwent a change in certain attributes, in relation to the total summ of working places in the industry branches under investigation.

(Source: Dostal 1978, p. 30, table 14)

(96) Many of the suggestions from the following discussion stem from an interview and articles by Mike Cooley who has for a long time been concerned with the issues commented upon. We therefore intend to concentrate on his arguments. Mike has a number of advantages over us: he is older than we are, more experienced and design and C.A.D. are part of his profession. Despite this undoubted superiority he will not expect us to merely repeat his theses, many of which we agree with. We will discuss them and thus hope to contribute to a process of understanding.
No doubt it would have benefitted our project if Mike Cooley had fed his ideas into it at an earlier stage. In a recent article for a German magazine he has most aptly stated a question that has concerned us from the outset of our project and that has become a more central issue the more we have thought about it: "The most subtle process whereby the designer examined quantitative information he has collected and then comes to a quantitative solution is extremely complex. The people who introduce C.A.D. systems into this interaction often state the view that quantitative and qualitative elements may be separated at will and that the quantitative elements may be transferred to the computer. This is merely the introduction of Taylorism to design work and will probably have grave consequences. The rate at which quantitative information is processed increases dramatically, leading to a distortion of dialectic interaction, often at the expense of quality. We therefore have reason to believe that the penetration of the computer into design work will lead to a decline in the quality of design work" (1979a, p. 19).

(97) The more Mike Cooley has concerned himself with this topic, the more radical in the sense of basic his position would appear to have become. Whereas initially the description of the technology itself in addition to anxiety about negative social consequences (shift work, devaluation of traditional working skills) predominated (1972, Computer Aided Design), Taylorism, as a fundamental process for the organization of work, and a professional destiny for the designer previously confined to workers on the factory floor have come to the focal point of his interest (1976, C.A.D.: A Trade Union Viewpoint). In his latest article, criticism is even more fundamental, attacking the principles of scientific thinking in the Western

hemisphere which emphasize analytical fragmentation as opposed to organic qualities and which prefer effective performance to unreliable creative performance. This tradition is attempting to subordinate mental work to the control of the machine instead of employing the wealth of technological achievement for the benefit of mankind (1979, The designer in the 1980's - The Deskiller deskilled).

(98) We shall conduct the following discussion under a series of headings as follows.

1. The historical role of C.A.D.
2. C.A.D. as means for mastering the future.
3. Technology and the means of its reproduction.
4. Computers as extensifiers and intensifiers of human experience.
5. Obsolescence of professional knowledge and skills and the development of new.
6. Knowledge: personal, implicit, and explicit.
7. Taylorism or mechanization.
8. Alternative Technology: human centred, action based, skill enhancing.

5.3.1 The historical role of C.A.D.

(99) C.A.D. may be regarded as a specific case of the introduction of the computer into an area of work. From this point of view, there would be nothing special to it and one could well leave the process of advancing automation and technization to its own means. There would be no new features in addition to those already familiar. C.A.D. would only be a new wave of rationalisation and, after all, Charles Babbage thought that the mechanization of mental work would be feasible as early as 1830. This line of thinking bloomed in the 1920s when offices were rationalized.

There are, however, a number of qualitative differences:

- EDP technology has reached a high standard of performance enabling the representation of extremely complex structures.

- The computer is a universally programmable machine and has thus transcended the role of a tool.
- Areas of work that previously appeared immune to this kind of process, such as design, complicated administrative processes and even management, are becoming more threatened.

(100) The last point mentioned explains why impending developments are not taken seriously by those affected by them: "It is surprising that the design community, which likes to pride itself on its ability to anticipate problems and plan ahead, shows little sign of analysing the problems of computerization 'until long after it is relevant'. Indeed, in this respect, the design community is displaying in its own field the same lack of social awareness which it displays when implementing technology in society at large" (Cooley 1976, Trade Union Viewpoint, p. 308). It does not appear too late to intervene in the process by developing and applying alternative technologies and forms of work organization. The areas of work mentioned would still appear to be subject to inherent complex patterns, no one has yet fully discovered. However even here there would appear to be progress (cf. Section 5.3.6). Research on this topic will only be successful if it is not confined to describing effects, but rather accompanies the introduction of technology, feeding in its own criteria.

5.3.2 C.A.D. as a means for mastering the future

Despite Mike Cooley's partially harsh criticism of the forms of present technology and thus also of C.A.D., one cannot deny that our civilization is extremely dependent on its products. He himself emphasizes: "One is frequently asked if technological change is a good or a bad thing. This is really a non-question. It depends entirely on how technology is used, and who controls it. We need not have any fear of technological change. It is in fact merely an extension of man's own capabilities" (1973, p. 25). Technology as an extension of organs would ever appear to be under the control of man: The telescope for the eyes, the steam engine or any other form of energy-converting machine for muscles, mechanical or electronic information stores for our memory etc. This is one point of view, but can one really still refer to C.A.D. as a tool?

A theory of mental work must thus also be a theory of machines as we have demonstrated at one point in our book (cf. pp 56 ff.).

(101) Further progress without the computer does not seem possible. Arthur Llewelyn stated this point of view in his interview with us. In reply to a question, whether C.A.D. would not in fact obstruct further innovation he stated: "I don't think so. In fact, the only thing that I would be absolutely sure about is, that of all the technologies the only one that I would back for the long term benefit of mankind is the use of computers for industrial processes. The reason for saying that is simply this: that no one can deny that we encounter enormous problems using materials with energy shortages, shortage of raw materials". Arthur Llewelyn uses the spiral to illustrate his views: Computers, if properly used encourage innovation at a new level, opening up a whole new range of possibilities hitherto unknown. Not only are problems becoming wider ranging and more complex, but also the precision and goal adequacy of planning must be improved as he expressly stated (e.g. in traffic and environmental planning). Thus we have arrived at the somewhat paradoxical situation where technical progress forces us to intensify the use of technical means.

5.3.3 Technology and the means for its reproduction

(102) Technologies would appear to develop the means for their own survival, so that we are increasingly slithering into the paradoxical situation described above. Machines provide precision and dependability. This is their reason for being and this is what they are needed for. By this means they contribute to a differentiation of our requirements and accustom us to hitherto unknown consumer values. The increasing complexity of machines and the potential for yet further increase of this complexity appears to necessitate the use of machines for their own production. The nature of complicated apparatus as a means becomes ever less apparent. Only computers are

able to construct computers, as Arthur Llewelyn put it. This is in our opinion a very important point and we therefore wish to especially emphasize it.

(103) Technical tools are however not only sophisticated organs but also very one-sided and limited since they only serve to represent outward reality. This very basic ambiguity and the simultaneous congency of technological machines is expressed most aptly in the section on the "mechanized image of the world" in Lewis Mumford's monography:

"As mechanical power increased and as scientific theory itself, through further experimental verification, became more adequate, the new method enlarged its domain; and with every fresh demonstration of its efficiency it shored up the shaky theoretic scheme upon which it was based. What began in the astronomical observatory finally ended in our day in the computer-controlled and automatically operated factory. First the scientist excluded himself, and with himself a good part of his organic potentialities and his historic affiliations, from the world picture he constructed. As this system of thought spread into every department, the autonomous worker, even in his most reduced mechanical aspect, would be progressively excluded from the mechanism of production. Finally, should these postulates remain unchallenged and the institutional procedures remain unchanged, man himself will be cut off from any meaningful relationship with any part of the natural environment or his own historical milieu" (Mumford 1971, Vol. 2, p. 65-66).

5.3.4 Computers as extensifiers and intensifiers of human experience

(104) Conventional interpretation of man-made tools as extensions and sophistications of his organs has already been mentioned. Once again, we should ask which novel features are appearing in the dawning computer age. Before we attempt to answer this question we should like to discuss a number of examples described to us by Arthur Llewelyn and Mike Cooley.

While we were discussing the role of professional experience in the light of technological systems, Arthur Llewelyn pointed out possibilities for the improvement of such experience, even for greatly experienced people. "You can present a civil engineer with a display where he has in effect a pictorial skeleton of a bridge and he can be given the loading dimensions and the loading of the bridge. He can also be allowed to interact with this display, so that he can choose the types of loadings and he can play with the loadings, vary them. Then he can immediately see the resulting stress and strain pattern in the parts of the bridge. And he can see these against safety limits. So he can see if when he puts a 40 ton truck on this part of the bridge, then immediately in this particular pier the safe stress limit is exceeded. He can do even better, he can run the truck across at twenty miles or twenty kilometres an hour and see what the effect is, dynamically. Now, he would never be able to do that in a normal office! And he'd only be able to do it in real life very expensively if he put sensors in the bridge and monitoring. So, I have sat down even experienced engineers with twenty, thirty years of experience in building bridges, and in half an hour they can play with more problems than they have ever experienced in their whole life! Now, that's adding to their experience" (Interview).

(105) Mike Cooley gave us the following example: "In beam construction, designers know through life-long experience where maximum load is concentrated and analyse only these places. Inertia is proportionial to load which means that an unskilled designer can play around with C.A.D. as he would with a "Lego" set. If the beam bends too much, he simply replaces it with a thicker one. He doesn't have to know anything about inertia or points of maximum load concentration".

Both Cooley and Llewelyn agree that professional experience and skills are of great value. There is also no controversy on the fact that mathematical or other models, inasmuch as they are valid - can enhance and intensify experience and, as Llewelyn demonstrated in a further example, lead to more sophisticated design in the field of bridge or aircraft construction. When we asked where young people should get this kind of experience if they grew up with technical systems he stressed, "You can't give them a short cut way, some magical experience. It has to be acquired". Indeed, this would appear to be the weak link: how much primary reality is put into professional training without the aid of models? If this problem is neglected, serious consequences may arise as Cooley described.

"The igniter in the after-burner of aero engines is roughly the same size, as a car's spark plug. In the design of an igniter using C.A.D. the decimal point was erroneously shifted one place to the right with the result that the igniter was built ten times too big by deskilled workmen. Some skilled workmen put the igniter on the designer's desk as a sort of joke. But he didn't even realize the igniter was ten times too big!" (Interview).

(106) The facility of mathematical and technical models to register the main parameters of a subject matter and to simulate and forecast the behaviour of technical objects is an intensification of experience only if and when previous experience has created a basis and when learning processes are organized in a manner that not only experience immanent to the model may be gathered. Technical progress therefore has two meanings, the first of which is the chance for the intensification of experience and the second is the necessity to gather experience with the new technology, whereby the technical medium must be transcended. This however, as Arthur Llewellyn pointed out, requires new forms of university education, e.g. in the sense of project orientated training.

5.3.5 The obsolescence of professional knowledge and skills and the development of new

(107) If one is discussing changing principles of experience gathering and using only abstract language in the process, it is only to easy to forget the substantial importance of this process for individual progress and indeed for each and every one of us. It would appear that we cannot stop this process of increasing knowledge and that we are all subject to a historical automaticism.

At least one gathers this impression when considering the growth of knowledge over the ages as Mike Cooley does in his C.A.D. book (cf. pp 72 et seq. German translation). The time one would need to invest to bring one's obsolete knowledge up to date is ever on the increase. According to model calculations discussed by Cooley in his book the investment would be about 15 % of daily working time or even more in especially dynamic areas of knowledge like the computer industry.

(108) This process is a special source of hardship for older workers as Mike Cooley stressed at the 1976 C.A.D.-Conference: "As there is no real or humane mechanism in our market economy for the retraining of older workers or the updating of their skills, the tendency is for employers to simply replace them by younger workers who are fresh from university with 'new knowledge'. The older members of the design community, who have devoted a lifetime to building-up the know-how embodied in the software packages, find that they experience a 'careers de-escalation'. At that stage, their status in the design team, and their salaries begin to decline, and graphs are presented at the conference to demonstrate this" (p. 310). This is an important field of activity for the unions. In West Germany some unions have negotiated so-called "agreements on protection from rationalization" which include among other points interim periods of several years with opportunities for professional training or re-training.

(109) New technologies do not appear to lead in every case to traditional skills being directly replaced. Martin Bell stressed that relative distance is of importance. There is no unambiguous correspondence of technology to skill structure. When a new technology replaces an old one, the old structures are initially transferred to the new technology. If the new technology is however created in something approximating a vacuum, skill structure is adapted to the requirements of the new technology. When computers were first introduced there was reason to doubt their reliability, so that there was some justification in retaining old skill structures. As trust in the new technology increased, skill structures were adapted to its requirements. This demonstrates once again the necessity for a reliable taxonomy of mechanization steps or even of a scale for mechanization. Attempts to

construct such scales have been made by Bell himself (1972), Kern and Schumann (1974) in Germany and Bright (1958). The difficulties involved in such a scale are obvious. By which means can one ensure that the stages are of equal distance from each other? Is the scale to take into consideration future developments? This analytical shortcoming, that the future is cut off, limits the value of statements on, say, the acceleration of technological progress, since the current phase of innovation is for the time being (by definition) not at an end!

(110) The above passage by Mike Cooley serves to demonstrate that it is not possible to transfer technological knowledge to algorithms in, for instance, software packages without the wealth of knowledge and skill developed in actual work. C.A.D. is setting a new frame of reference in the field of design. If a designer allows himself to be restricted to this frame he is running risk of being classified as deskilled by his colleagues. This kind of phenomenon may be observed especially in areas long regarded as art and which appeared secure from the grip of methodology: "However, in the relentless drive to control and exploit all who work, the system has not forgotten architects. For them there have been specifically produced software packages such as (appropriately enough) the Harness System. The concept behind such a system is that the design of a building can be systematised to such an extent that each building is regarded as a communication route. Stored within the computer system are a number of pre-determined architectural elements which can be disposed around the communication route on a visual display unit to produce different building configurations. Only these pre-determined elements may be used, and architects are reduced to operating a sophisticated 'lego' set. Their creativity is limited to choosing how the elements will be disposed rather than considering in a panoramic way, the type and forms of the elements which might be used. Thus the creativity of the architect is constrained and his or her imagination greatly limited; yet it is precisely our ability to use our imagination which distinguishes us from animal forms" (1997b, p. 4).

(111) The field of architecture is especially prone to the danger that expertise and creativity are mere assertions that cannot be borne out by performance. It is therefore hardly surprising that Tom Maver and the ideas

produced by the ABACUS group in Glasgow lay claim to an anti-ideological position. By explaining architectural methods they wish to place expert knowledge on a controllable foundation. Tom Maver writes partly in direct response to Cooley: "Given a design brief, the architect undoubtedly engages in a complex iterative process involving appraisal of design alternatives. The process, however, is wholly implicit and personal and, for all we know,, idiosyncratic. The professional press devotes virtually no space to the discussion of the methods and models of the design decision-making process, electing to fill journal pages with glossy photographs of products. The ultimate users of buildings, therefore, have no way of checking the validity of the decision-making procedures and, worst still, no idea of the value judgements inherent in the product" (1976, p. 314).

(112) Alan Bridges expands on these difficulties in the architecture design process elsewhere: "The first serious problem is the definition and quantification of the problem variables. Building design and planning involves the consideration of a diverse range of criteria and objectives. The very definition of all the relevant factors is a major problem in itself. ... The second problem area is the multi-objective nature of the design process. In building design the various (often conflicting) requirements imposed by constructional, environmental, functional, aesthetic and other requirements must all be met simultaneously. Often this characteristic has been ignored and a 'decision-tree' of successive design decisions established.... Thirdly the range of possible solutions to even a trivial design problem is enormous" (1976, p. 101).

We shall be discussing these arguments in greater detail from the viewpoint of interface design and in a section on participation. For the time being, let us suffice in stating that the development and democratization of expert knowledge requires - perhaps only inadequately - that the torch of methodology be carried into the realm of creativity, bringing with it the danger that genius may be expelled. The historical role of the architect has always fed off these two sources: on the one hand exact, mathematically based planning in road construction and military matters, on the other hand free, creative design, partially to demonstrate power and partially to wound its worn-out aesthetics. Possibly C.A.D. will facilitate the reconciliation of these differences.

(113) New technologies and skilled craftsmanship do not in every case lead to conflict. Arthur Llewelyn demonstrated this with an example. "There was a small firm, making competition gliders. The firm had just about 12 people. Now, they thought that they could perhaps make use of new material, fibreglass for fuselages, and they came to me to say - because they've heard of the Centre and C.A.D. - was there anything of interest to them. Now, as a case we took this on as a project and the thing which interested me was whether we were able to take someone, who was experienced in making gliders, but wasn't educated and didn't know anything of computers at all, sit him down in front of a television display and he - because he was a drawing man - was able to draw things on the display and make a shape that he knew is about right from a certain cross-sectional area, because experience told him what flies well. He was satisfied that he was doing this, just as he would on a drawing board. We were then able, of course, to put in parametric lines to break up the shape and he of course would not have known how to do that. But having done that, we then were able to hold that shape in a computer with a 3-D Model. We then checked it against very sophisticated aeronautic lift and drag equations. When that was done, the result was presented to him. He was told, well, the aerodynamics say that in fact you have to lengthen your fuselage by two feet. When it was put on the screen, he said, "Well, yes, perhaps this is like the sort of one I made five years ago". It did fly really well, but he never knew exactly why" (Interview). This example was important for an additional reason as follows: "Because the computer held a 3D model it was possible to produce cross-sectional drawings from which carpenters could make up the wooden frames and assemble a mould for the fibre-glass fuselage. In order words through C.A.D. a small, unsophisticated firm, without a drawing office or any analytical skills other than practical experience, could be helped to try out new ideas and use new and complex materials safely and inexpensively." We have narrated this example in full length since it illustrates the entire significance and drama of the scientific reconstruction of human experience. Let us confront it with another example of Mike Cooley's.

(114) Three scientists with Ph.D.s were given the task of mathematically defining the shape of an after-burner. The shape was especially complicated with spheres leading into cones and that kind of thing. After they had

worked on the project for some time, they visited one of the company's plants and were horrified to find exactly the shape of after-burner they were working on was already existing in reality. At first, they refused to believe it because they had been working three years on the mathematical definition of the after-burner. They were told that it had been designed by a qualified metal worker and a draftsman. One of the scientists remarked, "They may have built it, but they didn't know what they were doing" (Interview).

These examples lead us automatically to the question of how scientific models and methods reconstruct human and professional experience and how their limits and adequacy are determined. We shall be pursuing this thought in the next section. Before we do so, we wish to make another point.

(115) Professional skill and knowledge are acquired and passed on by means of a long, multi-strata process. Some findings are the direct consequence of experience, others are won by trial and error, some may be expressed and communicated as rules and yet others are the result of life-long preoccupation with the subject and material of one's profession. The means of communication are developed and refined in the process which spans many generations. C.A.D. has the potential of offering an alternative to this, although very special problems do arise, as Hatvany, Newman and Sabin point out. "The engineering drawing has been developed over many years into a very flexible and powerful method for representing the design objects found in all branches of engineering. Further, it can in turn be represented numerically very simply (albeit verbosely), as chains of straight line segments. It is therefore tempting to use the numerical analogue of the drawing as a representation of the object itself. This has the advantages of being simple, general, and directly translatable to and from familiar graphic representations. It has therefore been adopted in a number of systems... While the advantages of this approach are significant as long as the computer is merely acting as a fast and accurate drawing aid, severe difficulties appear as soon as attempts are made to link such representations to either analysis or manufacture. The abstraction of the information content of a drawing from the lines on it is not trivial. In

the context of integrated systems, therefore, it is advisable to capture the information content explicitly, in forms appropriate to the application, during the making of design decisions. Drawings may then be produced as a feedback to ensure that the design has been achieved" (p. 89).

5.3.6 Knowledge: personal, implicit, and explicit

(116) In the previous section we compared two examples with each other. The first demonstrated how C.A.D. may be employed as an efficient means to illustrate and represent shapes of flying objects, to mathematically represent them where previously vast experience was required. The other example served to demonstrate how even the most sophisticated mathematics failed to solve a complex problem and where the art of mathematical description was shown its limits by skilled craftsmanship. Although these examples very adequately illustrate the problematic relationship of personal knowledge, which is at the beginning of all experience, to implicit knowledge and knowledge embodied in models they do not explain how the following processes work.

- How is professional knowledge acquired?
- How do mathematical and technical models gain validity?
- How can previously implicit experience and personal knowledge be made explicit, i.e. by which means may methodological structures be exposed and where does this exploitation of human experience injure the principles by which it is formed?

The third question is probably the most important, since it refers to the methods by which the reconstruction of personal and tacit knowledge is accomplished, i.e. the problem of the relationship between "articulate and inarticulate knowledge" as Polanyi (1962, Chap. 5) put it. This implies that scientific methodology itself must be subjected to criticism.

(117) Mike Cooley had this kind of basic criticism in mind when he introduced his article on "The Designer in the 1980's - The Deskiller Deskilled"

with the following statement: "Probably, at no time in human history has the need for an examination of the underlying assumptions of science and technology been more relevant than it is today. We are, I submit, at a unique historical turning point" (p. 1). Despite this, the consequent employment of scientific methodology relying on the calculability of nature has produced the immense wealth of present day technical civilization. Must we then revise the conception of reality itself that conventionally colours scientific thinking? "Central to the Western scientific methodology is the notion of predictability, repeatability and quantifiability. Indeed, increasingly, if we are unable to quantify something, we like to pretend it doesn't exist. To do so we have to rarify it away from reality and it leads to a dangerous level of abstraction..."(ibid, p. 2). Thus quantifiability as proof of existence would appear to be part of best Western tradition. The companion to this way of thinking is the model of efficiency and optimality that allows people to forget subjective assumptions because of the stringency of the optimization function (cf. ibid, p. 3 f.).

(118) Howard Rosenbrock pursues a similar line of thinking in his article "The Future of Control". "Scientific knowledge and mathematical analysis enter into engineering in an indispensable way, and their role will continually increase. But engineering contains also elements of experience and judgement, and regard for social considerations and the most effective way of using human labour. These partly embody knowledge which has not yet been reduced to exact and mathematical form" (p. 390). Three questions concerning the relationship of explicit to implicit knowledge arise as a consequence of this argument:

- Must the relationship be regarded in a manner where boundaries are always merely temporary, i.e. that explicit knowledge will increasingly conquer the field of implicit knowledge?
- Are there but two forms of knowledge that may, in principle, be reconciled with one another and if so, by means of which construction or experience?

- Do both kinds of knowledge have certain basic characteristics that are in opposition to each other and how may this contradiction be exposed?

(119) Obviously, we have no ready solution to this problem, so we shall attempt a "model". It would appear that the following process has taken place in design during the last centuries: a) initially, perhaps before the craftsman stage, construction was both the making and the production of an object. Object, experience, method of action and pondering over alterations were one unit. b) The next stage could be described as that of craftsmanship. It is determined by rules drawn from and based on experience. These rules unite knowledge on material characteristics, production methods and man's own purposeful action. This may be described as method based on. experience. c) In the next stage, the process of gaining experience itself is subjected to scientific method. There is some danger that experience will be restricted to the frame of reference of the model which may no longer be transcended, and that human experience no longer has its "environment".

Obviously one should not think of subject and object as separate as, for instance, two neighbouring rooms are. One should assume a reciprocal effect whereby a subject changes itself simultaneously to changing the object. We, however, assert that technology, intruding into design in the shape of C.A.D., is itself structuring this reciprocal process. In the empirical studies we have carried out to date, we have gained the impression that the change brought about by C.A.D. itself assumes the character of a system.

(120) The partners in our discussions in the firms often employed the term "increasing abstractness of work" as a consequence of C.A.D. to denote a whole series of individual indicators. One could sum up the common characteristic in such a manner that work content (tasks), object of work (data for design) and means of production (slide rule, pencil etc.) become more abstract when C.A.D. is employed, i.e. that technical means no longer are directly manipulable but mediated by a whole system of tools. Work no longer serves to produce a sketch for design or a detail plan, it rather consists of the manipulation of appropriate programmes in accordance with their built-in logic. The object produced is no longer a lifelike construction drawing but, in the best circumstances, an image on a screen. Means of

production is no longer the slide rule but a series of commands that are entered by means of a terminal. C.A.D. is thus no longer merely a means of production or a tool but an increasingly complex technical system of action. We have tentatively suggested the term "mediation" to label this process of communication increasingly supported and controlled by technical means.

One consequence of the discussion as it appears to us is that one will only gain more knowledge on the processes described above if one actually observes them. This is what we intend to do.

5.3.7 Taylorism or Mechanization?

(121) In 1911, Frederick Winslow Taylor stated "The principles of scientific Management". An authorised German version was issued in 1913, a new edition a short while ago (Volpert & Vahrenkamp 1977). The principles developed in this book and other publications would appear to describe the aims of rationalization and, in the following period, their manifestations so fundamentally and aptly that the term "Taylorism" has often been employed as a figure of interpretation. Thus Braverman has dedicated Taylorism a diligent and extensive analysis and spent a large amount of thought especially on the conflict in the Midvale plant (cf. 1977, Chaps. 4 - 6). Braverman emphasized the following aspects of Taylor's principles.

- The separation of the work process from the worker's skills.
- The separation of planning and execution and their concentration in individual departments with the consequence that manufacturing work is stripped of mental work; (in our opinion Braverman rightly avoids the distinction between manual work and mental work).
- Detailed instruction of workers to ensure both success and control.

Braverman goes to lengths to narrate Taylor's ideas since he regards them as a direct embodiment of capitalist means of production despite a series of new features in the organisation of work such as job enlargement or the creation of semi-autonomous groups. Central to Taylor's concept is the separation of knowledge related to work and skill connected to concrete activity. The appropriation of this knowledge by management represents a de-qualification of work. Once work has run through this process, its organisation in machine form and the introduction of machines is no longer a fundamental problem - this is at least the hypothesis.

(122) Mike Cooley sets somewhat different accents. He emphasizes the economic angle more strongly in addition to the change in the organic composition of capital. The capital intensity of the production system increases. More intensive use of machine capacity and, by way of a precondition, the simultaneous stronger control of work are almost an economic necessity. This position of Mike Cooley's is partly drawn from trade union experience. The intensification of control is a central notion to Tayloristic ideas, since first-hand experience of the phenomenon of withdrawal of performance on the basis of greater knowledge of efficient working procedures than management posessed was responsible for Taylor's preoccupation with this matter.

(123) Mike Cooley, who is himself a senior design engineer, emphasizes another important point in his recent article: "What then is suggested here is that we have reached the stage where these problems are beginning to be significant in the design activity itself, and that the designer who at earlier historical stages designed equipment which deskilled and dehumanised the work of others is now beginning to be the victim of his or her own ingenuity" (1979, p. 3). This development is part of history's irony and it is to be feared that this professional group will be unaware of it, precisely because it is committed to a scientific and technological way of thinking.

(124) Are we then to expect Tayloristic means of production in the design office? There is much evidence that this will indeed be the case. In other areas of work there is much talk of Taylorism, e.g. in the field of management in connection with discussion on "Management Information Systems" the introduction of which would appear - for the time being at least - to have been unsuccessful (cf. Kirsch 1973, Kirsch & Klein 1977). Taylorism would imply a far-reaching division of activities into small steps. The minute analysis of time studies in manual work would correspond to an analysis of "mental motion". Does this work?

(125) In a number of places, Cooley has referred to an article in the journal "Work study" that introduces "A Classification and Terminology of Mental Work". In this article, an attempt is made to define "basic mental motions", which are classified analogously to the model of computers as input, output and processing. The first group includes SEE (passive component), LOOK (active component), READ, HEAR, LISTEN etc. Processing components are subdivided into two groups, one for computational motions (REST,STORE, RECALL, ADD, COMPARE, SELECT etc.), the other for "logical motions" such as EXISTENCE (does a statement have meaning within the processing rules adopted), TRUTH (is the statement true or not?), TAUTOLOGY (is the statement merely saying in different words something that has already been proved?),COMPATIBILITY (is a statement compatible with a given criterion?), CONCLUSIVENESS (does a statement follow as a consequence of others?), CONDITION (is a statement conditional as necessary or sufficient upon earlier ones). These units are called "yalcs" analogously to the term "Therblig" which is the anagramm of Gilbreth, who developed a classification scheme for the elements of physical work. The authors stress that their system requires further development and at present applies only to very simple forms of mental work. They do, however, wish to lay a foundation for M.T.M. studies in the field of mental work which can then serve as a basis for the compilation of standard times.

(126) "Whether or not one regards this type of research as pseudoscience, there can be little doubt about how it will be deployed. The employers of scientific, technical, and administrative staff (including some forms of managerial staff) will see it as a powerful form of psychological intimidation to mould their intellectual workers to the mental production line" (Cooley 1975, p. 711). Indeed, this lack of scientific validity hardly imposes barriers to the introduction of such systems. The described classification is no theory of intelligence, as Guildford has attempted (cf.1967), no psychology of productive thinking, as Duncker was concerned with (cf. 1935), nor is it a development theory à la Piaget (cf. 1947) and does not have as its point of departure a phenomenonology of thinking (cf. Graumann 1964). The anonymous authors rather use the computer itself as a starting point, in that they try to apply the computer as a model for human thought - or to be more exact - for the human brain.

(127) "The simplest work that the brain executes can be compared with the basic components of work carried out by electronic computers, since these have to be programmed in terms of combinations of a very few basic logical or computational processes. Computer programming, at the level of machine language, therefore affords valuable clues about the nature of some of the basic logical and computational processes of the brain. One does not have to start 'from square one' to devise a set of basic mental motions, since computer designers have already done this" (p. 25). If we re-apply the machine model of logical operations to human understanding, it will not be long before the mechanistic circle is closed. If human reason has by the development of certain principles developed the computer, why should not these same principles be applied to human reason itself? What are we dealing with when using such statements as TRUTH, TAUTOLOGY or CONCLUSIVENESS? Or is this simply careless argumentation?

(128) In one of our interviews in the development department of an automobile plant, we were made aware of the fact that vibration calculations were previously conducted by large groups of young women whose sole activity this was and who had only fairly elementary education.

The mechanization of mental effort is an ancient dream and was behind Babbage's idea of the differentiation machine - which incidentally never worked. Mechanization of problem solving is a well-researched area of human intelligence (cf. Luchins & Luchins 1959). Mechanization of mental work is thus possible and existed independently of Taylor.

We therefore prefer to talk of mechanization when referring to the principles by which mental work is organized. One may talk of Taylorism if concrete work is restricted to rigid structures imposed by the division of labour and if the content is restricted to a small area. This means of organizing labour may be efficient to a certain degree, but it was most certainly not scientific, even in Taylor's day as Howard Rosenbrock most emphatically asserts: "Without the close interplay of manual work in experiments and mental work in their interpretation, it is inconceivable that science could have developed. No society which separated manual work entirely from mental work could have given rise to it. Nor could science long survive such a total separation. In this respect Scientific Management is anti-scientific" (1979, p. 16f).

5.3.8 Alternative Technology: human centered, action based, skill enhancing

(129) The quest for alternative technology embodies two subordinate issues, one technological, the other economic. Howard Rosenbrock delivers an answer to the technological question by referring to his own model, which implies leaving the highly complex decisions to the designer, at the same time providing him with information on the state of complex activities by means of a highly informative graphic display. A central part is played by the stability of the system. For this purpose, Rosenbrock has developed a model based on the inverse Nyquist array: "To an experienced user, the inverse Nyquist array gives the kind of information he wants: whether the system is stable, what is its stability margin, what is its speed of response, how these aspects can be improved, and so on. One therefore ends with a way of using the computer which can truly be regarded as an aid to the designer's skill, helping him in the performance of his function; and indeed the software incorporating this method is now in widespread use. ...
The overwhelming majority of the research in my field was committed to a quite different approach, in which the aim was to replace the designer by the computer: to develop methods in which the operator of the computer (hardly any more a designer) would enter details of the problem to be solved, and the computer by means of some algorithm would then develop the solution. To transfer, that is to say, the essentially human judgement and critical ability from the designer to the machine" (1979, p. 3f).

Mike Cooley refers to a series of devices developed at Lucas Aerospace, designed to facilitate complicated remote control and very aptly designated "telechirics".

(130) These examples incorporate three features that we shall tentatively employ to characterize alternative technologies: the individual human being remains at the centre of the decision-making process in the control of an

object or a process and - on the basis of previous experience! - is in the position to acquire new, more sophisticated experience by means of extensions of his senses (Rosenbrock) or his facilities to manipulate (Cooley) receiving feedback from the system. This most important feature, namely retaining man's function as a maker of decisions, may also be claimed for those systems developed under the auspices of Tom Maver at ABACUS.

(131) Rosenbrock also discusses an important economic issue in the aforementioned article. This is related to the system boundaries of systems developing and employing technologies. Of which consequences are they aware and for which of them may they be held responsible? Are those technologies that survive economically really superior? What effort do we spend on the development of alternative technologies and which lines of development are extended simply for the reason that there has always been a great volume of investment in them and because alternative solutions ever have the burden of proof of their superiority?

(132) The use of technology in industry customarily has the aim of increasing the machine's control over itself and decreasing the necessity of human interference.

In doing so, chances are often wasted to produce designs that are technically feasible and where workers' representatives could make suggestions if informed in time and if they had the necessary expertise to plan complex plants. A German survey of petrochemical plants demonstrated that there is great opportunity wasted in this area. This is an important field for trade union activity (cf. Mickler et al. 1976).

(133) We seem to perceive technological change in a manner that we automatically approve in retrospect of the route we have taken. Reminiscing on personal experience on the Indian-Burmese border during the Second World War, Howard Rosenbrock has called this the Lushai Hills effect. It is a very apt metaphor. "Here and there were paths or game trails, but often the easiest route was to wade through the tunnels of vegetation which enclosed the streams as they came down the hillside, high and open where the stream

was broad, low and overhanging where it was narrow. Climbing upstream in this way, one would come to forks where two streams joined, and a choice had to be made. For a while, the choice was reversible - one could go back to the confluence and take the other branch, or sometimes cut accross the spur between. But after a short while the loss of time and labour in doing this was too great. One was committed to the chosen stream for good or bad. ... Resting in the evening and looking back over the lower hills, it is easy to say "At every fork we took the right-hand branch, and see how high we have climbed. Taking the right-hand branch must be the only way". Though, if we had sometimes taken the left-hand branch, we should in all probability be just as high and perhaps in a region which was in other ways richer, more friendly and more fertile" (1979, p. 17ff).

6. The Design of Interface and Man-Machine-Communication

6.1 Introduction

(134) The term "interface" is customarily applied to express the need to make two machines, designed to be connected with each other, compatible. In computer science we are, for instance, concerned with input/output interfaces and "transformation" may be achieved by either "hardware" or "software". If we only regard the hardware aspect, the expression "intersection", corresponding to the common German term "Schnittfläche", is most appropriate since plugs are introduced into sockets provided for this purpose. The expression "interface" is, however, also employed for the "intersection" between man and machine. In this case, though, we are concerned with anything but a smooth plane. The boundary to the human is rather a multifacetted mediatory process restricting, steering and facilitating human action related to EDP apparatus or the operation thereof. In the following section we wish to discuss these problems of interface.

(135) The design of interface is necessary for all manner of machines, starting with the design of a hammer's shaft and ending with software packages which control the behaviour of users in manifold, often intransparent ways.

One special problem is the design of processes for the communication of information and of reaction options (cf. Schmidtke & Graf Hoyos 1970). One of the most important aspects in this process is compatability between the options for reaction, the basic structure of human organs and assumptions implicitly made on the nature of the world. No one would consider a car whose steering wheel is moved to the right when turning left a good invention. Even if anyone had learnt, with the aid of much practice, to react in this kind of topsy turvy world he would most likely react according to the old pattern in the event of danger.

(136) In the course of a project lasting several years, Heibey, Lutterbeck and Töpel attempted to develop a systematic model for cause and effect in the application of computers. Referring to some of the distinctions they discuss in relation to man-machine intersection, we can expose the deep structure of man-machine interface (cf. figure 6). This demonstrates that contact between man and EDP configuration can fulfill a large variety of functions and can be very close or very indirect. This applies equally to the operators who control the computer by means of programmes and who themselves form a hierarchy. The computer is in fact merely a machine to simulate another machine:

"Thus the computer is foremost a machine whose purpose it is to simulate machines for a more limited number of data processing acts. They simulate machines that do not exist in reality and are thus called virtual machines. Virtual machines form a hierarchy in the computer. The programme unambiguously regulating the act of data processing defines for the user a virtual machine" (ibid, p. 84).

(137) The development and design of interface is an ubiquitous and inevitable aspect of the application of machines. It is closely connected with the design of products, the design of jobs and the process of implementation. Therefore it is hardly surprising that all of our interview partners contributed one or the other aspect to the discussion of this issue. This applies especially to those aspects dealt with under the heading "qualification" in the previous chapter. There is a close relationship since the design of interface to a large extent determines what an individual user or designer can do or what he cannot do.

In the following section we will be discussing several issues involved in interface design. In the concluding third section we will be concerned with issues involved in the construction of models.

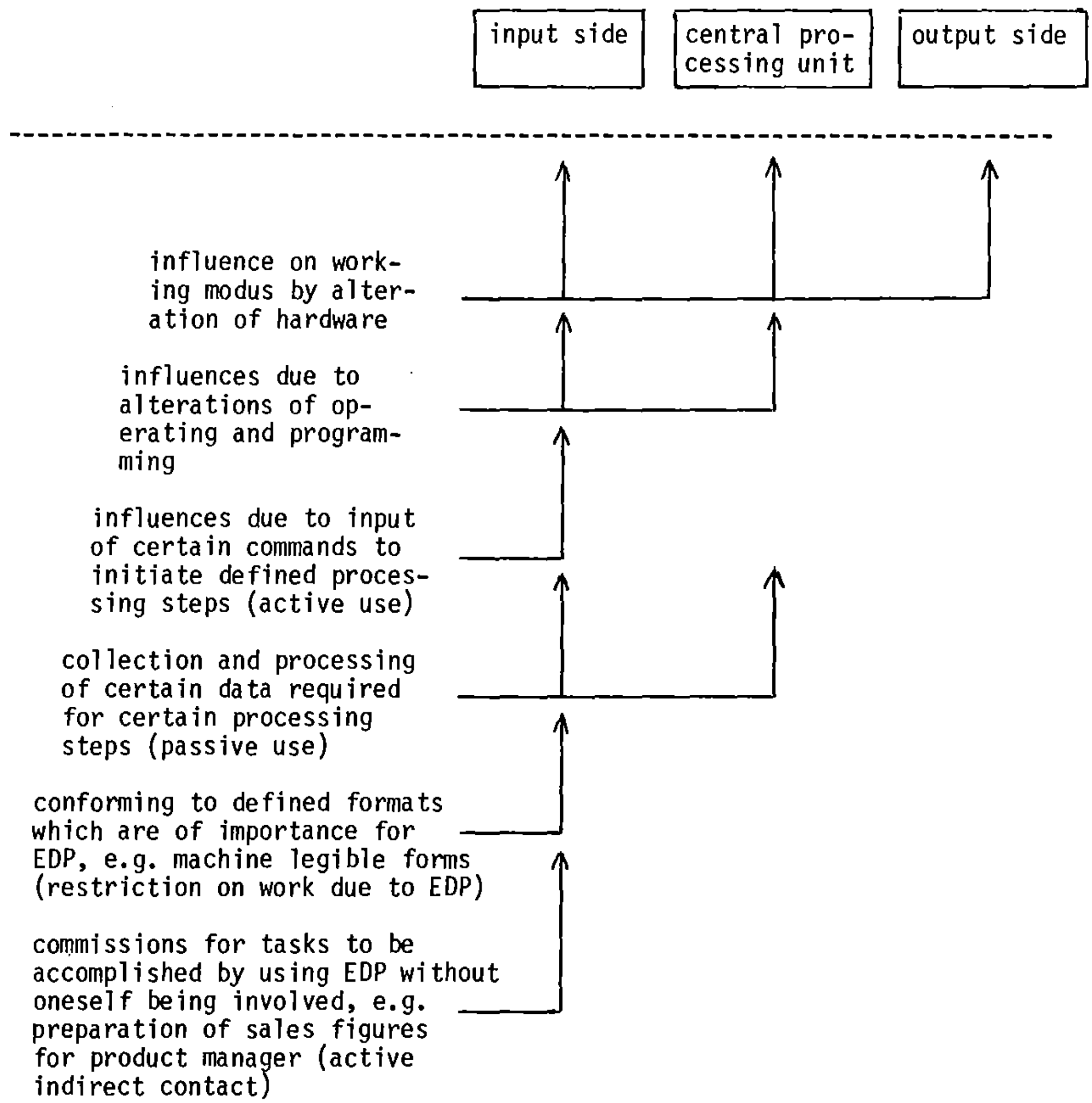
6.2 Interface: On the relationship between the logic of programmes, the design method and idiosyncratic working styles.

(138) The rather ponderous heading to this section is intended to express the complexity of the problem. When an individual is operating or using an EDP configuration, three components combine:

- The logic of a programme or a command language which enables a user to set in action certain defined work steps. The programme employed forces him to use a certain method and working style which was previously unknown and which he has to learn in any event.
- The task in hand, or in more general terms the scientific discipline, embraces certain structures which may be more or less explicit and do, however, as "factural logic" determine the working style of the user. This factural logic may contradict programme logic.
- The individual user has certain preferences or even established idiosyncrasies in regard to his working style. This can lead to conflict with programme logic since the capacity of the computer acting as a universal machine with the ability to represent highly complex structures leaves the designer a large number of degrees of freedom in the development of programmes. Only a small proportion is "logic", a great deal is probably once again his own idiosyncracy.

(139) Hatvany, Newman and Sabin (1977) go into problems of interface in a large number of places, e.g. in regard to questions of graphic input and output, command languages and the not fully used capacity for the user himself to define macros, i.e. sequences of commands. "One difficulty with macros is that their definition is not just a series of independent commands: it is a description in which internal structure has to be represented. The syntax of a 'define macro' command has to be distinct from that of the other commands" (p. 86). Harold Thimbleby also emphasized the importance of such manipulatory options in reference to text editing systems. In our own

Figure 6: Some aspects of the deep structure of man-machine-communication



interviews in firms we realised that the option for writing one's own small application programmes was of great importance to the satisfaction of designers. In the case referred to, the designers did not have the option.

Special difficulties in interface design are created by the fact that thought must be given to it early on and that on the other hand there is much room for variation:
"It is essential that the design of an application program, its information structures and its interface with the user should all be considered together. In particular, the degree of interaction must be determined at an early stage. ... It is often very difficult to determine what degree of interaction will be desirable in a C.A.D. system. This is not just a problem of choosing between batch, keyboard interaction and interactive graphics. Within each of these three classes, there are many ways of designing the user interface ..." (ibid., p. 91).

(140) The profile of interface contributes to determining for which components of human labour additional skills may be developed or not. It is obvious that there must be some kind of interaction retaining specifically human labour contributions. Howard Rosenbrock sketches this out in an article headed "Interactive Computing: A new Opportunity" (1977). His intersection is described as follows:
"My subject will be the use of a computer for problem-solving, in such a way that a significant part of the solution is generated in the user's mind, and another significant part is handled by the computer. Specifically, constraints on the solution, and decisions about whether a solution is satisfactory, and if not how it is to be modified, will largely be left to the operator. The computer will analyse specific configurations, and produce from them a concise and informative report to the user to guide his decisions. This report, if it is to provide enough bandwidth for rapid communication, will almost inevitably be in some graphical form" (ibid., p. 1).

This input is the inverse Nyquist array commented on previously. " We used a computer with graphical output, and were able to develop displays (figure 7) from which the designer can assess stability, speed of response, sensitivity to disturbances, and other properties of the system in which he is interested. At the same time, if the performance of the system is not satisfactory, the display suggests how it may be improved" (ibid., p. 4).

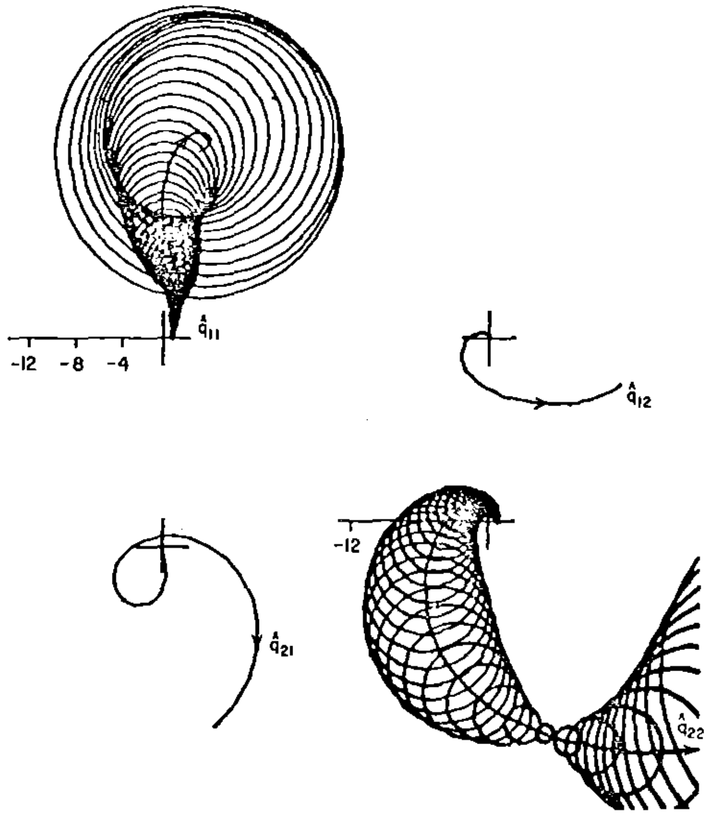


Figure 7: Inverse Nyquist Array and Gershgorin bands graphic display. (Source: Rosenbrock 1974, p. 160)

(141) An ideal interactive system would thus appear to be characterized not by its proscribing a fixed mode of interaction but rather by its both enabling and channelling such interaction. "The ideal interactive system would allow the user great freedom to change the facilities, for example by generating macros for sequences of operations which he wishes to perform frequently. At the same time, the system should help the user by picking up his errors before he has engaged himself deeply in a particular erroneous sequence of calculations. These two requirements, for freedom and for guidance, are in conflict: how can this best be resolved? ... It has to be recognised that within our culture, science has come to be regarded as something opposed to, and superior to, human skill. So it is much more

natural for us to regard the computer as central, rather than the man. To suggest that computers should be used to assist and enhance human skills is to oppose deep-seated attitudes in our society" (ibid., p. 6).

(142) Harold Thimbleby examined the interaction between user and software in an entirely different field, namely the development of user orientated text editing systems, in "Dialogue Determination" (1978). In concluding the paper he states: "The concept of dialogue determination has been introduced. Both over and under determination are bad and usually avoidable. The degree of determination depends crucially on the design of the computer interface, and hence on the awareness of the programmer of the problems of interactive systems design; but ultimately the determination is actually user referenced. Whether a user is under or over determined depends on her experience and frame of mind. The same dialogue may be under determined for one user and over determined for another user, or even the same user at another time: an ideal computer system should adapt itself to the specific needs of the user, even on a day to day basis" (p. 8).

Thus the concept of interaction is placed in a dynamic frame of reference, and this appears most important to us: dialogue determination is relative

- to the particular field of application,
- to the particular amount of knowledge posessed by various users,
- to the degree of experience of one and the same user,
- to the operations required in any case.

This last point thus means that determination must also be regarded as relative to procedure. "Under close examination a particular dialogue has partial attributes of both being over and under determined: this is not a paradox but a consequence of the reductionist approach and it simply means that the system is <u>ill</u> determining overall. If a video terminal screen is cluttered with lots of information this might simultaneously over and under determine the user: over determine because she has to use that information in the order and way it is displayed, under determine because she cannot locate what she wants at all easily" (ibid., p. 4).

According to Thimbleby, the following more precise criteria may be employed to determine the nature of dialogue:

- consistency, i.e. the degree of internal consistency of the language used in programming;
- immediacy, i.e. the time needed for the computer to evaluate input expressions;
- intromission, i.e. the degree to which the computer permits statements inserted out of order or asynchronously;
- visibility and clarity, i.e. that the user knows exactly what is going on in the computer and what is the actual state of processing and this is shown up on the display;
- variability, i.e. the degree to which the computer allows for varying the language, e.g. to more complex statements for skilled users;
- flexibility, i.e. a very complex attribute, because an inflexible system is over determining but a too flexible system is formless.

The question of active and passive systems may not be dealt with quite so simply. By means of the features mentioned above, interface influences the microstructure of work activity. If individual labour is not restricted to Taylorised tasks, potential and restrictions may only be defined relatively to the user. An extensive discussion on active and passive systems was conducted in relation to management information systems by Kirsch & Klein (1977).

(143) "Interactive technology" takes this critical relationship to the user into account as Thimbleby emphasizes in a further paper. "Interactive technology does not do things for people: it does things <u>with</u> people. The user of interactive technology is responsible and also feels responsible, because the technology does not try to remove him or her from the potentially positive human-machine symbiosis. Thus, perhaps paradoxically: interactive technology is <u>passive</u>. Too many useful things result in too many useless people: a technology that does too much dehumanises. And plainly a totally technicalized world would be lifeless" (ibid., p. 3f).

(144) The symbiosis referred to is, however, an ideal condition never achieved, since the software, with which the eventual user has to struggle or may enjoy, is produced by people who make their own assumptions on the kind of model eventual users will employ or they make no assumptions at all and presume that users will imitate their own working style. Thimbleby stresses this specific kind of projection elsewhere and obviously does not mean projection in the sense of a defense mechanism. "Projection occurs all the time when people use computers: most especially whilst using interactive systems. The user tends to assume that the computer will work in the way that he or she expects. This expectation is not usually consciously expressed - and this becomes a very real problem when the user has little or no programming experience. Indeed programmers often fail to notice how idiosyncratic their 'programming' mode of thought is, partly because their assumptions about the working of other programmer's systems often correspond closely to the way they were really implemented. Consequently programmers never experience the dissonance between their model and a machine's to anything like the same degree that computer-naive users often do" (ibid., p. 3). Since Harold Thimbleby uses the term "projection" he seems to think that there are technologies that are completely transparent and devoid of projection. This may yet apply to the telephone (ibid., p. 5) but even here we are forced to react in a paradoxical manner, i.e. to behave as if our partner was closeby, simulating face-to-face communication, which is, on the other hand, impossible, thus forcing us to translate the qualitative elements of our communication into speach or to neglect them entirely. These pragmatic effects of technical communication can be very far-reaching as we will demonstrate later.

(145) Bob Kenyon is working as a computer science specialist in an area more closely related to architecture. Previously, he had done work on a programme system for planning hospitals and gathered very similar experience in regard to implicit model structure. "We developed some algorithms based on operations research - quadratic assignment techniques. You give the programme a brief in terms of what the department is supposed to do. It sounds a very grand and helpful concept, but in practice it is very limited - it's just saying how close each room ought to be to each other in terms of expected traffic. ... It was a very limited viewpoint

to think only in terms of improving traffic flows, whereas there are much more important things to consider such as energy or what things are made of as well as things like privacy, the amount of spaces ..." (Interview). The programme could also not accomodate the iterative style usually employed by designers. This applied especially to value decisions made implicitly, but not being made explicit: "For example, if you're comparing the amount of traffic between rooms, the question arises, whose traffic is important? How do you compare the importance of getting a doctor from one room to another with, say, a patient, a porter or a nurse? ... In a lot of these programmes the assumptions are buried deep in the middle of the programme. The user of the programme has no access to them and usually no information about them. Consequently he probably has no confidence in the results either. We weren't quite so bad because we put parameters, which said what was important" (Interview).

(146) Kenyon later worked on the Property Services Agency's CEDAR system, which is a large, interactive graphics system with a central data base. "One of the main criteria in our design of that system was that we recognized that architects are very loath to get involved with mathematics, with electronic machines and have a large preference for communicating with each other via graphical media, drawings. So we put a lot of effort into trying to adapt the system to the architect's needs rather than the other way round. We designed a command language to tell the computer what do, using English words, not full English sentences" (Interview). Interface design must thus take into account not only individual users but also to a far greater extent habitual patterns of thinking and communication of the members of a professional group.

(147) The considerable effort spent on the development of C.A.D. software packages can easily create a skill imbalance between developers and the eventual users so that these have greater confidence in the system than in their own ability. "Sometimes I wonder whether people begin to rely on computer programmes to do their calculations for them. This is true especially if they don't understand what's going on in the middle, they have to have blind acception of the results. If there is a mistake in the programme, there can be catastrophic failure in the building when it's built.

There's a nice press cutting here on a programming error which shut down several nuclear power stations. ... What we need is very strict validation for programmes and that is what the Design Office Consortium is doing for architectural programmes", stated Bob Kenyon.
In the interview at the C.A.D. Centre in Cambridge, Malcolm Sabin also came out very much in favour of rigorous programme testing.

(148) Occasionally the objection is raised to C.A.D. that it is leading away from the drawing board, the medium to which the designer is accustomed and introducing very serious restrictions in the shape of small screens. Once again we quote Bob Kenyon: "The difference to the screen isn't as dramatic as you're suggesting. People are still manipulating 2-dimensional representations, although there's a lot to be said for the pencil as more natural and feedback is much quicker than using a screen". He then referred us to developments at MIT, where screens using sensors are being developed enabling lines to be drawn using a finger. This would be a close approximation to human styles of communication. On artificial intelligence he stated: "I think artificial intelligence techniques and concepts ought to be applied more to architectural computing research and implementation. Partly to make the interface between the man and the machine better. Maybe we can use natural language. Then we can speak to the computer and hear actual answers, so you can keep your hands free".

(149) Difficult as it may be for the professional programmer to develop programme structures largely conforming to professional methods in order to avoid resistance and to enhance the acceptability of systems, the situation is several times more difficult when software is intended to enable communication with the naive user, at the same time structuring communication with experts. This is the not entirely modest goal that ABACUS is aspiring to, i.e. the Architecture and Building Aids Computer Unit at Strathclyde University. This aim is expressed in both the group's self-descriptory material (General Information) as well as being stated most eloquently by our partners in interview, Alan Bridges, Harvey Sussock, Morven Hirst and Julian Watts.
"Our main concepts, which we've built the programmes around are those of design analysis and design appraisal. That we can provide tools to help

the architect structure his problem and derive initial design solutions which we can then describe to the computer and, using models we built into the computer, measure how good a solution that design proposal is: Cost it, measure the areas, analyse the energy consumption of the building. And with an interactive graphics system we give the architect the opportunity to modify his design very quickly and easily. Once he's seen this design feedback about how it performs he can then run through the cycle again. He's modified the costs, for instance - the idea being that we are appraising the whole building together. Because very often traditionally the architects may just concentrate on the circulation structure, optimize that and just try to fit things around it. We feel that architecture is such a multivariate discipline - everything is interdependent - and the only way one can get a successful building is to look at everything together, which you can get the computer to do.And essentially all of our work fits into this simple model" (Interview).
"It's hard to convince people that they should take that approach. In fact the programmes are very simple to use. They're designed in such a way that the interface between man and machine is very apparent to him. It's nothing to do with computer-knowledge. That's hidden away as much as possible. All he sees are the figures that are relevant to him" (Interview).

(150) The model of the design process itself is central to this concept, above all the analytical distinction between analysis, synthesis, appraisal and decision. This is shown in a diagramm by Tom Maver (1970, p. 200).
The evaluation of a design does therefore not take the form of a concluding judgement, but by means of providing information relevant to decision-making, i.e. above all performance values for the building. This information is designed to be equally powerful for all the members of the design team. This is an aspect of the discussion on democratization conducted at greater length elsewhere (cf. section 7). The proposition is that improved information produces improved decisions. This approach is also employed in the participation of naive users in planning procedure.

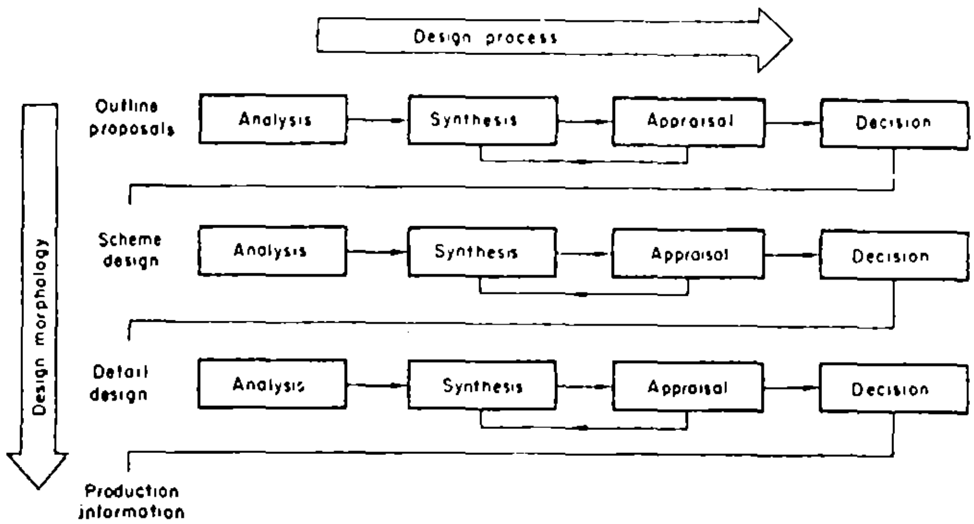


Figure 8: Model of the Design Activity
(Source: Maver 1970, p. 200)

(151) To date, three studies have been conducted by ABACUS on user participation in the design process. These are described in papers by Watts and Smith (Interim Report on Individual and Collective Participation in Computer Aided Design, Jan. 1979), Watts and Hirst (User Participation in the Early Stages of Building Design. Some Issues for the Architect and the Social Scientist, n.d.), and by Smith and Watts (Further Development of a Participatory Computer Based Design Aid, Feb. 1979). In this section we will be giving our attention exclusively to problems of interface design.

(152) According to the summary statement im Smith and Watts (1979) the interface of the programme systems employed was in special need of further development. E.g. "... methods of data handling should be improved, especially management of data files to shorten response times of the computer; improved methods of data input and graphic manipulations, e.g. feasibility to built up a tablet; possibly the use of twin screens, a master screen and a slave screen as a 'scratch area', allowing the naive designer to experiment with shapes and their 'fitting' together; appraisal measures and methods of outputting information should be improved, i.e. presentation of the space budget, the use of colour for input, output and representation."

(153) Watts and Smith comment on the truly interesting point under the heading 'Compatibility of the design tool with naive designers' methods of design synthesis': "Shortcomings in the program PARTIAL were observed by the researchers and commented upon by participants which inhibited the efficiency of certain aspects of graphical manipulation. These were primarily concerned with the actual method of design synthesis, the need to pre-specify sizes of areas in square metres before drawing them, difficulties in 'renaming' areas, limitation to rectangular spaces and difficulty in reverting to an earlier stage of design if an exploration of modifications was made" (1979, p. 55).

(154) Laymen design methods were clearly exposed in the Nursery School Design by Headteachers Project.

- The majority of the participants used functional and organizational requirements of nursery schools as their point of departure and not aesthetic, technological or economic considerations.
- A foundation of experience was of great importance for initial drafts, i.e. knowledge on nursery schools already in existence.
- When establishing room size, participants resorted to relative specifications, e.g. "larger than" (a certain room they knew from somewhere else). Architects tended to use metric representations, proceeding from absolute room measurements.

The design solutions suggested by the naive users tended, in the opinion of independent experts, to be of equal quality to those of the architects. This gives the experiment the air of a remarkable validity. The dedicated field work involved in these experiments on the whole deserves our unreserved admiration.

6.3 Modelling the Relationship between Man and Computer

(155) The subject of this section is so immense that one can only refer to the standard monographies on the subject (e.g. Weizenbaum 1976; Lewis Mumford 1964, 1966) or take no further notice of it. We shall, neverthe-

less attempt to take an intermediate course and select a few arguments that are of basic importance for closer attention. They are the following:

a) Models for the specific performance capabilities of the human and the computer.

b) Issues involved in processing data and information and the structure of communication.

c) Models of man in the anthropological sense.

ad a)
(156) It is often pointed out that human capacity for work and that of the computer should be able to meaningfully combine if work is appropriately organized. Tom Maver provides a more detailed survey of the issues involved than is customary in his article "A Theory of Architectural Design in which the Role of the Computer is Identified" (1970, p. 201). This so-called "Fitts List" includes the components displayed in Table 2.

(157) Maver's decisive argument is to employ the specific capability of the computer in areas of the design process where the architect can best use them. This can equally be the case at the stage of analysis, synthesis or appraisal using predominantly mathematical models, heuristic models or simulation. Since all of these models incorporate certain dangers resulting from the simplification of a "model" in comparison with reality and the performance of an experienced architect, the further development of a design, the redefinition of problems and the final appraisal are left over to the architect and not the computer. "The proposed approach is based on the theory that if a number of variables are to be manipulated simultaneously it is not feasible to generate, explicitly, a design solution as effectively as an architect can intuitively; but that it is possible, using an intuitive synthesis as a first approximation, to explicitly appraise it in such a way that promotes convergence by iterative modification towards an optimum solution" (ibid., p. 204f).

(158) Mike Cooley is not fully in agreement with this line of argumentation, at least he refers to two further problems related to the segmentation into

Table 2: Comparison of man-machine performance measures

	Machine	Man
Speed	Much superior	Lag 1 s
Power	Consistent at any level; large constant standard forces	2.0 hp for about 10 s 0.5 hp for a few minutes 0.2 hp for continuous work over a day
Consistency	Ideal for: routine; repetition; precision	Not reliable: should be monitored by machine
Complex activities	Multi-channel	Single-channel
Memory	Best for literal reproduction and short term storage	Large store, multiple access. Better for principles and strategies
Reasoning	Good deductive	Good inductive
Computation	Fast, accurate Poor at error correction	Slow, subject to error Good at error correction
Input sensitivity	Some outside human senses, e.g. radioactivity	Wide energy range (10^{12}) and variety of stimuli dealt with by one unit; e.g. eye deals with relative location, movement and colour. Good at pattern detection. Can detect signals in high noise levels.
	Can be designed to be insensitive to extraneous stimuli	Affected by heat, cold , noise and vibration (exceeding known limits)
Overload reliability	Sudden breakdown	"Graceful degradation"
Intelligence	None	Can deal with unpredicted and unpredictable; can anticipate
Manipulative abilities	Specific	Great versatility

(Source: Maver 1970, p. 201)

component parts and the organization of labour.
The performed parts must be regarded as dialectical opposites and not as complementary to each other. Conventional classification implies the separation of creative and non-creative components. "The design activity cannot, in this arbitrary way, be separated into two disconnected elements which can then be added and combined like some kind of chemical compound. The process by which these two opposites are united by the designer to produce a new whole is a complex, and as yet ill defined and ill researched area. The sequential basis on which the elements interact is of extreme importance" (1979b, p. 4f).

The second objection concerns the organization of labour. Even if the basic argumentation against a separation into component parts were correct - and in our opinion it is indeed valid - the opportunity for men to make creative contributions is by no means guaranteed by the actual organization of labour. The trend seems to be to build the human being into a mechanism constructed in accordance to technical standards, giving him the task of conforming to a guiding value. "In engineering terms the subject is then part of a closed-loop control system or servo-mechanism whose function is to "follow-up" the course pointer" (Cooley 1972, p. 83).

ad b)
(159) Heibey, Lutterbeck and Töpel (1977), in their previously mentioned project, made an attempt to elaborate on the differences between human performance and that of the computer. If one confines the definition of the computer to hardware, the following basic features must be mentioned (cf. p. 82 et seq.).

- The computer is a finite machine, i.e. it can only process a limited number of commands in a limited period of time using limited storage capacity.
- The computer is an universal machine simulating other virtual machines by means of programmes.
- The computer processes data represented by binary symbols and alternate voltage values. The sequence of alterations in voltage must be completely, i.e. deterministically, caused and controlled by commands.

On the other hand, the human being processes "information" rather then data, information being symbols endowed with meaning, placed in a pragmatic context and used for predetermined purposes.
For the purpose of analysis of a "process" we shall distinguish the following units: Objects (i.e. any random thing in our perception that must, however, have the property of being variable); activities (which cause variations in the conditions of objects); actors (human beings, machines) and rules (which determine the ways by which variations may be achieved). The main differences between human information processing and machine data processing are in their objects, actors and rules but not between the activities or operations carried out on the data or information. These may be registration, transport, storage, combination or delivery. This "formal identity" is thus in opposition to qualitative differences (cf. p. 43 ff.)! There is some danger of neglecting qualitative difference on the background of formal identity (which is itself merely identity on the foundation of a model).

(160) Another fundamentary argument that was developed in a project conducted by Dehning and Maass and seems of importance concerns the replacement of human communication by man-computer interaction (cf. p. 113ff). The authors assume "that the human partners in interaction behave themselves during man-machine interaction as if communicating with humans, at the same time not accepting the computer as an equivalent partner in communication. This contradiction is caused by the following differences between interaction and communication:

- "Interaction is conducted by written and not by spoken language.
- The computer cannot make use of expressions dependent on situation or context such as secondary meaning, irony, emotional expression, etc. (there is no accomodation for so-called connative code).
- Human norms of language are determined by social norms. The output rules for the computer do not accomodate for this.
- For the human being the outward situation in which man-machine interaction takes place depends on the computer, for the computer it depends on the human being.

- The computer has no intention (i.e. built-in model of the environment) whilst interacting and can therefore not adapt to its partner" (p. 133ff.).

The intentionality which constitutes each and every kind of human communication and action is therefore lacking in man-machine interaction. The human being must compensate for this deficit on the machine side by adaption and paradoxical communication. The degree of complexity involved in operating computers at the same time leads to operation being left to specialists so that problem-orientated information processing by humans is frequently also organizationally separated from problem formulation.

ad c)
(161) During the course of the development of user orientated text editing systems, Harold Thimbleby came to the conclusion that the computer should play an own distinct part instead of trying to simulate the human being. "Humans have considerable conversational skills and part of the problem of having a dialogue with machines is that they do not have the same skills. Indeed, the way the computer works often tends to invalidate the person's skills. Determination is a concept borrowed from interpersonal psychology: however I am not suggesting that the panacea is for computer to better simulate aspects of human conversation but, rather, whilst systems are designed ignoring human needs then they will be neither successful nor desirable. If computers are to be symbiotic (Licklider 1960) then they can do this best by better being computers rather than simulating humanoids" 1978, p. 3).
This concealement of true functions is probably one main reason for the completely inappropriate assessment of reactions to the language programme ELIZA by naive users (among them psychiatrists)(cf. Thimbleby 1979, p. 2). These were the source of greaty anxiety to Weizenbaum and were the cause of his spending a great deal of effort in examining the relationship between man and the computer (cf. introduction to book, 1976). Machines of the complexity of the computer, whose means of functioning may be fully understood only after considerable intellectual effort, were perfected with the aid of labour and ambition of generations of excellent computer science

specialists. These machines force the human being to use paradoxical forms of communication. The unforcible nature of the machine system and the complexity of posssible reaction by the machine partner deceive the human into assuming "natural" attitudes to communication, which are, however, disappointed at every step. The human can apparently only conduct conversations with the machine in an anthropogenous style. This may be impressively demonstrated by analysing the language in which programmers talk about their machines!

(162) In his article "On the Impact of the Computer on Society" (1972) Weizenbaum expresses this difference in communication theory extremely clearly: "How does one insult a machine?" The answer is simple: one can't. However the other way around it is possible. This argument is developed by Weizenbaum in the article mentioned.
The threat from computers is connected to the fact that we can make them work on the foundation of models and that these models work even if they are not valid or later proven to be so (p. 601f.). However, at first these models "survive" continuing to determine our thinking and thus taking away from us important questions <u>we</u> should be posing on technology, or at least prejudicing the answers in a certain direction: "The success of the technique and some technological explanations has, as I've suggested, tricked us into permitting technology to formulate important questions for us - questions whose very forms severely diminish the number of degrees of freedom in our range of decision-making" (p. 612).

7. Computers and Participation

7.1 Introduction

(163) Experts are by no means unanimous in their prediction of how computers will affect the structure of society. On the one hand, computers have the capacity for processing information to make society more transparent and democratic. On the other hand, they could also be used to set up the most oppressive and perfectly controlled society, confirming Orwell's worst visions for 1984. In the course of this section, we will be concerned with the participation of people in creating their work environment centred around computers and with the use of computing to make society more democratic.

7.2 Participation in Job Design

(164) The introduction of the computer into a firm represents a more radical change in the working environment than that of a more conventional machine. In Germany, Kubicek (1975) and others have shown that information technology has a distinct effect on the organizational structure of companies using it. The successful use of information technology depends on appropriate organizational adjustments being made and its acceptability to the people or groups of people using it. This fact is apparently often not recognized by management. According to Larry Farrow, management frequently expressed the view "that computing ought to be costed and introduced in much the same way as any other technical innovation such as new machine tool or an accounting machine. It was not clear whether the attitudes that would be inferred from the actions of managers were always in strict accordance with this verbal expression of attitudes. The difference probably arises due to the much smaller ratio of social content to technical content in the design of a machine tool or accounting machine. However, the verbal attitudes of managers were generally carried into their actions with regard to job design, which was generally regarded as a by-product of system design and not as a skill in its own right" (Farrow 1977, p. 28 f.).

(165) This impression is confirmed by Kubicek (1975, p. 17 ff.), who observed the failure of companies to carry out analyses of the units or departments intending to introduce computers or even to carry out cost-benefit analyses. The realisation that organisational structure and information technology mutually influence one another is one reason for the recommendation of participative approaches to the design of work.

(166) Larry Farrow, of the National Computing Centre, has written a report for the Commission of the European Communities on the effects of computers on attitudes and working skills of employees. As a result of his findings, the N.C.C. has published Guidelines for the various groups of people affected by the introduction of computers. The guidelines are designed to assist in providing those affected by computers with satisfying jobs and work environments.
The report came to the conclusion that technical and economic aspects play a more important part in the design of computer systems than do effects on attitudes and jobs of employees. It also comes to the conclusion that employee attitudes do influence the degree of success of the implementation of computer systems. However, most of the managers interviewed did not expect useful contributions from the employees toward the design of computer systems or they believed that the effort required to collect the contribution was too large compared with the resultant increase in efficiency of the system. The N.C.C. apparently expects strategies that consider attitudes and requirements of the employees to be more successful than those that do not. Thus, the report recommends that systems designers acquire basic knowledge and skills in behavioural sciences and participatory approaches to job design.

(167) Enid Mumford of Manchester Business School quotes a number of strategies groups use to ensure the compliance or cooperation of other groups. These vary on a spectrum from deference, because a group "knows its place", through to compliance through negotiation and shared control and participation in decisions. The actual use of one or other of the strategies in an organisation depends on values, expediency and power.

(168) Enid Mumford herself is member of a group of people throughout Europe who favour a policy of user participation in designing work. These approaches, which vary somewhat depending on the political views of the people involved, are described in detail in a book by Kubicek (1979). Enid Mumford quotes four principal arguments in favour of the use of such an approach when new computer systems are being designed:

1. People have a moral right to control their own destinies and this applies as much in the work situation as elsewhere.
2. Activities are ultimately controlled by those who perform them. People who took no part in decision making tend to ignore the decision once those responsible for making it have departed as would be the case if jobs were designed by people from outside a company.
3. The knowledge necessary to carry out the jobs being designed is located with the people who will actually do them.
4. Involvement acts as a motivator and will lead to more productivity and efficiency.

Whereas managers and trade unions will probably have mixed motives from the above to favour a participatory approach, employees will place more value on the effects it will have on their work and work situation.

(169) Enid Mumford distinguishes 3 different types of participative approaches to the design of work, all of which she herself has tried out in practice.

1. Consultative design: The main decisions are still made by professional systems specialists. They do, however, take into consideration the needs of the user, in particular in regard to job satisfaction.
2. Representative design: Representatives of all the groups affected make decisions on design jointly with the systems analysts and representatives of management.
3. Consensus design: Design by this method attempts to involve all members of the user department in decision-making. The employees elect representatives to a project group which has the task of developing a new form of work organization "...while continually receiving and giving ideas from and to departmental colleagues and allowing the final decision to be taken by the department as a whole" (Participative Design, p. 1).

(170) Together with her colleagues, John Hawgood and Frank Land, Enid Mumford has developed a set of tools to assist the design process. To some extent, these could also be used as instruments to measure the effects an information technology has on the strucure of an organization. A brief description of the design tools follows.

I. Describing the essential organisational system:

"Essential" functions are those an organisation must take into consideration if it is to achieve its main aims. The description of the essential organisational system consists of five steps:

a) Finding out the reasons for redesigning the system.
b) Definition of the system's boundaries with aid of an input-output model.
c) Defining the primary aims of the system.
d) Defing the main "unit operations" which are attached to aims or groups of aims. These are sets of activities which can be defined by input, time or location and can be logically separated from others.
e) Establishing the activities associated with each unit operation.

Activities can further be differentiated by functions, i.e. whether they are part of the production process, serve to avoid the collapse of this process, coordinate individual stages of the process, contribute towards the improvement of efficiency or adapting to change or whether they permit supervisory activities.
In the course of this first stage, the needs of users in regard to job environments are established and compared with the actual situation.

II. Discrepancy analysis.

This tool serves to identify weak points in the organisational structure. The current state of the organisation is confronted with an ideal state. Results should show both the areas where the existing situation is well suited to the organization's aims and the employees' needs and areas where there is little correspondence.

III. Setting objectives and evaluating strategies.

The formal setting of primary objectives is an important precondition for the design process. The ideal solution would fulfill the most important aims of all the groups affected. This procedure consists of 4 steps:

a) Establishing interest groups not represented in the design group. Individual members of the design group take over the task of acting in the interest of groups not represented (e.g. customers, owners, managers, tax payers);
b) Setting up a short list of those objectives which are of greatest importance to the interest group;
c) Assigning weights to each goal for each interest group. By this means, the relative importance of each objective compared with the others may be expressed;
d) Development of alternative design strategies to be compared with the current system.

This procedure forces all the groups to reveal their objectives and requires the setting of design criteria, such as the new system being considered an improvement on the current system by all the groups involved, even if alternative solutions may promise greater advantages for individual groups. It will not be possible to meet these criteria in every case, for instance if insoluble conflict between individual groups arises. In this situation, a "political" solution must be arrived at.

IV. Socio-technical system design.

The most frequently adopted philosophical approaches to work design are "job enrichment" and the "socio-technical approach". The latter approach is derived from the premise that a production system consists of both a technology and a social structure that links the human operators both with the technology and with each other. A socio-technical system is any unit of an organisation consisting of a technological and social subsystem with a common goal or task to accomplish.
The socio-technical analysis consists of a logical analysis of the technical components of a work system (machines, procedures, information) and of assigning these to unit operations.

Using this approach, one or more unit operations are assigned to each group. The tasks are distributed to the individual members of the group and training is carried out with the aim of giving every member of the group the competence to carry out all tasks.
The analysis of the social system reveals the relationships which are necessary to ensure that the system operates efficiently. This analysis incorporates the measurement of job satisfaction requirements of the system operators. After a design proposal has been agreed upon, the design is implemented and evaluated. The criteria for evaluation are on the one hand comprehensiveness of the solutions to problems, on the other hand a widespread increase in job satisfaction.

(171) Practical examples of systems design using this approach have been carried out and described by Enid Mumford in a number of papers. In the cases described, the designs met with the approval of both employees and management. The system had the effect of generally enhancing working skills and the only problems encountered by management were those of other departments trying to entice away employees on account of their increased competence and employees asking for an increase in earning for the same reason.

(172) Kubicek (1979) raises 3 main objections to this approach:

- The approach requires that management relinquish part of its directive powers.
- For the purposes of the approach, employee interests are confined mainly to subjective job satisfaction.
- In the examples in which the approach has been adopted, solutions to technical and organisational problems are apparently relatively independent of each other. In cases were there is a strong relationship between work situation and technical solution, there are probably also greater problems in regard to skills and competence.

(173) Whereas the examples described by Enid Mumford tried to avoid deskilling effects, excluding them by means of the design criteria, effects of this kind would seem to be almost inevitable for at least part of the employees operating C.A.D. systems. However, it has not in our opinion yet

been proved conclusively that C.A.D. must lead to de-skilling in every case, for instance Rosenbrock is attempting to produce systems that will enhance the skill of users, and other experts (e.g. Llewellyn) believe that C.A.D. can be used in just such a way. Possibly a participative approach to designing C.A.D. systems and the setting of objectives such as avoiding de-skilling and displacement of labour could force those responsible for designing C.A.D. systems to accomodate for such factors.

7.3 Democratization by Use of Computers

(174) In a paper (Maver 1976) on democracy in design decision making, Professor Tom Maver construed a controversy between himself and Mike Cooley on the use of computers in design. Whereas he himself clearly advocates the use of computers in design decision making because of their democratic potential, he asserts that Cooley's desire to protect the interests of designers is a reason for the rejection of computers in design. The alternative positions are started as follows:

- "Do we accept that the over-riding professional responsibility is to bring about a state of affairs in which the profession as we know it is no longer needed?

  or
- Do we close the ranks in our professional institutions and Trade Unions to maintain the status and power of the designer as we currently know it?" (op. cit., p. 318).

(175) The question arises whether these are in fact genuine alternatives, or whether the use of computers to enable democratic participation in decision making cannot also be achieved preserving at least the skills and working styles of designers. It is probably safe to say both that Mike Cooley would be in favour of increased democracy in design and that Tom Maver would be opposed to de-skilling or the deterioration of working conditions.

(176) In his paper, Tom Maver points out that the methods for introducing democracy to the design process in architecture could be applied with equal

justification in other fields of design endeavour, "...whether or not the products of the design activity are artifacts - cars, toothbrushes, TV receivers - or social systems - educational, medical, political" (Maver 1976, p. 318).

(177) An area where computers could probably be fruitfully applied is that of town planning. In Germany, participation of the public in town planning is legally prescribed. Before plans are finally approved by local authorities, they are publicly displayed in order to give the opportunity of raising objections or suggesting amendments. The process is not entirely successful, since various groups affected by the planning make varying use of the opportunity to participate. One obvious reason for this has been the difficulty of transforming two-dimensional symbolic plans into a visual image of what the area planned would look like when actually realised. A three-dimensional, coloured display could be used in this kind of situation and to settle arguments.

(178) This was also pointed out to us by Arthur Llewelyn: "... in every country we have problems of planning (....) everyone wants to argue about it. Now, you can't argue unless you've some interchange. If you sit people around in a room and they just argue, you get nowhere. The only way to have a sensible discussion around these topics is in fact to have a computer, linking the argument together, because if you object to a bridge that I want to build over there, and you claim that it's going to destroy the whole view, and we can go on arguing and never getting anywhere because you've got your view and I've got mine. Now, once you bring a computer in, I can say this is the bridge that I'm going to build and I can give you a visualization of it. You say, "Yes, but not that. It's much higher than the environment." And I say, "No it isn't. Where are you standing?" And you have to come down to a different viewpoint, so you narrow down the differences. You force people to come to grips with their problems". The visual representation of designs obviously is also a means of surmounting language barriers which often crop up in communication between members of the professions and the unitiated.

(179) This all stems from very similar considerations to those put forward by Enid Mumford in favour of the participation of employees in the design of work. Arguments related to values, expediency, location of knowledge and motivation may be equally applied to any other product of design endeavour as to that of the design of work. This is, in fact, pointed out by Watts and Smith (1979, p. 2) who also point out that architects operate on unsystematic hypotheses in regard to users' requirements.

(180) However, Tom Maver and the ABACUS group use slightly different considerations as their point of departure. In a paper on the subject of democracy in decision-making (Maver 1976, p. 313), design is defined "...as making explicit proposals for a change from some existing state to some future state which more closely approximates to man - and womankind's conception of the ideal." The ideal state in this sense is identified by four necessary and sufficient conditions: politico-economic, scientific, ethico-moral and aesthetic (R.L. Ackoff 1969). The definition implies that the ideal state is unobtainable but also approachable without limit. The first step in this approach is to define a system of objectives on which is based a system of goals which are predictably and surely attainable in contrast to the objectives which are considered as obtainable, although not within a fixed time-span.

(181) Maver proposes a simple model of design objectives consisting of four main subsystems, each of which can be further subdivided. The first of these is the building hardware - construction, services and contents - which serves to create a built environment, consisting of spatial, visual and physical sub-systems. Within this environment, a number of client or user activities take place in order to fulfill a number of objectives of the client/user organization.
"The crux of the design problem is to provide <u>building hardware</u> which will create a <u>built environment</u> which will promote rather than inhibit <u>client/user activity</u> and thus satisfy the <u>client-user objectives</u>" (Maver 1976, p. 313).
The cost for the building hardware and built environment represent the <u>investment</u> side of the model, whereas the degree to which the activities through them the client/user objectives are promoted represents the <u>return</u> an organization gets from a building.

(182) The design solution strived for by the designer aims at maximizing the returns on the user/client organization's investment. Whereas this all appears very simple when applied to the model, it is in fact a very complex affair. In particular, evaluating performance, i.e. return, implies the consideration of a composite set of measures on disparate and often conflicting criteria. This is very similar to what Howard Rosenbrock says in respect to there being no "best" solution to a design problem.

(183) The programmes developed by ABACUS can be used in two alternative ways: Firstly, in design decision-making to iteratively converge on the "optimum" solution in the circumstances, secondly, in a research and development context to establish the effects individual variables have on overall performance. This may be done by systematically varying one variable whilst holding all other aspects constant.

(184) Before the use of the computers, the process whereby architects appraised design alternatives was shrouded in mystery and virtually ignored by the professional press. Thus, the user of buildings had no way of checking the validity of the decision-making process or of the premises inherent in the design.
In a model such as those developed by ABACUS, the individual performance attributes are imagined to be linked by some unknown mechanism. A change in one performance attribute is accompanied by a change in most other performance attributes. The ultimate design decision is based on value-judgement which can take the form of greatly differing strategies, for instance demanding consistent performance on all attributes or allowing great variation, where some performance attributes are extremely good and others are extremely poor.

(185) If we are to equate the degree of consensus on the value of a building (or any other product) with worth, an experiment conducted by Cakin is of great interest. He presented various groups of people, architects and non-architects, with five alternative solutions to a design problem. The subjects were provided with two forms of information: "crude information", which consisted of plans and elevations, and more "sophisticated in-

formation", which additionally included performance profiles output by the computer. His most important findings may be stated briefly as follows:

- The better the quality of the information provided, the greater is the degree of consensus achieved on the quality of a design, independently of whether subjects are architects or non-architects.
- Groups of architects provided only with "crude information" achieved lesser degrees of consensus than did any other group. This is of course, the traditional manner of value judgement employed by architects.

(186) From discussions in Maver's paper and another by Alan Bridges (1976), another member of the ABACUS group, three paradigms emerge which could be used as the basis for a new design philosophy:

"The plan is the process - the role of the professional designer is to develop and make generally available the processes of design decision-making, rather than to produce solutions.

The process is design-in-use - design is a continuing activity; the processes for decision-making should be as relevant to the modification, adaption, growth and management of the product as to its original specification.

Design-in-use is participatory - design decision-making is the province of those affected by design decisions; the processes must therefore be usually by naive, as opposed to professional, designers" (Maver 1976, p. 317).

(187) The programmes developed by ABACUS are intended for design-in-use. However, Maver also considers existing software for architectural design is at present rather crude, since it is confined to numerical appraisal, whereas a more experiential appraisal would be desirable. One serious shortcoming of the programmes applied by ABACUS, which are as yet based on numerical appraisal, is that although users are given the opportunity to modify design elements in the light of performance appraisal, the appraisals are based on abstract technical measures which can only be interpreted by the professional. Although computer simulation of the visual or indeed accoustic attributes of a building may provide an extension of the

information on which judgements are based, it is by no means certain that the shortcomings described above can be fully compensated.

7.4 Participation in Use

(188) At this point it may be useful to relate some of the experience gathered using architectural design appraisal programmes. In addition to the study by Cakin already mentioned, the monitoring of experience with the programmes has been part of the ABACUS group's policy and we were given three papers outlining some important aspects of user participation.

(189) Perhaps one of the central problems involved in participation in the design of the environment is getting people to "...give meaningful or accurate answers to questions about environments they have not yet experienced, especially ideal ones" (Canter 1975). The ABACUS group's research into decision-making has been confined rather to those aspects that can be examined at the small-group level rather than at societal level. For this purpose, a programme called PARTIAL with the following characteristics has been developed:

- "The user can set up a preliminary brief, in the form of a space budget, and gain feedback on the brief;
- "the user can define the relevant performance features (e.g. cost, energy consumption) and define average values against which feedback can be sought;
- "the user can generate and manipulate a layout using graphical manipulation commands" (Watts & Hirst, n.d., p. 2).

(190) The programme has been used in 3 projects described in the papers (Watts & Hirst, n.d.; Watts & Smith 1979). The first project involves a fairly homogenous group of nursery school headteachers, who were asked to set design objectives and to generate layouts for nursery schools. Thus, the project was not concerned with architect/user relationships or with the entire design decision-making process. It is a study "...of the competence

of participants in carrying out this phase of the design independently of the active involvement of design professionals" (Watts & Smith 1979, p.4).

The issues explored can be divided into two groups, design aspects and aspects of process. Among the design aspects covered were the following:

- Comparison of information processing with aid of the computer or by more conventional means.
- The overall evaluation of solutions in comparison to solutions already built.
- Comparison of the degree of consensus in evaluation achieved for individual and for group solutions.
- Examination of individual factors contributing towards achieving consensus.

The aspects concerning the process were not actually covered by the project in hand but are given as a list of issues worthy of further consideration.

- To which extent do the means of setting up goals by users/clients involve the incorporation of experience and standards known to the users/clients?
- By which means is design synthesis achieved? Does it merely involve the combination of the individual rooms to an entity? What part do the horizons of the participants, existing designs and perceptions of the degree to which aims are fulfilled play?
- What is the role of the researchers in the consensus process?

The fact that the layout had first to be completed before such details as walls, doors and windows could be added was perceived as a restriction by some of the participants, although they were free to return to the layout once the detailing phase had been reached.

Preliminary interviews were carried out in order to establish nursery school teachers' conceptions of what nursery schools should ideally be like. Appraisal was carried out with a standardised scale devised by Canter (1971) for the purpose of building evaluation. Alternative design proposals were also compared by means of ranking.

(191) The most important conclusions were:

- Layouts produced by group discussion were evaluated by experts as the equal of professionally produced plans by architects. The own individual plans tended to be more highly rated than those of other individuals, but not as highly as those produced by the groups in which the individuals participated.
- Design objectives were incorporated to a degree of about 70%, which is considered very satisfactory. However, the setting of objectives depended very largely on background knowledge on functional and organizational requirements of nursery schools. Aesthetic and financial considerations played a far lesser role.
- The participants generally lacked the competence to deal with the absolute size of areas, thus making restraints imposed by the brief in this regard an absolute necessity. This however also inhibited participants' willingness and ability to carry out extensive alterations once an area had been drawn.
- Individuals did not take extensive advantage of the possibility to carry out modifications based on performance feedback. Rather, they tended to create an initial design hypothesis and carry out only minor deviations from the mean in performance measures.
- There was little difficulty in achieving consensus on design, independently of whether participants had previous experience in designing or not.
- Group design process involved greater consideration of performance information than did individual design.

(192) It is pointed out that the participants in this survey had extensive knowledge of the type of building under considerations, a high educational level and a fairly definite conception of nursery schools' functions and organizational structure. Parallel experiments should be conducted in cases where less direct knowledge of requirements can be assumed. As it was carried out, the process involved the combination of the requirements of isolated individuals. It has been argued that interactive groups might provide

a more effective structure for decision-making. The method of problem presentation and the tool employed for problem-solving also probably influence the effectiveness of the process. For instance, manipulation of room sizes relative to each other will possibly produce different results than when changes must be represented in terms of absolute size. Effectiveness could probably also be increased by 3-dimensional representation. Research is necessary into the areas where the most effective contributions by participants can be made and into the matching of participation mechanisms to characteristics of participants. Finally, the authors advocate the extension of research beyond homogenous groups and the area covered. Summing up, they come to the conclusion that "In general, these findings provide strong evidence that direct participation by building users in design is feasible, increases user-satisfaction with proposals and produces high quality solutions" (Watts & Hirst, p. 3).

(193) The second project described differed from the nursery school design by headteachers in that it involved a more heterogenous group and in that it was concerned with an actual building as against the hypothetical situation in the first project.
A committee of local residents designed a community centre using the PARTIAL programme. Originally, no financial restrictions were imposed and this led to a conflict, eventually resolved by a compromise, between a group favouring voluntary limits and another group opposed to them. An important aim, set drawing on experience, was that the centre should enable informal neighbourhood contact.

The area budget was intended to be calculated employing information on area and timing required for the activities to be carried out in the centre. However, the design group was unable to carry out the necessary calculations with tables provided for the purpose and eventually an approach was employed, whereby the individual rooms were defined beforehand and the activities were distributed to the rooms.

During the design process, severe financial limitations were, after all, imposed. In this event, the problem was solved by splitting the design into four annual phases, each of which would, in itself, present a complete solution.

(194) There was some disagreement on the process by which design was to be achieved and on the part the researchers should play. The group of 11 participants in addition to the researchers was apparently too large for effective communication. The researchers attributed some of the difficulties encountered to a lack of preliminary discussion on aims and a general scheme for process. In addition, time was restricted.

Outcome of the process was a design which was finally discussed and modified with the aid of an architect experienced in the type of design involved.

The problems encountered in this project involved design decision-making strategies and methods and role definitions rather than competence and were thus rather different from those encountered in experimental situations.

(195) The third and final project described involved nursery schools headteachers' appraisal of a standard 60-place nursery school design and the formulation of aims for this kind of building. The architects participating in the workshop were given the opportunity of explaining their decision-making processes and the trade-offs made between individual performance attributes.

In actual fact the workshop served the purpose of explaining why quality of equipment was generally sacrificed to size of the built-over area. Thus, the conclusion was reached that it is not of great value to base participation on the appraisal of one design, since architects tended to try to justify decisions instead of adapting the design to accomodate suggestions put forward by the users. However, this kind of cooperation is considered as potentially fruitful, "...providing that some change takes place in role definition on the architects' part" (Watts & Hirst, n.d., p. 8).

(196) Although the 3 projects described are by no means comparable, a number of conclusions may be drawn. First of these is, that under the circumstances described in the first experiment, participative approaches to design decision-making can produce designs of equal quality to those of pro-

fessionals. Another important fact emerging from this project is that naive users tend to base their conceptions of size on rooms actually experienced rather than on terms of absolute size as is the case for architects. The second project described demonstrated forcibly the necessity of setting aims and carrying through preliminary discussion in order to avoid conflict on these matters at a later stage. As a further consequence of their experience with PARTIAL, the authors emphasize the necessity for congruity of design tools with the decision-making structure. In this respect, they formulate three conditions:

a) That communication be possible beyond those aspects introduced by the building users.

b) That solutions may be visualized, combined and modified using the participants' own terms to communicate size and scale.

c) That feedback in respect to feasibility be possible.

PARTIAL would appear to satisfy the first and third condition, whereas it has shortcomings in respect to the second condition.

7.5 Some Issues in Participation in Design Decision-Making

(197) At the outset of this section, we posed the question whether participation in design decision-making could only be achieved by sacrificing privileges of the professions involved. To this we must add the question whether participation actually improves the quality of design. We can, of course, not finally answer either of these questions, since for one thing the C.A.D. system which could provide satisfactory answers has yet to be produced. However, we feel a brief summary of some of the issues involved may be in order.

(198) Which are the areas of design where participatory approaches to decision-making may be fruitfully employed? For instance, are there design circumstances under which information processing is too complex to be communicated to the naive user and where satisfaction possibly derived from participation is offset by disappointment with the results when compared to a professional job? Are there areas where participation is not desirable

on moral, ethical or legal grounds? Medical care is one area many people would dearly love to demystify - in Germany, where health care is run much as private enterprise, as much out of financial considerations as for reasons of curiosity. A remedy or a therapy could, to some extent at least, be compared to a design so that parallels could be drawn. Patient involvement could also be desirable for psychological reasons. However, doctors are extremely reluctant to accept outside intrusion into the running of their profession.

(199) Another barrier to user participation is the degree of public concern regarding a particular issue. Obviously, not too many motorists would wish to participate in the design of certain parts of a motor car such as part or the whole of the engine. They are, however, greatly interested in the design of the whole car in terms of appearance, performance, fittings and so forth. In this case, the desire to de-mystify the undoubted expertise involved in the design of automobile engines is negligible in comparison to the wish to participate in the design as a whole of, say, the car's body or indeed of its dashboard. After all, this is what many of us have spent many a boring school lesson doing. If participation has the effect of diminishing privileges, why should working conditions of people be determined by the interest we take in their jobs and not by, say, the importance of their jobs in our everyday lives or by their potential effect on our health?

(200) In the course of the discussion of experience with the PARTIAL programme, we heard that some users expressed the desire to go about the design process in a different manner to that prescribed by the programme. It may be hypothesized that the restraints thus imposed serve to inhibit people from making contributions to decisions in manners not accomodated for by the computer programme.

This latter is, of course, an objection which may be levelled at almost any computer programme and not only at those intended for use by the naive user.

(201) Another issue which applies equally to the naive participant and to the professional designer using another's programme is the question of

responsibility if something goes amiss. The more complicated and, in scientific terms, controversial the process for design decision-making is, the more reluctant people will be to participate in such a process. Once again, this narrows down the field of design activities for which particpative approaches may be employed.

(202) Does participation in decision-making, in particular in the field of design, encourage conservatism? We have already mentioned a general inability of the naive user to "feed forward" as opposed to "feed back", i.e. to imagine environments or artifacts he or she has previously not encountered. Will participation, even with the aid of such advanced and sophisticated tools as computers, tend to inhibit innovation? Man and woman are subject to rapidly changing fashion, which may or may not be a good thing. Even if we deny the value of fashion, we occupy ourselves with explaining why it changes and passing judgements on the relative values of various fashions or "non-fashions". In any case, viewed over a reasonable passage of time, it would appear that aesthetics is by no means based on absolute values. Will the computer change all of this? Are our future aesthetic judgements to be based on a set of performance attributes or do these allow a variation in aesthetic standards? Is the set of attributes on which our conception of a satisfactory product is determined set for all time or is it also subject to shifts in attributes? Once again, the question is where are we to draw the line? In which areas of design endeavour may we fruitfully employ the computer? What part will "irrational" human creativity play, possibly at the expense of performance? How will we take into account shifts in human values? How, indeed, are these to come about if we involve the computer, possibly impeding their very creation? If we are to combine the computer and human creativity in design decision-making, at which point do we create the inlet for creativity?

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